UNIVERSITY OF CRETE
COMPUTER SCIENCE DEPARTMENT

Using Ambient Intelligence Technologies for Producing and Disseminating Paintings

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University of Crete
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Dissertation submitted by
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Heraklion, November 2013

I haven't yet found a greater teacher.
To you father I owe everything.

This thesis is dedicated to the memory of my father, John.

Declaration of Originality

I herewith certify that all material in this dissertation which is not my own work has been properly acknowledged.

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Χρήση Τεχνολογιών Διάχυτης Νοημοσύνης για την Ανάπτυξη και Αξιοποίηση Πινάκων Ζωγραφικής

Νικόλαος Ι. Παρταράκης

Διδακτορική Διατριβή
Τμήμα Επιστήμης Υπολογιστών
Πανεπιστήμιο Κρήτης

Περίληψη

Η «τέχνη» στην αρχαία Ελληνική γλώσσα είχε πολλαπλές ερμηνίες, συμπεριλαμβάνομένης της διαδικασίας για την παραγωγή κάποιου προϊόντος. Επίσης η «τέχνη» ετυμολογικά αποτελεί τη ρίζα της λέξης «τεχνολογία». Στην εποχή μας οι Τεχνολογίες της Πληροφορίκης και της Επικοινωνίας έχουν εξελιχθεί με αποτέλεσμα να επηρεάζουν πολλά πεδία της ανθρώπινης δραστηριότητας, συμπεριλαμβανομένων των μαθηματικών, της ιατρικής, της φυσικής, κ.τ.λ. Οι τεχνολογίες αυτές έχουν πλέον καταστεί αναπόσπαστο κομμάτι της καθημερινότητας. Παρόλα αυτά μέχρι σήμερα δεν έχουν επηρεάσει επαρκώς τον τρόπο με τον οποίο η τέχνη δημιουργείται, διαδίδεται, διδάσκεται και απολαμβάνεται στο πλαίσιο της καθημερινότητας.

Καθώς οι υπολογιστές ενσωματώνονται όλο και πιο συχνά σε καθημερινά αντικείμενα αλλά και στο περιβάλλον, η Διάχυτη Νοημοσύνη έχει ταυτιστεί με το όραμα ότι οι άνθρωποι θα έχουν τη δυνατότητα στο μέλλον να ζουν σε ψηφιακά περιβάλλοντα στα οποία οι ηλεκτρονικές συσκευές είναι ευαισθητοποιημένες σχετικά με τις ανάγκες των ανθρώπων, παρέχουν προσωποποιημένες υπηρεσίες ανάλογα με τις απαιτήσεις τους, και αντιλαμβάνονται και αντιδρούν σε ερεθίσματα που σχετίζονται με την ανθρώπινη συμπεριφορά. Αυτά το έξυπνα περιβάλλοντα θα φέρουν επανάσταση σε όλα τα μήκη και τα πλάτη των ανθρωπίνων δραστηριοτήτων, όπως η διασκέδαση, η διαβίωση, η εργασία, οι κατασκευές, κ.τ.λ.

Η παρούσα εργασία σκοπεύει στο να αλλάξει, μέσω της χρήσης τεχνολογιών Διάχυτης Νοημοσύνης, τον τρόπο με τον οποίο η τέχνη παράγεται, διαδίδεται και διδάσκεται, και πιο συγκεκριμένα εξυπηρετεί: (α) τη δημιουργία έργων τέχνης ακολουθώντας τα βήματα και τις τεχνικές των μεγάλων δασκάλων της ζωγραφικής, (β) την εκπαίδευση και διδασκαλία της ιστορίας της τέχνης αλλά των τεχνικών για την δημιουργία Έργων Τέχνης, (γ) την αλλαγή του τρόπου με το οποίο οι άνθρωποι

έρχονται σε επαφή με αυτήν, (δ) την επέκταση του νοήματος που δίνουμε στα έργα τέχνης επιτρέποντας τη μεταφορά τους από τα ιδρύματα πολιτιστικής κληρονομιάς προς τα σύγχρονα έξυπνα περιβάλλοντα διαβίωσης. Σε αυτό το πλαίσιο η τέχνη ανακτά το ρόλο της στην καθημερινότητα μας και διασυνδέεται μοναδικά με καθημερινές δραστηριότητες όπως η πληροφόρηση η διασκέδαση και η εκπαίδευση.

Σε αυτήν την κατεύθυνση, στο πλαίσιο της παρούσας εργασίας, οι ρόλοι που διαδραματίζουν σημαντικό ρόλο σε αυτές τις δραστηριότητες αναγνωρίστηκαν και αναλύθηκαν έχοντας ως σκοπό την εξαγωγή συγκεκριμένων απαιτήσεων έτσι ώστε οι δραστηριότητες αυτές να μπορούν να εξυπηρετηθούν από τη Διάχυτη Νοημοσύνη. Τα περιβάλλοντα αυτά ξεκίνησαν ως μία γενική ιδέα που εν συνεχεία έγινε πράξη ως τρισδιάστατες αναπαραστάσεις οι οποίες εμπλουτίστηκαν με τεχνολογία Διάχυτης Νοημοσύνης. Εν συνεχεία αναπτύχθηκε μία αρχιτεκτονική που βασίζεται στην αλληλεπίδραση υπηρεσιών, αλλά και τα διάφορα υποσυστήματα της ώστε να υποστηριχθεί η διαχείριση εμπλουτισμός και ανάκτηση της γνώσης, εναλλακτικές τεχνικές αλληλεπίδρασης, υποσύστημα προσωποποίησης και προσαρμογής. Με βάση την υποδομή αυτή, μία σουίτα εφαρμογών που αξιοποιούν τις τεχνολογίες Διάχυτης Νοημοσύνης δημιουργήθηκε μέσω της χρήσης ενός κοινού για όλες τις εφαρμογές πλαίσιο επαναχρησιμοποιήσιμων διεπαφών. Οι εφαρμογές αυτές συμπεριλαμβάνουν εφαρμογές για την υποστήριξη ενός πλήρως λειτουργικού καλλιτεχνικού εργαστηρίου ζωγραφικής (αναζήτηση σχετικής πληροφορίας, δημιουργία συνθέσεων, σχεδίαση, δημιουργία έργων τέχνης κ.τ.λ.), εφαρμογές για την υποστήριξη ενός μουσείου (οθόνες πληροφόρησης, αλληλεπιδραστικά εκθέματα, αλλά και εφαρμογές που επεκτείνουν την εμπειρία των επισκέψεων σε μουσεία) και τέλος εφαρμογές στο πλαίσιο έξυπνων περιβαλλόντων διαβίωσης (αλληλεπιδραστικά ντοκιμαντέρ, εκπαιδευτικά παιχνίδια, εφαρμογές πληροφόρησης με χρήση της τέχνης). Οι εφαρμογές αυτές ενσωματώθηκαν σε έναν χώρο προσομοίωσης του εργαστηρίου Διάχυτης Νοημοσύνης του ΙΠ-ΙΤΕ όπου τα οραματισθέντα σενάρια δοκιμάστηκαν, είτε εικονικά είτε στο πλαίσιο μελετών, με σκοπό να διαπιστωθεί η πρακτικότητα του εγχειρήματος. Τέλος οι εφαρμογές αυτές αξιολογήθηκαν τόσο από ειδικούς στο χώρο της ευχρηστίας όσο και στο πλαίσιο αξιολόγησης ευχρηστίας με συμμετοχή χρηστών. Στόχος των αξιολογήσεων αυτών ήταν ο εντοπισμός τυχών προβλημάτων ευχρηστίας πριν την πρακτική αξιοποίηση των αναπτυχθέντων υποδομών.

Using Ambient Intelligence Technologies for Producing and Disseminating Paintings

Nikolaos I. Partarakis

PhD Thesis

Computer Science Department
University of Crete

Abstract

‘Techne’ (τέχνη) is an Ancient Greek word meaning art, craftsmanship, skill, but is also the etymological root of the word ‘technology’.

Today, Information and Communication technologies have progressed to a point where they substantially influence many fields of human activity, including mathematics, medicine, physics, etc., and are becoming an integral part of everyday life. However, so far they have not yet affected the way that art is created, disseminated, learnt, taught and enjoyed by people in their living environment.

As computers increasingly become embedded into common artefacts in our surroundings, Ambient Intelligence (AmI) has become the vision of “people living easily in digital environments in which the electronics are sensitive to people's needs, personalized to their requirements, anticipatory of their behaviour and responsive to their presence”. These smart environments are intended to revolutionaries all human activities such as entertainment, live, work, education, creativity etc.

This research work is targeted to apply AmI technology in all aspects of art creation and fruition, and in particular to: (i) producing visual art following the footsteps and techniques of the great art masters, (ii) learning and teaching art history and techniques, (iii) augmenting the way that art is perceived by altering the museum experience, and (iv) expanding the meaning of art from the cultural institutions to the modern smart living spaces. In this context art regains its role in our everyday lives and is uniquely interleaved and interrelated with activities such as information, entertainment and education.

In the context of this research work, the stakeholders involved in these envisioned activities were identified and their requirements were analysed. This analysis resulted in the elaboration of functional and non-functional requirements allowing the

definition of interaction scenarios within the context of smart environments. These environments were envisioned, designed in 3D and populated with AmI technology. A service oriented architecture was conceived, together with the various subsystems, to support knowledge management annotation and extraction, alternative ambient interaction techniques, personalisation and adaptation. Based on the above, a suite of AmI applications were developed through the usage of a common user interface framework for art. These applications, which include the applications to support a fully functional artist's workshop (background research, composition, design and art creation etc.), a museum scenario (information displays, interactive exhibits, applications that extend the museum experience etc.) and finally a smart living spaces scenario for transferring museum experiences at home (interactive documentaries, educational games, informative art displays etc.), were deployed within an AmI simulation space in the FORTH's Ami facility where the envisioned scenarios were run virtually but also in the context of several feasibility studies. Finally, expert based and user based evaluation was conducted in order to identify potential usability barriers prior to the practical exploitation of the concepts.

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Abbreviations and Acronyms

UI	**U**ser **I**nterface
CLIs	**C**ommand **L**ine **I**nterfaces
CH	**C**ultural **H**eritage
CHIs	**C**ultural **H**eritage **I**nstitutions
GUIs	**G**raphical **U**ser **I**nterfaces
HCI	**H**uman-**C**omputer **I**nteraction
ICT	**I**nformation and **C**ommunication **T**echnologies
U2I	**U**nified **U**ser **I**nterfaces
AmI	**Am**bient **I**ntelligence
ISTAG	**I**nformation **S**ociety **T**echnologies **A**dvisory **G**roup
XML	e**X**tensible **M**arkup **L**anguage
RDF	**R**esource **D**escription **F**ramework
OWL	**W**eb **O**ntology **L**anguage
iHCI	**i**mplicit **H**uman **C**omputer **I**nteraction
MR	**M**ixed **R**eality
PDA	**P**ersonal **D**igital **A**ssistant
RFID	**R**adio Frequency **ID**entification
EAGER	**E**mbedding **A**ccessibility, **G**rac**E**ful transfo**R**mation and ease of use in Web-based applications
OWL-DL	**W**eb **O**ntology **L**anguage-**D**escription **L**ogics
DMSL	**D**ecision-**M**aking **S**pecification **L**anguage
URI	**U**niform **R**esource **I**dentifier
HTML	**H**yper**T**ext **M**arkup **L**anguage
SGML	**S**tandard **G**eneralized **M**arkup **L**anguage
HMD	**H**ead **M**ounted **D**isplay

1 Introduction

1.1 The evolution of Technology and its impact on Art?

Computers started developing in the 1950s. The Internet Protocol Suite was invented in 1982, and by 1995 the internet was opened to all. Since that time the speed of microprocessors has increased year upon year. Both software and hardware progress so rapidly that systems soon become out-dated. In terms of communication, in 1993 only 1% of communication was carried out using the internet. By 2007 more than 97% of the world's communication was through the internet and the World Wide Web. Cables have been laid all around the world to facilitate faster and better communication. At the same time a multitude of mobile nowadays make computing available at the reach of our hands. The contribution of modern technology has been substantial in many fields of human activities including mathematics, medicine, physics, etc., and today is an integral part of everyday life. But how does technology affect Art? Art is the process or product of deliberately arranging elements in a way that appeals to the senses or emotions. It encompasses a diverse range of human activities, creations, and modes of expression, including music and literature. According to [119], art has non-motivated purposes which are integral to being human and motivated ones which are intentional, conscious actions on the part of the artists or creator. So far, the advances in computer science have enabled providing and improving digital tools for artists (better resolution, more colour variety etc.). But art remain the same. It's what experience the artist can deliver to his audience that is provocative, that can change their thoughts. The way that an art piece can change the

relationship of its audience to the world has not changed. At one point in history, the colour blue was a near impossible pigment to obtain; ultramarine could only be made using lapis lazuli, a rare semi-precious stone that most commoners couldn't afford. When artificial pigments burst onto the art scene, suddenly skies were literally bluer and artists were faced with a whole new palette of choice. This exact fact makes technology irresistible; it's cheap and affordable to all. Thanks to the Internet, artists can share their work with millions of people, far more than would have ever seen an exhibit in a gallery. But no matter how we use technology, the human mind will always be at the centre of art, guiding the tools to create the artist's vision.

1.2 Penetration of technology into Art experiences

Technology has opened a world of opportunities for Art to reach the recipients of the modern information society and the potential directions of its usage are daily expanded.

1.2.1 Augmenting Museum Experience through modern technology

Nowadays museums strive to design and implement exhibitions that facilitate modern technology to offer **enjoyable and personalised** educational experiences trying to overcome two major issues: (1) most visitors might visit only once, and (2) a typical museum visit only lasts for a very short time, and only few minutes are spent on each exhibit [251, 252]. At the same time Worldwide, there have been a number of museums that have installed, temporarily or permanently, **interactive exhibits** in their premises. **Interactive Games Installations in Museums** mainly focus on providing alternative learning experiences to children. According to [269], existing **mobile applications for museums** fall into the following categories: 45% provide guided tours of permanent exhibitions and the museum in general, 31% provide guided tours of temporary exhibitions and practical information about the museum visit, 8% provide combinations of the first two, 8% are apps devoted to a single object or artwork from the collection, 4% offer content creation or manipulation from the user inspired by artists' work, and 3% are games based on the exhibits. As the **World Wide Web** is being widely used by a constantly growing number and variety of people and that technology has evolved in the area of digital culture and cultural heritage preservation, many museums have established some presence on the (World Wide) Web by creating their web sites. The main purposes of these sites is making

material available to a wide audience, but also providing additional information about museum visits, temporal exhibitions etc. Socialisation is considered under the concept of **Social Media**, which includes web-based and mobile technologies used to turn communication into interactive dialogue [274]. For the moment, museums are mostly involved with one-way communication strategies using mostly Facebook and Twitter to focus on event listing, reminders, reaching new audiences and promotional messaging.

1.2.2 Art in our everyday lives

Modern technology has been also employed as a means of transferring art in our everyday lives mainly in the domain of **informative art** and **games**. Informative art is computer augmented, or amplified, works of art that not only are aesthetical objects but also information displays, in as much as they dynamically reflect information about their environment [87]. The presentation of art has been used as a means of visualizing information by altering its appearance. For example, the Andy Warhol's paintings of Campbell soup cans have been employed for visualizing a count-down clock or "egg-timer" [34]. The usage of cultural resource in the context of games include games based on exhibits, as well content creation or manipulation from the user inspired by artists' work.

1.2.3 Modern technology for Art creation

Art creation is probably the only aspect of Art affected less from the digital revolution. Technology has not yet altered the means of artistic creation but has resulted in the generation of novel art forms. Digital architecture, digital painting and digital sculpture, all premised on digital drawing using the "ingrained" algorithms of the computer, are new modes of art with unexpected and still incompletely explored creative, aesthetic and visionary potential [130].

1.3 Ambient Intelligence: A window on the future of interaction

Ambient Intelligence (AmI) presents a vision of tomorrow where 'intelligent' environments react in an attentive, adaptive and active (sometimes proactive) way to the presence and activities of humans and objects in order to provide appropriate services to the inhabitants of these environments. It is an emerging field of research and development that is rapidly gaining wide attention from an increasing number of

researchers and practitioners worldwide, particularly in Europe [101]. In this context, Ambient Intelligence moves forward from traditional interaction techniques to altering interaction itself. Ambient Intelligence technologies integrate sensing capabilities, processing power, reasoning mechanisms, networking facilities, applications and services, digital content and actuating capabilities distributed in the surrounding environment. While a wide variety of different technologies is involved, the goal of Ambient Intelligence is to either entirely hide their presence from users, or to smoothly integrate them in their surroundings as enhanced environment artefacts rather than technological gadgets. This way, the computing-oriented connotation of technology essentially fades out or even disappears in the environment, providing seamless and unobtrusive interaction paradigms. Therefore, people and their social situation, ranging from individuals to groups, families or friends, and their corresponding environments (office buildings, homes, public spaces, etc.) are at the centre of the design considerations [101].

1.4 Art & Ambient Intelligence

This work builds on the evolution of Ambient Intelligence and the penetration of technology within art experiences to alter the way that art is experienced within cultural heritage institutions, and used in the context of our everyday lives. At the same time the production of Art is revolutionised through Ami technologies with respect to the mediums, processes and techniques of the Art Masters. This creative renaissance is expanded to produce valuable results regarding the preservation of cultural heritage and the education of young Artists.

2 Background and Related Work

This work aims at establishing the foundations for facilitating the usage of art in Ambient Intelligent Environments and at the same time establishing the means to support novel forms of AmI augmented creativity. The usage of art in accordance to modern technologies poses requirements both for the point of view of art (use art in a way that doesn't contradicts its original purpose) and from the point of view of modern technology (be able to facilitate human activities in an optimum way). This section establishes the foundations of this research work by identifying the state of the art in the targeted application domains.

2.1 Ambient Intelligence

The term "Ambient Intelligence" was coined from Philips Research' vision of "people living easily in digital environments in which the electronics are sensitive to people's needs, personalized to their requirements, anticipatory of their behaviour and responsive to their presence" [81]. This concept was adopted by the Information Society Technologies Advisory Group (ISTAG) as one of their research focus. In their report [47], ISTAG show the concrete vision that humans will, in an Ambient Intelligent Environment, be surrounded by intelligent interfaces embedded in everyday objects (as furniture, clothes and the environment [47]). This environment should be:

- non-obtrusive
- **aware** of the specific characteristics of human presence and personalities

- able to **adapt** to the needs of users
- capable of responding intelligently to **spoken** or **gestured** indications of desire
- capable of engaging in **intelligent dialogue**. It should be able to **adapt to the needs of the user** in a relaxed and unobtrusive manner.

Ambient intelligence, although an active research field for a substantial period, is still lacking practical exploitation in many domains. To achieve this [47], research has to be conducted in fields such as:

- **Components for ambience**
    - **Smart materials** that can emit light efficiently; e.g. electronic wallpaper or large synthetic foils that can emit light, materials that can be used for touch and tactile movement, and synthetic materials that enable mass storage and processing of digital data, and that can be integrated into fabrics.
    - **MEMS and sensor technology**, including ultra-low power (mechanical) effectuators, sensor devices bridging between the physical world and the cyber world, i.e., touch, vision, smell, and technology for the integration of smart materials, micro systems, and microelectronics into systems.
    - **Embedded Systems development technology** for re-configurable real-time embedded computing platforms, for remote diagnostics and repair of embedded systems, and to build in security and trustworthiness to embedded systems.
    - **Ubiquitous communication** including ubiquitous pico-radio networks for active and passive tagging, Internet accessibility for any physical object, and ubiquitous broadband access to content and data.
    - **I/O device technology** that supports ubiquitous hands-free speech control, ubiquitous touch-pads and whiteboards, and can turn any surface into a display.
    - **Adaptive software** that is self-managing or has self-adjusting capabilities that can detect and adjust to the health or otherwise of its environment, re-allocating resources as required and automating much of the system configuration work that now has to be done manually.
- **Components for intelligence**

- **Media management and handling** including presentation languages that support "produce once" and "present anywhere", methods and tools to analyse content and enrich it with metadata, and tools to exploit the Semantic Web.
- **Natural interaction** that combines speech, vision, gesture, and facial expression into a truly integrated multimodal interaction concept that allows human beings to interact with virtual worlds through physical objects, and that enables people to navigate the seemingly infinite information they will be able to access.
- **Computational intelligence** including conversational search and dialogue systems, behavioural systems that can adapt to human behaviour, and computational methods to support complex search and planning tasks.
- **Contextual awareness**, for instance systems that support navigation in public environments, e.g., in traffic, in airports and in hospitals, service discovery systems that enhance the shopping experience, and context aware control and surveillance systems.
- **Emotional computing** that models or embodies emotions in the computer, and systems that can respond to or recognise the moods of their users and systems that can express emotions.

To this end, regarding the technological aspects and requirements set in the context of Ambient Intelligence, an in depth study of research conducted in many application domains is necessary. The fundamentals of **semantic data modelling** are important both for achieving seamless information access and information induction from a centralized "intelligent" source. In the same context, **user and context modelling** by means of semantically enabled user profiles are important for achieving user and context awareness. These facilities together with modern user and context oriented **interaction techniques** can meet the requirements set by modern ambient intelligent environments. At the same time, considerable effort must be put on the way these environments are interfaced through interactive applications, taking into account that the traditional means of human computer interaction dissolve as new interaction requirements and paradigms evolve. To this end, Implicit Human-Computer Interaction (iHCI) addresses goal-oriented interaction of humans with the environment and with artefacts. Within this process, the system acquires implicit

input from the user and may present implicit output to the user. The driving force of iHCI is the existence of Intelligent User Interfaces that are becoming increasingly important as users face increasing system complexity and information overload. These interfaces are adaptive to heterogeneous user populations, employing the full power provided through modern user and context modelling facilities. At the same time, the environment itself is changing; microprocessors are integrated into everyday objects like furniture, clothing, white goods, toys, even paint. Ubiquitous Communication enables these objects to communicate with each other and the user by means of ad-hoc and wireless networking. Mixed reality (MR) (encompassing both augmented reality and augmented virtuality) refers to the merging of real and virtual worlds to produce new environments and visualisations where physical and digital objects co-exist and interact in real time. In this new environment machines are more than ever becoming anticipatory and responsive to human needs.

2.1.1 Interaction in Ambient Intelligence

2.1.1.1 Intelligent User Interfaces

The term Intelligent User Interfaces [354] is defined as an approach to interfaces that supports more sophisticated and natural input and output, to enable users to perform potentially complex tasks more quickly, with greater accuracy, and to improve user satisfaction.

2.1.1.1.1 Characteristics of Intelligent User Interfaces

Intelligent interfaces are becoming increasingly important as users face increasing system complexity and information overload, and at the same time the **user populations become more heterogeneous**. These systems are typically characterized by one or more of the following properties [59].

- **Multimodal input**: they process potentially ambiguous, impartial, or imprecise combinations of mixed input such as written text, spoken language, gestures (e.g., mouse, pen, data-glove) and gaze
- **Multimodal output:** they design coordinated presentations of, e.g., text, speech, graphics, and gestures, which may be presented via conventional displays or animated, life-like agents.

- **Interaction management:** mixed initiative interactions that are context-dependent based on system models of the discourse, user, and task. This new class of interfaces promises knowledge or agent-based dialogue, in which the interface gracefully handles errors and interruptions, and dynamically **adapts** to the current **context** and **situation**. The overarching aim of intelligent interfaces is to both increase the interaction bandwidth between the human and the machine (e.g., by increasing interactive media and modalities) and at the same time increase interaction effectiveness by improving the quality of interaction. For example, by explicitly **monitoring** user **attention**, **intention**, and **task progress**, an interface can explain why an action failed, predict a user's next action, and warn a user about undesirable consequences of actions or suggest possible alternative actions.

2.1.1.1.2 Design considerations

Facilitating art in the context of Ambient Intelligence entails the need to address design issues far more complex than those faced within the traditional human computer interaction scheme. This results from the need to address the usage of application from various contexts (workshop, smart home, art gallery, etc.) and with diverse interaction techniques (speech, gestures, touch input etc.). Furthermore, issues arise from the diversity of the target user population, making design for all approaches mandatory. The term design for all (or universal design) is used to describe the need of providing seamless access to all users regardless of age, education, culture, or disability. In this context, according to [198] several principles must be taken into account:

1. **Equitable Use** – The design is useful and marketable to people with diverse abilities.

- Provide the same means of use for all users: identical whenever possible; equivalent when not.
- Avoid segregating or stigmatising any user.
- Provisions for privacy, security and safety should be equally available to all users.
- Make the design appealing to all users.

2. **Flexibility in Use** – The design accommodates a wide range of individual preference and abilities.

- Provide choice in methods of use.
- Accommodate right or left-handed access and use.
- Facilitate the user's accuracy and precision.
- Provide adaptability to the user's pace.

3. **Simple and Intuitive Use** – Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills or current concentration level.

- Eliminate unnecessary complexity.
- Be consistent with user expectations and intuition.
- Accommodate a wide range of literacy and language skills.
- Arrange information consistent with its importance.
- Provide effective prompting and feedback during and after task completion.

4. **Perceptible Information** – The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

- Use different modes (pictorial, verbal, tactile) for redundant presentation of important information
- Provide adequate contrast between essential information and its surroundings.
- Maximize "legibility" of essential information.
- Differentiate elements in ways that can be described
- Provide compatibility with a variety of techniques or devices used by people with sensory limitations.

5. **Tolerance for Error** – The design minimizes hazards and the adverse consequences of accidental or unintended actions.

- Arrange elements to minimize hazards and errors; most used elements, most accessible; hazardous elements eliminated, isolated or shielded.
- Provide warnings of hazards and errors.
- Provide fail-safe features.
- Discourage unconscious action tasks that require vigilance.

6. **Low Physical Effort** – The design can be used efficiently and comfortably and with a minimum of fatigue.

- Allow user to maintain a neutral body position.
- Use reasonable operating forces.
- Minimize repetitive actions.
- Minimize sustained physical effort.

7. **Size and Space for Approach and Use** – Appropriate size and space is provided for approach, reach, manipulation and use regardless of user's body size, posture and mobility.

- Provide a clear line of sight to important elements for any seated or standing user.
- Make reach to all components comfortable for any seated or standing user.
- Accommodate variations in hand and grip size.
- Provide adequate space for the use of assistive devices or personal assistance.

2.1.1.2 User and Context Profiling

The scope of user profiling is to provide information regarding the user currently accessing an interactive application. In this context, a user profile initially contains attributes specified by the user prior to the initiation of interaction or during interaction (based on interaction monitoring). On the other hand, context profiling aims at collecting context attribute values related to [62]:

- The environment (the physical space the user is located, relationships to other people (people in the same neighbourhood, people connected to by the communication services), the position of the user, the direction and speed etc.)
- The situation the user is in. (emergency situation, someone's birthday, a car accident, etc.)
- The activity of the user
- The role of the user
- The service the user has access to and/or is using.

Regarding the required characteristics in creating effective user modelling systems, these have been documented in [2] and [96]:

- **Generality, including domain independence.** User modelling systems should be usable in as many domains as possible, and within these domains for as many user modelling tasks as possible.
- **Expressiveness and strong inferential capabilities.** Expressiveness is a key factor in user modelling systems; they are expected to express many different types of assumptions about the users and their context. Such systems are also expected to perform all sorts of reasoning, and to perform conflict resolution when contradictory assumptions are detected.

- **Support for quick adaptation.** Time is always an important issue when it comes to users. User modelling systems are required to be adaptable to the users' needs. Hence, they need to be capable of adjusting to changes quickly.
- **Precision of the user profile.** The effectiveness of a user profile depends on the information the system delivers to the user. If a large proportion of information is irrelevant, then the system becomes more of an annoyance than a help. This problem can be seen from another point of view: if the system requires a large degree of customization, then the user will not be willing to use it anymore.
- **Extensibility.** A user modelling system's success relies on the extensibility it offers. Companies may want to integrate their own applications (or API) into the available user models.
- **Scalability.** User modelling systems are expected to support many users at the same time.
- **Import of external user-related information.** User models should support a uniform way of describing users' dimensions in order to support integration of already existing data models.
- **Management of distributed information.** The ability of a generic user modelling system to manage distributed user models is becoming more and more important. Distributed information facilitates the interoperability and integration of such systems with other user models.
- **Support for open standards.** Adherence to open standards in the design of generic user modelling systems is decisive since it fosters their interoperability.
- **Load balancing.** User modelling servers should be able to react to load increases through load distribution and possibly by resorting to less thorough (and thereby less time-consuming) user model analyses.
- **Failover strategies.** Centralized architectures need to provide fall-back mechanisms in case of a breakdown or unexpected situation.
- **Fault tolerance.** In case a user inserts wrong data in his/her profile by mistake (i.e. a user denotes an opposite gender), the system must prompt the user to adjust the corresponding parameters, rather than reset his/her profile.

- **Transactional Consistency.** Parallel read/write procedures on the user model should lead to the deployment of sufficient mechanisms that preserve and restore possible inconsistencies.
- **Privacy support.** Another requirement that user modelling systems must meet in order to become acceptable by the general public is to respect and retain the user's privacy. In order to meet these requirements, such systems must provide a way for the users to express their privacy preferences, as well as the security mechanisms to enforce them

On the other hand, effective context modelling systems must be able to [55]:

- **Gather context information of different types.** The technique should be flexible enough to handle different kinds of context information and should not be limited to any specific type of context information, for e.g. information about a user's location from various location sensors.
- **Gather context information without end user intervention:** The technique should be able to be used in self-supporting or self-learning environments and should not require explicit end user input, for e.g. downloading the users' interests from their personal web pages instead of inserting from scratch all their profiles' parameters.
- **Aggregate context information from potentially multiple sources:** The technique should enable the aggregation of context information from potentially multiple sources, for e.g. accessing various URIs to download and aggregate all users' profile parameters.
- **Predict context behaviour:** The technique should be able to derive additional information from the information in the context information representation, such as prediction of context behaviour. For e.g., if a user deviates too often then the system has to adjust her routing preference accordingly, in order to be conformed to her profile.
- **Adjusting behaviour in a certain (pre-defined) situation:** The technique should be able to describe behaviour (next to context) and define rules when certain behaviour (action) should be executed. For e.g., if a user deviates, then an appropriate rule should be fired in order to force dynamic path-replanning.

- **Handle different representations of context information: The** technique should be able to handle different representations of context information, for e.g. dealing with different calendar formats.

2.1.1.2.1 Approaches to User and Context modelling

Static profiling

Static profiling entails the complete specification of attributes prior to the implementation of the reasoning engine of an interactive application. Where static profiling is employed, the process of altering the logic used for generating the adaptable behaviours of the system is semi-automatic and cannot occur on the fly. More specifically, it is not feasible, when such an approach is followed, to enrich the decision logic while the system is running to perform meta-adaptation. This can only be achieved in the context of adaptations that occur based on collecting and analysing usage data.

Extensible profiling using special purpose languages and Design Support Tools

A potential solution to the problems of static profiling is to separate the logic under which adaptations occur from the system performing the adaptation. This is achieved through the creation of special purpose languages for the specification of the decision logic. An example of such a language is DMSL [91], employed by the AVANTI browser. When such languages are used, the design of an application in term of alternative styles and their activation can be carried out using special purpose design support tools, such as MENTOR [9], which can be used to produce the decision logic of an application and therefore orchestrate the user interaction.

Extensible profiling using semantic data modelling

Recent approaches to information representation have made possible the creation of a profiling scheme using a knowledge base modelled with the help of a web ontology language such as OWL to store the appropriate information in the form of semantic web rules and OWL-DL [78] ontologies. This approach has many advantages, as it offers enough representational capabilities to develop a formal context model that can be shared, reused, extended for the needs of specific domains, but also combined with data originating from other sources, such as the Web or other applications. Moreover, the development of the logic layer of the Semantic Web is resulting in rule languages

that enable reasoning about the user's needs and preferences and exploiting the available ontology knowledge [66].

2.1.1.3 User Interface Adaptation

In computing, the notion and importance of *adaptation*, as the ability to adapt a system to the user's needs, expertise and requirements was only recently recognised. In a natural environment, the survival of all living organisms is often, if not constantly, subject to their ability of constantly changing, adjusting and functioning according to the surrounding environment. In similar terms, the "survival" of users (in other words, system adoption) could also be considered as subject to: (a) their ability to adapt to a given system (environment), on the one hand, and (b) on the other hand, to their freedom to modify the settings of the system in question. Clearly, early forms of UIs were rather based on the first case alone. This was mainly due to the fact that early interfaces had to be taken as de facto, restricting their users to make convenient changes to the style, presentation and behaviour of a given UI. A radical change in this pattern has recently emerged with the introduction of adaptation in user interfaces: the computationally empowered environment can adapt itself, at various degrees, to its 'inhabitants', thereby reducing drastically the amount of effort required from the user's part. Taking into account the principles of iHCI and employing the information that ambient intelligence can provide regarding the current situation, it becomes possible to build user interfaces that employ adaptation to answer user requirements through implicit or explicit input. According to [93], in systems where context is available during runtime, it becomes feasible to adjust the software part of the UI at runtime. At a very general level, the requirements for the UI are dependent on the application, the UI hardware available, the user and the context. The requirements defined by the application may be quality parameters for the visualization of certain content. The UI can be a single device with specific properties or a distributed configurable UI system with various input and output options. In this context some preliminary adaptation issues include [93]:

- **UI adaptation for Distributed Settings:** In environments where there is a choice of input and output devices it becomes central to find the right input and output devices for a specific application in a given situation. In an experiment where web content, such as text, images, audio-clips, and videos are distributed in a display

rich environment, for example, the context is a key concept for determining the appropriate configuration [58].

- **UI adaptation in a Single Display:** Adapting the details in a single user interface at runtime is a further big challenge. Here in particular adaptation of visual and acoustic properties according to a situation is a central issue. Simple examples that are by now available in different commercial products are the adjustment of the volume according to the environmental sound level and the regulation of backlight depending on the ambient light level. Experiments have been conducted in order to evaluate the concept of having fonts and font sizes in a visual interface that are dependent on the situation. Mainly dependent on the user's activity the size of the font was changed. In a stationary setting the font was small whereas when the user was walking the font was made larger to enhance readability [3]. The orientation aware display described in [4] belongs also in this category.

2.1.1.3.1 User Interface Adaptation toolkits

Data stemming for user and context profiling are used by adaptation toolkits for dynamically generating the interface instance that is more appropriate for the specific user and under the specific context of use. These frameworks in their most advanced implementation consist of a collection of alternative interaction elements mapped to specific user and context parameters. The automatic selection of the appropriate elements is the key for supporting an exponential amount of alternative interface instantiations.

EAGER [19] is a development toolkit that allows Web developers to build adaptive applications using facilities similar to those offered by commonly user frameworks (such as ASP.NET [11] and Java server faces [48]). It is a developer framework build over ASP.NET providing adaptation enabled ready to use dialogs. By means of EAGER, a developer can produce Web portals that have the ability to adapt to the interaction modalities, techniques and UI elements most appropriate to each individual user, according to profile information containing user and context specific parameters.

Another similar toolkit, reported in [56], aims to facilitate the implementation of adaptive-aware user interfaces for mobile services. UI widgets supported by this framework encapsulate all the necessary information and are responsible for requesting and applying the relative decisions. The Toolkit employs DMSL to allow

UI developers to turn hard-coded values of lexical attributes to adapted UI parameters specified in an external preference file. As a result, the UI Implementation is entirely relieved from adaptation-related conditionality, as the latter is collected in a separate rule file.

2.1.1.3.2 Adaptation and personalisation in AmI environments

In Ami environments, user profiling is aimed at providing a model for holding the information regarding the user currently accessing an interactive application. In this context, a user profile initially contains attributes specified by the user prior to the initiation of interaction or during interaction (based on interaction monitoring). An example of user profile ontology is UPOS, developed in the context of the SPICE mobile ontology project [246]. Examples of ontologies to formalise context are CODAMOS [247], and CAMUS [248]. Recent approaches to information representation have made possible the creation of a profiling scheme using the OWL 2 RL. Such a profile is aimed at applications that require scalable reasoning without sacrificing too much expressive power [250]. OWL 2 RL reasoning systems can be implemented using rule-based reasoning engines. This approach has many advantages, as it offers enough representational capabilities to develop a formal context model that can be shared, reused, extended for the needs of specific domains, but also combined with data originating from other sources, such as the Web or other applications. Moreover, the development of the logic layer of the Semantic Web is resulting in rule languages that enable reasoning about the user's needs and preferences and exploiting the available ontology knowledge [62].

2.1.1.4 Ubiquitous Computing

Ubiquitous Computing means integration of microprocessors into everyday objects like furniture, clothing, white goods, toys, even paint. Ubiquitous Communication enables these objects to communicate with each other and the user by means of ad-hoc and wireless networking [7]. In Ubiquitous Computing, as the computer disappears in the environments surrounding user activities, the objects therein become augmented with Information and Communication Technology (ICT) components (i.e., sensors, actuators, processor, memory, wireless communication modules) and can receive, store, process and transmit information [52]. In the context of Ubiquitous Computing two types of "disappearance" have been defined [103]:

- Physical disappearance is achieved by the miniaturization of computer parts that allows convenient and easy integration into other artefacts, mostly into "close-to-the-body" objects, so that the result can fit in your hand, can be integrated in clothing or even implanted in the body, etc. As a result, features usually associated with a computer are not visible anymore and the interaction happens via the compound artefact in which the computer parts disappeared.
- Mental disappearance of computers is achieved by becoming "invisible" to the "mental" eye of the users. This can happen by embedding computers or parts of them in the architectural environment (walls, doors) or in furniture (tables, chairs, etc.) or other everyday objects. Then, computers are not perceived as computers anymore – although the artefacts can be quite large – but as adding interactive, communicative, and cooperative aspects to traditional everyday objects (e.g., an interactive wall or an interactive table is a "table", a "wall" that is interactive and not a computer built into a table or the wall).

According to [52], AmI artefacts differ from traditional objects in a number of properties and abilities:

- **Information processing:** The information that an artefact processes can be descriptions of the context of use, data to be used for a task, guidelines on how to perform a new task (i.e. a program), messages to be sent or that have been received from other objects. The result of information processing is a set of services, that is, a set of abilities that appear in the digital space and relate to information; an artefact may offer or request services
- **Interaction with environment:** artefacts can perceive properties of their context of use (via their embedded sensors, or by communicating with other artefacts) and can also produce responses to these stimuli (via their actuators)
- **Autonomy:** the operation of artefacts depends on electrical power; thus their autonomy depends on the availability of electrical power (which most of the times depends on the capacity of their battery)
- **Collaboration:** artefacts can exchange messages via (usually wireless) communication channels; the content of these messages may range from plain data to complex structures, including programs, database parts etc.

Artefacts possess two new affordances with respect to objects:

- **Composeability:** artefacts can be used as building blocks of larger and more complex systems. This is a consequence of the fact that artefacts possess a communication unit, and requires universal descriptions of tasks and services
- **Changeability:** artefacts that possess or have access to digital storage can change the digital services they offer. In other words, the tangible object can be partially disassociated from the artefact's digital services, as they are based on the manipulation of information.

2.1.1.5 Empathic Computing

The Impressionist painter Claude Monet is believed to have developed cataracts in later life, and the effect may be seen in his paintings. Tones in his later paintings became muddy; whites and greens became yellow [12, 195]. Edgar Degas was almost blind for his last twenty years. He worked mostly in pastel with increasingly broad, free handling. Henri Matisse lost his mobility in his later years. He had to draw from his bed and let his assistant cut the paper. Can a machine have empathy to understand human's feeling or states? What can an empathic artefact do for people at home? For years computers have been viewed and actually were apathetic machines that only accept or reject instructions. René Descartes claims that thoughts, feelings, and experience are private and it is impossible for a machine to adequately understand or know the exact feelings of people. On the other hand, Ludwig Wittgenstein states that there is no way to prove that it is impossible to adequately imagine other people's feeling [65]. Alan Turing argues that machine intelligence can be tested by dialogs through a computer keyboard [82].

Empathic computing emerges as a new paradigm that enables machines to know who, what, where, when and why, so that the machines can anticipate and respond to human needs gracefully. Taking into account research efforts so far, however, Empathic computing is narrowed down to understand 'low-level' subconscious feelings, such as pain, illness, depression or anomaly. Empathic computing is a combination of Artificial Intelligence (AI), network communication and human-computer interaction (HCI). To these end, pioneer attempts in the field of empathic computing include:

- ELIZA is a software application capable of engaging an empathic conversation [111]. By performing simple keyword matching, the program appears to be a 'good listener' to psychiatric patients showing that a small

program could generate pseudo-empathy at a certain degree. However, human feelings and states are more than just verbal communication.

- Cyborg [145] is probably the most daring physical empathic artefact. The pioneer implanted an electrode array under his skin that interfaced directly into the nervous system. The signal was fed into a robot arm that mimicked the dynamics of Warwick's own arm. Furthermore, the researcher implanted a sensor array into his wife's arm with the goal of creating a form of telepathy or empathy using Internet to communicate the signal remotely.

2.1.1.6 Mixed Reality and Augmented surfaces

Mixed reality (MR) (encompassing both augmented reality and augmented virtuality) refers to the merging of real and virtual worlds to produce new environments and visualisations where physical and digital objects co-exist and interact in real time. A mix of reality, augmented reality, augmented virtuality and virtual reality is discussed in [113]. The usage of mixed reality in the context of Ambient Intelligent has been proposed in various contexts, such as Office applications [85]. Such applications use tables for providing a convenient environment for people to meet, discuss, look over prepared documents, and to present ideas that require face-to-face collaboration. In this context, this concept has been used for achieving collaboration of a team of website designers [95]. In some cases ([70], [90]) the augmented table infrastructure is combined with the usage and integration of mobile devices for combining the usage of traditional working environments together with modern collaboration platforms.

2.1.1.7 Interaction techniques for Ambient Intelligence

The emergence of Ambient Intelligence (AmI) is leading to the elaboration of new interaction concepts that extend beyond current user interfaces based on the desktop metaphor and menu driven interfaces, thus driving a transition to more natural and intuitive interaction with everyday things [239]. Natural interaction refers to people interacting with technology as they are used to interact with the real world in everyday life, through gestures, expressions, movements, etc., and discovering the world by looking around and manipulating physical objects [240]. Typical examples are input techniques such as touch, gestures, head and body position tracking and manipulation of physical objects, which seamlessly integrate the physical and digital worlds and support the direct engagement of the user with the environment [241].

Augmented Reality (AR) allows virtual imagery to augment and enhance physical objects in real time. Users may interact with the virtual images using real objects in a seamless way [242]. Progress in computer vision approaches largely contributes to innovative interaction in AmI environments through techniques such as like image acquisition, image processing, object recognition (2D and 3D), scene analysis, and image flow analysis, which can be exploited for humans' and objects' recognition and tracking [243]. At the same time, ICT components are embedded into everyday objects like furniture, clothing, white goods, toys, etc. [244]. Augmented objects can be used for providing implicit or explicit input to systems while their physical and mental existence as computational devices disappears [245]. Ambient interaction merges real and virtual worlds to produce new environments and visualisations where physical and digital objects co-exist and interact in real time. Additionally, in Ambient Intelligence environments interaction is monitored and implicit input is also extended to include empathy to understand human's feeling or states.

2.1.1.7.1Input

In this section the most popular input techniques in the context of ambient intelligence are presented.

Gestures

Gestures are employed in the context of ambient intelligence for providing alternative ways of user input in a human like fashion. Gestures when used in the context of human to human communication are a quick and intuitive way of communication. On the contrary, identifying human gestures in a computerized environment is not an easy task. Research conducted in this field involves the usage of gestures for providing input to augmented desk interface systems using multiple fingertips recognition (identify fingertips and their trajectories and infer gestures based on these trajectories) [77], [71]. In the same context, computer vision is used for identifying hand gestures, facial expressions and body postures [76]. Furthermore, the usage of thimble-shaped fingertip markers made of white printing paper with a 'black light' source has been proposed for providing gesture recognition in the context of back projection walls [54]. Finally, gaze recognition has been employed for facilitating alternative gesture based input [74], [75], [73].

Speech input

Input through speech is not particularly new. Research has been conducted in this field for years, and today thousands of commercial and research product have been developed. Although much work has been done to date, the research field of human language processing is more than active mainly due to the fact that modern speech interfaces enable the communication through identification of simple voice commands on a predefined grammar. In the context of Ambient Intelligence, although desirable, human language understanding is not crucial. However, it is crucial to provide the means for error free detection of speech when such input is required. This is essential mainly because Ambient Intelligence aims at making the interaction with computing technology transparent to the user from the one hand and as affective as the usage of traditional means. It is therefore argued that the adoption of new technologies resides at least on being as affective as the main stream technologies used at the time of their presence.

Augmented objects

The paradox of demassification is an expression introduced by Brown and Duguid several years ago [14]. This research work outlines how digital technology and new media introduce new material and social conditions for the design of artefacts. The process of Demassification involves the loss of mass while artefacts are transited to the virtual word and can be distributed and accessed globally. Demassification is considered a design problem, because it deprives the artefact of material "border resources" for shared interpretation. The shape, texture, and weight of the book may still be an important aspect of its "bookness" and how people experience it as a book. It seems that a feasible design strategy must find ways to counter this loss of mass [20]. Embodied interaction does rethink the borders of the digital artefact. Starting from the position that interaction with artefacts, also digital artefacts, is experiential, it suggests accepting that there is no such thing as an entirely digital artefact. Instead the design materials for digital artefacts are both spatial and temporal [20]. Augmented objects have been used for facilitating collaboration for design purposes (painting computer generated visual overlays as texture on physical models using a physical-digital brush, displaying visual overlays on and around physical models and using physical Building Blocks for illustrating ideas and concepts in very concrete, interactive full-scale mock-ups and prototypes) [20].

2.1.1.7.2 Output

This section discusses how ambient intelligence employs various technologies and techniques for providing output to the user.

Ambient Displays

Ambient displays go beyond the traditional notion of "display" in conventional graphical user interfaces (GUI) found on PCs, notebooks, PDAs. Ambient displays are designed employing observations of nature and their corresponding metaphors, and were proposed to provide users with information considered relevant at arbitrary points of work or living engagement, originating from many different sources, and presented at the periphery of human (visual) perception [1]. Having the displays operate in the periphery of a user's awareness allows other user tasks to sustain primary roles [30] [61]. Peripheral displays move to the centre of attention only when appropriate and desirable. Such kind of information is usually "implicit" by being available in the periphery, compared to traditional "explicit" GUIs. Ambient displays are envisioned as being all around the environment, and thereby moving information off the conventional screens into the physical environment. They present information via changes in light, sound, movement of objects, smell, etc. Early examples are described in Ishii et al. [46], Wisneski et al. [196], Gellersen et al. [28], and ways of evaluating them are discussed in Mankoff et al. [60]. Ambient displays have been used to trigger the attention of team members in a subtle and peripheral way by communicating the atmosphere and thus providing a sense of a place in an ambient Agora [103].

Non-Visual output

Although blending gestures with visual interfaces is a common practice in Ambient Intelligence environments, there is a substantial need for providing non visual output to potential users. Several considerations lead to this requirement, but mainly the fact that in many cases requiring visual attention from a user is not always the most appropriate solution. Non-visual interfaces are frequently understood to involve tactile, haptic or audio interaction. Work with the visually impaired demonstrates that audio can serve as an effective representation for both visual and conceptual information [8, 10 and 68] and therefore audio can be considered as an effective approach for providing non visual output. In the same context, the significance of audio output has been proven through the creation of audio only feedback system to

be employed by users on the move (where employing user attention for visual output is not only less efficient but can also dangerous) [92]. Towards this direction, since visual output devices may not always be available in an Ambient Intelligence environment, audio as an output channel is considered to be equally important.

2.1.1.8 AmI and HCI: Implicit Human Computer Interaction (iHCI)

Interaction needs in the context of ambient intelligence are much more diverse than the ones of traditional human computer interaction. Many aspects that influence the interaction between humans are not present in traditional human computer interaction. The influence of situation, context, and environment offers a key to new ways of HCI. Towards the aim of creating interaction between humans and systems that is closer to natural interaction, as defined by the Ambient Intelligence initiative, it is crucial to include] implicit elements into the communication, in addition (or as an alternative) to the traditional explicit dialog. The following definition characterizes the new paradigm of implicit human computer interaction (iHCI) [93]

- **Implicit Human-Computer Interaction (iHCI)** is the interaction of a human with the environment and with artefacts which is aimed to accomplish a goal. Within this process the system acquires implicit input from the user and may present implicit output to the user.
- **Implicit Input** are actions and behaviour of humans, which are done to achieve a goal and are not primarily regarded as interaction with a computer, but captured, recognized and interpret by a computer system as input.
- **Implicit Output** is the output of a computer that is not directly related to an explicit input and which is seamlessly integrated with the environment and the task of the user.

The basic idea of implicit input is that the system can perceive the users interaction with the physical environment and also the overall situation in which an action takes place. Based on perception, the system can anticipate the goals of the user to some extent and hence it may become possible to provide better support for the task the user is performing. The basic claim is that iHCI allows transparent usage of computer systems. This enables the user to concentrate on the task and allows interacting in the

physical environment rather than with the computer system. Some indicative scenarios of implicit input/output in the context of iHCI application are [93]:

- The user drives into the driveway with her car. The car and the garage are equipped with communication units. The car communicates with the garage (e.g., a challenge response authentication protocol) and if the car has permission to enter the doors open automatically
- The heating/air condition control system of an office building has access diaries of the people working in the building. Office rooms are not heated/cooled when people work offsite or are away. Meeting rooms are heated/cooled in advance of scheduled meetings
- A garment that can measure pulse, skin temperature, and breathing combined with an outdoor location sensor and a communication unit can be used to monitor a user's vital health signals. In case of a problem, an emergency call can be issued.

Analysing applications and domains relevant to iHCI, the following basic issues are central and have to be addressed in order to create such applications:

- **Perception as precondition.** To create applications that offer iHCI capabilities it is inevitable to provide the system with perception for context. This includes sensing, abstraction and representation
- **Finding and analysing situations relevant for the application.** When applications are based on implicit interaction, it becomes a central problem to find the situations that should have an effect on the behaviour of the system
- **Abstracting from situations to context.** Describing a situation is already an abstraction. To describe what should have an influence on applications, classes of situations have to be selected
- **Linking context to behaviour.** To describe an iHCI applications classes of situations and in a more abstracted way contexts must be linked to actions carried out by the system.

2.1.1.9 Ambient information visualization

Unlike traditional information visualization, ambient information visualizations reside in the environment of the user rather than on the screen of a desktop computer [107]. Ambient visualization has been used to present information in alternative ways to the traditional text or photo based visualization. For example, ambient visualization has been used for mapping email traffic to screen elements (rectangles) using different

colour field on a display for each specific user mailbox. The same scheme has been used for presenting Bus Departure Times [107]. According to [83], designers of ambient information systems make decisions about how much information to display, what specific aspects to depict, and how exactly to display it, transparently or abstractly, on a monitor or via a decorative sculpture. The design dimensions that capture the space of ambient information systems are:

- **Information capacity:** Information capacity represents the number of discrete information sources that a system can represent.
- **Notification level:** Notification level is the degree to which system alerts are meant to interrupt a user.
- **Representational fidelity:** Representational fidelity describes a system's display components and how the data from the world is encoded into patterns, pictures, words, or sounds.
- **Aesthetic emphasis:** Concerns the relative importance of the aesthetics of the display. Some system designers seek to build displays and artefacts with sculptural or artistic conventions. For these systems, being visually pleasing is a primary objective. Others however place relatively little focus on aesthetics and typically focus more on information communication ability.

Based on the aforementioned design dimensions, four main archetypes can be identified in existing ambient information system design [83]:

- **Symbolic Sculptural Display:** ambient information systems that display very few pieces of information, usually a single element.
- **Multiple-Information Consolidators:** ambient systems that display many individual pieces of information in a consolidated manner.
- **Information Monitor Display:** displays that are a peripheral part of a user's computer desktop.
- **High Throughput Textual Display:** displays that use text and very simple graphics (icons) to denote information.

Some efforts in the field of ambient information visualisation include:

- Information Percolator is an ambient display that consists of 32 transparent, water-filled plastic tubes, each with an aquarium air pump mounted at the bottom. By releasing a short burst of air in a tube, a "pixel" is created that

travels up the tube. The display is thus able to show any pixelated image of a resolution of approximately 32x25 pixels. The display was used for several applications, including a movement awareness display and a reminder clock [31].

- The Ambient Media System was developed at TeCo in Karlsruhe, Germany, aiming at the creation of general mechanisms for integrating ambient media with digital information. The system connects hits on web pages to ambient devices in the environment, such as lamps, table fountains and a humidifier; thus integrating web awareness into the environment [94].
- At Berkeley, the Group for User Interface Research has created a generalized mobile interface where six objects can be hung in strings from a "staging area" and, depending on some information, be lowered up to three feet. This interface has been used to create different ambient mobiles like the Weather Mobile and the Bus Mobile, which present weather and bus traffic information, respectively.
- Hello.Wall is an ambient display consisting of LED-clusters forming light patterns that convey information. The display has three different modes and activation areas, one of which is ambient. Hello.Wall also has features connecting to the to the research on media spaces and awareness from the 1990's, where it is used to connect "commons" in two geographically dispersed offices by displaying abstract activity information [84].

2.1.1.10 Understanding the user experience

The centrality and role of user-centred design approaches in the emergence and development of Ambient Intelligence environments is discussed in [288]. The user-centred design process is analysed in the light of the requirements posed by AmI, focusing on emerging problems and potential solutions towards applying and revising existing methods and techniques or developing new ones. User experience factors which are considered as critical in such context include natural interaction, accessibility, cognitive demands, emotions, health, safety and privacy, social aspects, cultural aspects, and aesthetics.

Recent research on capturing and understanding the museum visiting experience focuses on conceptual and methodological approaches to planning, designing and

assessing the integration and deployment of interactive technologies in the museum context. A study conducted on the use of multi-touch interfaces in museum [289] addresses methodological aspects and advocates the adoption of broader approaches targeting not only user performance, but also the user overall satisfaction and experience. Such an approach should target the visitors' use of and engagement with interfaces, as well as an analysis of design usability and functionality (through qualitative approaches such as interviews), coupled with quantitative data of the museum visit provided by sensing technologies). [290] discusses engagement, appropriation and personalisation in experiencing digital arts, and supports the conclusion that empowering people to make an artefact their own lies at the centre of user-centred designed in domain of culture. Multidisciplinary co-design of cultural exhibits involving museologists, designers, computer scientists, domain experts, etc. is applied in [291] to the design of interactive exhibits based on Augmented Reality and Tangible Interfaces. The co-design process includes requirements definition, museum exhibit and interaction design, implementation and evaluation phases, thus covering the entire development from the earliest analysis phase until the final concrete installation. The formative evaluation of touch screen and table based interactive museum artefacts in real settings is discussed in [291], aiming at ecological validity and at understanding 'natural' group interaction involving users of different ages. Finally, [292] elaborates on design principles for museum exhibitions, identifying five main principles and exemplifying their applications through case studies. The principles are summarised by the keywords clarity, layering, engagement, authenticity and resonance.

In this research work we adopt a user-experience based design methodology, and take particular care in designing the testing methodology to suit the requirements of experience art in various smart environments.

2.1.2 Requirements for successful Ambient Intelligent systems

The above description of AmI suggests some requirements for the successful adoption of AmI technologies. They should be accessible to and or serve the user in a proactive yet unobtrusive manner [110], become aware of the user and her needs and responds intelligently to the context and needs of the user. Aarts and Marzano review the five key technology features that portray an AmI system [6]:

- **Embedded.** Networked devices are integrated into the environment.
- **Context aware.** System recognizes people and their situational context.
- **Personalized.** System can tailor itself to meet people's needs.
- **Adaptive.** System can change in response to people.
- **Anticipatory.** System anticipates people's desires without conscious mediation.

2.1.3 Applications of Ambient Intelligence

2.2.3.1Collaboration

The Human-computer Interaction group at Stanford University investigates the collaboration of groups in a meeting room and possible support by information technology [49]. The interactive room allows the integration of mobile devices to control explicit room functions. Also the intuitive movement of content data from screen to screen or from application to application is possible. Meetings rooms were initially also the starting point for the Roomware® concept and prototypes ([105], [104]) developed at the Fraunhofer-Institute for Integrated Publications and Information Systems (Fraunhofer-IPSI) but then extended to the more comprehensive notion of Cooperative Buildings [104] that provide smart or intelligent environments. The AMBIENTE-Team at Fraunhofer-IPSI built a number of different Roomware® components (i.e., the integration of room elements like walls, doors, furniture with information technology) and populated the AMBIENTE-Lab, an experimental space investigating the interaction with interactive walls (DynaWall®), tables (InteracTable®, ConnecTable®), and chairs (CommChair®) and its usage in group collaboration and coordination ([105], [104]).

2.1.3.2 Ambient Assistive Living

Very well-known is the Oxygen initiative from the Massachusetts Institute of Technology [79] that develops a bunch of different technologies and applications (e.g., specialized sensors, follow-me music applications, indoor navigation) that realize some kind of assistive behaviour. The Aware Home project from the Georgia Institute of Technology [53] is implemented in a real house that consists of two floors including living rooms, bedrooms and baths. Here, ultrasonic sensors, radio frequency technology and cameras are used to observe users and to test assistive technologies that should maintain their autonomy and independence of life. Applications that are

able to find daily items (key, pairs of classes for instance) are typical examples. The Ambient Assisted Living laboratory of the Fraunhofer-Institute for Experimental Software Engineering (Fraunhofer- IESE) is exploring technologies for supporting elderly to help them feeling safe and secure. Different applications (e.g., fall detector) are prototyped and tested.

2.1.3.3 Ambient Games

Games that are designed to be played on an ambient environment are not a new trend in ambient intelligence. Several approaches for creating such games to date include:

- **Virtual Hockey:** Based on HI-SPACE's framework [42], Hockey is a fast paced, two-person game that combines aspects of an air hockey table and pinball.
- STARS' games (Monopoly and KnightMage) [17,16]
    - The **Monopoly** adaptation profits greatly from the rotation functionality, because a high amount of textual information is involved with the original Monopoly game.
    - **KnightMage** implements a basic set of rules for medieval hack'n slash style role-playing adventures. The players explore and ransack dungeons and landscapes filled with horrifying monsters, moderated by a human Game Master (GM).
- **Monkeybridge [43]:** is a multiplayer game, where users place real and virtual objects onto a physical surface, thus influencing the behaviour of the characters. The characters autonomously choose: the path the walk on; decide how to get from one platform to the other, automatically choose the straightest path from several available tiles; and fall into the water if there is no suitable piece of landing stage to walk on.

Virtual Hockey

Monopoly

KnightMage

Monkeybridge

Table 1: Four examples of Ambient Games

2.2 Ontology Models in AmI and the Cultural Heritage Sector

One of the main goals of the research work reported in this thesis is to systematically model a large amount of information to be used by a wide range of AmI applications. This poses a fundamental requirement for enabling these applications to process and "understand" the data that they display. A potential response to this requirement is the use of ontologies for data modelling. Ontology can be defined as “an explicit specification of a conceptualization” [29]. As pointed out in [22], ontologies define the concepts and relationships used to describe and represent an area of knowledge. According to [62], ontologies are used to classify the terms used in a particular application, characterize possible relationships, and define possible constraints on using those relationships. The relationships typically include hierarchies of classes. A hierarchy specifies a class C to be a subclass of another class C’ if every object in C is also included in C’. For example, all faculties are staff members. Apart from subclass relationships, ontologies may include information such as:

- properties (X teaches Y)

- value restrictions (only faculty members can teach courses)
- disjointness statements (faculty and general staff are disjoint)
- specification of logical relationships between objects (every department must include at least ten faculty members).

In practice, ontologies can be very complex (with several thousands of terms) or very simple (describing one or two concepts only).

2.2.1 Ontology specification languages

XML: The Extensible Markup Language (XML) [21] is a subset of SGML. Its goal is to enable generic SGML to be served, received, and processed on the Web in the way that is now possible with HTML. XML has been designed for ease of implementation and for interoperability with both SGML and HTML. XML documents are made up of storage units called entities, which contain either parsed or unparsed data.

RDF: The Resource Description Framework (RDF) [86] is a general-purpose language for representing information in the Web. The RDF specification describes how to use RDF to describe RDF vocabularies. This specification defines a vocabulary for this purpose, and defines other built-in RDF vocabulary initially specified in the RDF Model and Syntax Specification. The RDF vocabulary description language, RDF Schema, is a semantic extension of RDF. It provides mechanisms for describing groups of related resources and the relationships between these resources.

OWL: The OWL Web Ontology Language [78] is designed for use by applications that need to process the content of information instead of just presenting information. OWL facilitates greater machine interpretability of Web content than that supported by XML, RDF, and RDF Schema (RDF-S), by providing additional vocabulary along with a formal semantics.

2.2.2 Ontology models for cultural resources

In the Cultural Heritage Domain, the use of ontologies for describing and classifying objects is now a well-established practice. The Getty vocabulary databases, maintained by the Getty Vocabulary Program, provide a solid basis that is a de facto

standard in the area [236]. These databases are thesauri compliant with the ISO standard for thesaurus construction. They comprise: the Art & Architecture Thesaurus (AAT), the Union List of Artist Names (ULAN) and the Getty Thesaurus for Geographic Names (TGN). The AAT, in particular, contains more than thirty thousand concepts, including terms, descriptions, bibliographic citations and other information relating to art. The AAT is organized as a hierarchy with seven levels, called facets, in which a term may have more than one broader term. The Getty Research Institute has also developed a metadata schema, called the Categories for the Description of Works of Art (CDWA), for describing art works. CDWA includes 381 categories and sub- categories, a small subset of which are considered core, in the sense that they represent the minimum information necessary to identify and describe a work. Complementary to CDWA, the Conceptual Reference Model (CRM) of the International Committee for Documentation of the International Council of Museums (ICOM-CIDOC) has emerged as a conceptual basis for reconciling different metadata schemas [237]. CRM provides definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation. CRM is an ISO standard (21127:2006) that has been integrated with the Functional Requirements for Bibliographic Records (FRBR) and the Europeana Data Model [238], which plays the role of upper ontology for integrating metadata schemes of libraries, archives and museums.

2.2.3 Annotation models for cultural resources

Digital annotations present higher potential than paper annotations. These annotations can be applied in a variety of digital media and according to the lexical and syntactic constructs used to express annotations can be categorised as follows [365]:

- By medium: lexical (text or hyperlink), visual (icon or high-lighting), or acoustic (audio signal).
- By locality of reference: Annotations may refer to entire texts, parts of texts or both
- By process: textual, link and semantic. Textual annotation involves adding some form of free text commentary to a document. Link annotation provides information in the form of the contents of a link destination, rather than an explicit piece of text or other data. Semantic annotation, finally, assigns markup elements according to a specified model, which take values from

controlled vocabularies, and it aims at both human readers and software agents.

Recent approaches regarding annotating cultural heritage resources have introduced methodologies to annotate artefacts which are semantically enriched by using annotations. To achieve this, an infrastructure to systematically enrich 3D shapes in a collection by using propagated annotations has been defined proposing also the means for annotating, propagating and structuring the annotations using the CIDOC-CRM ontology [363]. In the same context existing approaches focus on the provision of the appropriate tools to handle different kinds of multimedia objects, allowing for querying and annotating text, 2D images or 3D artifacts [364]. Furthermore generic annotation models have been defined that could be applied in the context of cultural heritage resources such as the Open Annotation Core Data Model[1] which specifies an interoperable framework for creating associations between related resources, annotations.

2.2.4 Ontology models for User Awareness

An example of user profile ontology is UPOS, developed in the context of the SPICE mobile ontology project [246]. This ontology, defined in OWL, allows creating situation-dependent sub-profiles. The User Profile Ontology [345] created in the context of Cloud4All [346], aims to introduce a semantic model capable of (a) capturing the domain knowledge that is relevant with user needs and preferences in the context of user interaction, taking into account standardization efforts in the field, (b) offering the required expressiveness for describing user profiles based on personal needs and preferences across applications, platforms and devices, and various conditions that these needs and preferences shall be applicable for (e.g., considering the user state, the user activity, the physical environment, etc.), (c) linking user (interaction) requirements with user needs and preferences, which are in turn expressed through a common terminology (i.e. a Registry of common terms), (d) providing the basis for developing tools to facilitate effective user profile initialization and management, and (e) providing the foundation for developing semantics-based matchmaking approaches among user needs and preferences and applications/services

[1] Open Annotation Data Model: http://www.openannotation.org/spec/core/

based on semantic rules and automatic reasoning techniques (cf. Specification of Cloud Semantic Infrastructure).

2.2.5 Context Models

Context.owl is an OWL ontology presenting a generic context model that can be used for describing the structure and elements of context aware systems. It is developed in the context of LoCa, a Swiss National Research Project and it is a part of the OSIRIS Next [344]. OntoNav [343] is an integrated context aware navigation system for indoor environments that uses UNO [342] ontology, an extension of GUMO and eliminates the redundant information modelled in GUMO. OntoNav is purely user centric in the sense that both the navigation paths and the guidelines that describe them are provided to the users depending on their physical and perceptual capabilities as well as their particular routing preferences.

2.3 Technologies for Art Digitisation and Artefact Recognition

2.3.1 Automatic and Semi-automatic annotation of Art

Computer science proposed statistical machine learning approaches to perform automatic and semi-automatic annotation of paintings [203, 204 and 205]. Modern attempts in the same field where partially based on employing well defined theories of art and colour such as the artistic colour theory of Itten [206], together with an ontology based hierarchy of artistic concepts and machine learning techniques.

2.3.1.1 Manual Annotations based on Art ontologies

In the field of manual annotation attempts have been made to standardize all possible interpretations of an image. To this end arts-oriented ontologies that include artistic and general concepts have been developed allowing human experts to perform the annotation task. These ontologies often include artistic and general concepts, which describe and characterize an image at various levels of detail. This includes visual characteristics of paintings as well as description of its objects, mood, theme etc. Such ontologies include ICONCLASS [207] and the Art and Architecture Thesaurus (AAT) [208].

2.3.1.2 Computer vision for Art Classification

Computer vision algorithms are also used in the implementation of a service able to perform image classification for knowledge annotation tasks. Several different classification criteria have also been investigated in the past years [280]. Such criteria can be roughly classified in two distinct classes according to the human ability to see the visual features they are based on. The first class corresponds to human-readable features, i.e. features that can be easily interpreted by human experts. The second class corresponds to higher-level features, which are hard to detect "by the naked eye", if at all. This research work will evaluate not only how these features allow the classification of entire paintings and of their subregions, but also how effective they are in a semi-automatic approach, where a human expert needs to understand the computer output.

2.3.1.3 Annotations and Art retrieval

While annotating art is a highly important task effort has also been put on employing knowledge stemming from this field for enabling image retrieval systems to perform more accurate image searches. To this end it was identified that knowledge such as high level description of image contents should be facilitated by image retrieval systems [211]. At the same time various visual attributes (colour value, palette, texture etc.) and high level concepts (art period, location) has also been proven significant for art retrieval [212]. At the same time effort has been put on understanding the relationship between query concepts and user backgrounds. Research has grouped users of such systems into novice and expert user groups [213 and 214]. To this end it was pointed out that there is a significant relationship between the user's background and the textual descriptions for the painting provided to him/her.

2.3.1.4 Discussion

Research conducted in the fields of automatic and semi-automatic annotation of art has been proven successful for performing such annotations with large possibility of success but these percentages usually apply to a relatively small dataset where artists and concepts of their work are predefined. It is therefore not feasible to perform automatic annotation of artwork stemming from unknown sources (such as the internet) but only extract some meaningful information regarding the artistic concept used for producing the artwork in question. At the same time there is always the need

for manual confirmation of the produced annotations by experts in the domain. Manual annotation can be achieved using external ontologies as the ones already presented in the previous sections. These ontologies represent a complex tool for manual annotation that contains a vast number of terms that require extensive knowledge of the respective domain from the annotators. In an attempt to assist in the annotation process, various researchers [209 and 210] developed ontology-based tools for annotation. However, even with these ontology-based tools, the human effort required for annotation is still substantial. In the context of the work presented in this paper it is argued that manual annotation is not adequate. The recipients of smart environments are people with different backgrounds, different tastes for art that cannot be covered by an objective expert based categorization of art. Each of us understands art in his own personal way. A joyful painting for a specific individual can wake bitter memories of the past to another. It is therefore important to introduce the concept of subjective judgment in the core of art annotation. Research in the context of art retrieval and annotation systems has produced valuable results regarding the significance of identifying and using user expertise in order to adapt what is presented to whom and what is required by whom.

In this research proposal we present a hybrid method for annotation and retrieval of art and its usage in the context of smart environments. To this end ontology of artistic concepts has been created and populated with an initial dataset of Artists, Artworks and Annotations (created by experts in the domain). This ontology also models the potential user profiles involved in the retrieval of such knowledge. At the same time services build on top of this ontology provide the option to alter and enrich its content using automatic inferred artistic concepts and manual ones selected by end used based on their expertise. In these terms we incorporate the means for subjective artefact annotation based on the assumption that subjective annotation although not always scientifically valid is totally aligned with the believes, desires and intentions of the end user.

2.3.1 Visual Media Acquisition and Processing for Art

Multiple visual media have been used so far for the production of multimedia presentation or museum installations. The generic term digitization is usually adopted to encompass many different processes, each one specific for a selected media type.

For most of those medium, digitization and the production of formats customized for the specific application requires the application of specific (and in many cases quite complex) post-processing operation. This is surely the case of 3D data.

Professional Cultural Heritage applications introduce high demands over the 2D medium used, aiming at high quality images (this requires to take into account calibration aspects both in the acquisition and while processing the digital images), and high-resolution images (to be able to zoom in at the level of the very small details, such as brush strokes or colour detachments, a very high sampling density is needed on, possibly, very large surfaces, e.g. large paintings or fresco surfaces. Techniques have been recently developed that allow to align and stitch multiple images on common overlap regions and to extend significantly the native resolution of the CCD used, without serious compromise on data quality).

Moreover, Reflectance Transformation Imaging (RTI) is being adopted. RTI is a computational photography technology that captures a subject's surface shape and colour and enables the interactive re-lighting of the subject from any direction [308]. RTI also permits the mathematical enhancement of the subject's surface shape and colour attributes. The enhancement functions of RTI can reveal surface information about the subject that is not available through direct empirical examination.

Computer vision algorithms are also used in the implementation of a service able to perform image classification for knowledge annotation tasks. Several different classification criteria have also been investigated in the past years [309]. Such criteria can be roughly classified in two distinct classes according to the human ability to see the visual features they are based on. The first class corresponds to human-readable features, i.e. features that can be easily interpreted by human experts. The second class corresponds to higher-level features, which are hard to detect "by the naked eye", if at all.

The last few years have witnessed a mayor evolution of both the devices for 3D digitization and the algorithms and tools for post-processing the 3D sampled data [310]. Open source solutions exists (e.g., CNR's MeshLab platform [311]) that have reached maturity and have a very large community of users. 3D models can now be acquired quite efficiently, at a high level of accuracy, including also the acquisition and mapping of the colour [312] and not just shape as it was until very recently. Support is also appearing to provide capabilities to render those high-quality 3D models on the web, using WebGL [313] or other web-based platforms [314].

A strong limitation to the use of the digital 3D medium in museums or didactical tools has been the lack of suitable 3D presentation software tools; most of the multimedia have been developed so far using platforms (e.g. Director, formerly Macromedia and now Adobe) that are not well suited to include 3D data and interactive manipulation. One successful example of public 3D is the Arrigo VII presentation by ISTI-CNR (Pisa, Italy) based on CNR's high-end software for display of massive multi-resolution models (the Virtual Inspector system [315]). It employed successfully the novel concept of a "complementary exhibition", where a 3D-workstation is placed next to the real object. So visitors could explore close-up details of the statues, and were provided with additional information when clicking on hyperlinks on the 3D model. Providing access to multimedia data by means of links defined over the digital surface of an artwork is also a basic feature for supporting documentation of study and restoration. A flexible system is still missing that could be mastered by Cultural Heritage professional or multi-media installation designers, supporting the interlinking of the available literature and knowledge on top of the digital 3D model, transforming this model in the 3D index to available knowledge.

2.3.2 Recognition, Alignment, and Retrieval in Mobile Devices

The idea is to automatically recognize the artwork present in the scene and to show relevant information to the users. Techniques for image content recognition have been successfully proposed and used in limited and well defined scenarios, like for instance landmark recognition ([316], [317]), painting recognition [318], advertisement recognition [319]. In order to perform these recognition tasks, classification algorithms ([320], [321]) are typically used that, given a set of examples of the subjects to be recognized, some tuning parameters, and using some specific visual features [322], are able to decide if and which (trained) subject is contained in a given image. Research, recently, has aimed at offering at the same time high efficiency and effectiveness, and to make the process scalable so that it can be used from mobile devices.

2.4 Augmenting Art with Modern Technology

2.4.1 Personalised Information in Museums

Nowadays museums strive to design and implement exhibitions that offer enjoyable and educational experiences. However, designing such an exhibition is not an easy

task. The exhibition has to cater for the needs of different types of visitors and the selection of the most prominent technologies is further restricted by two important issues: (1) most visitors might visit only once, and (2) a typical museum visit only lasts for a very short time, and only few minutes are spent on each exhibit [251, 252]. The provision of a personalised experience to the visitors may help alleviate the problem of limited time and may more generally enhance the experience of any visitor if properly customized. Personalised access to information is also essential for people with diverse backgrounds, knowledge and interests to seamlessly access cultural resources.

Museum Guide 2.0 is an eye-tracking based personal assistant for museums and exhibits. Visitors wear a head mounted eye tracker whilst strolling through the exhibition. As soon as gaze on a specific exhibit is detected, the application plays an audio file that provides additional information about the specific exhibit [253]. The AGAMEMNON project aimed at providing visitors of sites of historical interest with personalized, information enriched experience through 3G cell phones [254]. The Macrographia system [255], installed in the Archaeological Museum of Thessaloniki, presents personalised information to users based on their position and language. Virtual Digital assistants have been also been employed for providing personalised information to users. The virtual agent Max has a full-time job as a central exhibit at the Heinz Nixdorf Museums Forum since 2004. He welcomes and entertains visitors though text based and gestures based interaction [256].

Current approaches to presenting personalised information in museums are mainly based on the concept of contextual personalisation (presenting information regarding the artefact currently in focus). This research work will introduce extended content personalisation based not only on the current context, but also based on the device or objects used for interaction, as well as the art ontology, combined also with personal annotations. This will allow users to fine-tune their visits according to their interests, but also to access related virtual exhibits as well as rich scientific, technical and historical information on art, and to ‘bring home’ their personalised museum experience. At the same time data from monitoring of users’ interests will be included (e.g., time spent on specific artefacts).

2.4.2 Interactive Exhibits

Worldwide, there have been a number of museums that have installed, temporarily or permanently, interactive exhibits in their premises. The "Fire and the Mountain" exhibition comprised four hybrid exhibits aiming to promote awareness about the cultural heritage of the people living around the Como Lake [257]. ARoS, an art museum in Denmark, employed four interactive exhibits targeted in an exhibition of the Japanese artist Mariko Mori [258]. The Austrian Technical Museum in Vienna opened a digitally augmented exhibition on the history of modern media [259]. The Archaeological Museum of Thessaloniki hosts "Macedonia from Fragment to Pixels" [260], an interactive exhibition of prototypical interactive systems with subjects drawn from ancient Macedonia. The Panoptes system allows the browsing of artefact collections, while Polyapton offers multitouch, multiuser gaming experiences with archaeological artefacts [255]. The Art-E-Fact Project [261] has developed a generic platform for interactive storytelling in Mixed Reality that facilitates access to a knowledge base of objects of art and art history. One installation was placed in the Bargello Museum (Soprintendenza Speciale pei il Polo Museale Fiorentino).

The above approaches either support a single user (e.g., in the case of kiosks or immersive simulations) or support multi user interaction through multi-touch surface for a number of users. In most of these cases, however, the focus of attention is not the exhibit itself, but rather the smart technology. This research work aims at bringing the attention back to the exhibits by augmenting the ways that the latter can communicate information to visitors. This will be achieved by (a) supporting simultaneous usage of exhibits by multiple users through gestures and hand tracking, (b) providing multi user tracking through vision using inexpensive cardboards for simultaneous presentation of information to multiple users, (c) engaging mobile devices such as smartphones and tablets carried by visitors as information displays and combining them with short burst projections on the periphery of each artefacts, and (d) providing for all the aforementioned facilities simultaneous access to information allowing a hybrid interaction metaphor where various users can interact simultaneously with a single exhibit.

2.4.3 Interactive Games Installations in Museums

Interactive games within museums mainly focus on providing alternative learning experiences to children. The Interactive Playground [262] in the WroArt Centre, a

modern art gallery in Wroclaw (Poland), is targeted to small children learning about the "classical rules and terms of arts (perspective, colour, texture), as well as various aspects of media technologies used in contemporary art (image and sound processing, interaction, real time processing)". Historical Orchestra is an interactive installation that makes use of a physical tangible interface to enhance the museum experience of an ancient illustrated manuscript kept in archive of the Topkapi Palace Museum in Istanbul [263]. The Asian Heroes puzzle game is a simple jigsaw puzzle presented in a story mode for children. The objective of the puzzle is for the player to put together five scenes from the story of Hua Mu Lan and learn more about the legendary heroine and the values and culture that define this character. The colourful visuals, lively music and clear audio narrations contribute to the aesthetic appeal of the game [264].

Museums are also showing increasing interest in providing games which facilitate an exploratory visiting style. 'Ghost of a Chance' [265], launched in The Smithsonian American Art Museum (SAAM) in 2008, was the first Alternate Reality Game (ARG) to be hosted in a museum. ARGs are immersive experience games that encourage players to interact with a fictional world using the tools of a real world (websites, email, telephone conversations, etc.). The plot of 'Ghost of a Chance' involved putting spirits that haunted museum objects to rest by solving several clues embedded into various media such as emails, websites (Facebook, Flickr and YouTube) and in-gallery meetings of participants and museum workers. As a final event, held in the SAAM, visitors could join six quests that were linked to six spirits and, by completing them, put those spirits to rest. The "Re-Tracing the Past" exhibition of the Hunt Museum was designed to show how interactive computer technologies could be introduced into a museum setting to create an exhibition that would be an engaging experience for visitors, open new avenues for exploration, allow for the collection of visitor opinions, and add to the understanding of the Museum's exhibits [266]. The Ragghianti Foundation held an exhibition entitled "Puccini Set Designer" that used new technologies to convey to the audience Puccini's work as set designer. This exhibition reinterprets the museum space as a scenic place where lighting, choreography, narrative rhythm, costumes and colours are produced with the aid of state-of-the-art technologies [267]. The "Gallery Tag!" of the Brooklyn Museum [268] is an interactive game where users tag museum objects aiming to win points and awards. It is based on exploration and discovery of exhibits which, according to the players, fit to a series of predetermined tags. The game encourages visitors to find and

tag objects from different floors of the museum rewarding them with additional points, is linked to the mobile version of the museum's website, and supports the convergence of the game's tags with the online collection, thus bridging the physical with the virtual collection.

The game installations to be created in the context of this research work will exploit new ambient interaction techniques through a variety of devices and everyday physical objects. In this context, museum tours, games, digital and physical artefacts will coexist and interrelate to provide a unique visiting experience to all, combining information, entertainment and learning.

2.4.4 Museum Mobile Applications

According to [269], existing mobile applications for museums fall into the following categories: 45% provide guided tours of permanent exhibitions and the museum in general, 31% provide guided tours of temporary exhibitions and practical information about the museum visit, 8% provide combinations of the first two, 8% are apps devoted to a single object or artwork from the collection, 4% offer content creation or manipulation from the user inspired by artists' work, and 3% are games based on the exhibits. Some of these applications are designed to be used during the museum visit to enrich the visitors' experience, and can be downloaded once the user enters the museum space (e.g., the TAP app from the Indianapolis Art Museum, [270]). The navigation of these apps is structured according to the spatial arrangement of the exhibits in the museum, include interactive or simple floor plans of the museum's exhibition spaces with the exhibits marked, or offer activities for enriching the museum visit, such as the "Gallery Tag!" [268]. In some cases the use of these apps is encouraged in the museum by orientation services which take advantage of users' location tracking technologies (e.g. [271]), and the incorporation of a keypad for selective access to audio narratives about particular exhibits. Additional features include various ways of navigating (e.g. spatial, chronological), the availability of images of high resolution and magnification, the linking and correlation of the system's content and links to additional online material (e.g., [272]). Another feature offered to users to assist their interaction with the content is the tagging of material as 'favourite' or the use of bookmarks and the creation of related personal collections.

Existing mobile applications for museums offer (a) navigation (spatial, chronological, alphabetical), (b) some degree of exploitation of technologies such as location

tracking and guidance, (c) some degree connectivity with the museum's online presence, (d) layering of content, (e) limited effort to incorporate different and interdisciplinary perspectives, (f) interaction focused mainly on magnification of images and (g) can be used mainly during the museum visit. This research work will enhance the user experience in a number of directions. Mobile devices and applications will constitute an integral part of the ambient interaction experience. Anonymous user profiles will be used, together with context and interaction monitoring, for allowing personalised access to information. Exhibit recognition technologies will be used for locating information. Support for deep zooming will be enhanced with annotations and inline presentation of point of interests. Subjective end user annotations of exhibits, posting of user comments and content download will also be supported. Finally, the transfer of knowledge from the museum to the living environment and its use in a number of applications including entertainment, learning and information will be supported.

2.4.5 Museums presence on the Web

As the World Wide Web is being widely used by a constantly growing number and variety of people and that technology has evolved in the area of digital culture and cultural heritage preservation, many museums have established some presence on the (World Wide) Web by creating their web sites. The main purposes of these sites is making material available to a wide audience, but also providing additional information about museum visits, temporal exhibitions etc. Probably the most important project aiming at making cultural heritage available online was not initiated by a museum, but established very strong collaboration with many art partners around the world. The Art Project [273] is collaboration between Google and 151 acclaimed art partners from across 40 countries. Using a combination of various Google technologies and expert information provided by our museum partners, Google has created a unique online art experience. Users can explore a wide range of artworks at brushstroke level detail, take a virtual tour of a museum and even build their own collections to share. Through Google Art Project people can access over 30 000 works of art from sculpture to architecture and drawings and explore over 150 collections from 40 countries, all in one place. This work extends the vision of the Google Art Project by enhancing user engagement with Art through AmI technologies within

museums and by facilitating knowledge from museum visits to produce unique Art experiences in our everyday lives.

2.4.6 Museum Social Applications

Socialisation in this research work is considered under the concept of Social Media, which includes web-based and mobile technologies used to turn communication into interactive dialogue [274]. Social media tools allow people to interact around ideas conveyed through images, video, audio, and animations. They have proven to be very effective not only in connecting audiences but also in engaging them, providing museums with real opportunities to dialog with their audiences in new conversations and learning experiences.

For the moment, museums are mostly involved with one-way communication strategies using mostly Facebook and Twitter to focus on event listing, reminders, reaching new audiences and promotional messaging. However, there does seem to be some evidence to suggest that museums are trying to increase their use of social media for more two-way and multi-way communication strategies [275]. The Brooklyn Museum uses a social media game (Freeze Tag!) to correct questionable tags that have been applied to its online collection [276]. The Victoria and Albert Museum's "World Beach Project" is an online global art project in which visitors upload photographs of patterns made with stones on beaches around the world. The photographs are linked to a map showing where they were taken [277]. According to Satnam Alag "when a group of individuals collaborate or compete with each other, intelligence or behaviour that otherwise didn't exist suddenly emerges; this is commonly known as collective intelligence" [278]. More formally, collective intelligence is defined as the "effectively use the information provided by others to improve one's application".

Collective Intelligence can be explicit, knowledge gathered and recorded by people, or implicit tacit intelligence that results from the data generated by the activities of many people over time. Both types of Collective Intelligence have proven to have compelling applications in the network: explicit data allow refining knowledge through the contributions of thousands of authors (e.g., Wikipedia and Freebase), whereas implicit data allow the discovery of entirely new knowledge by capturing key clicks and decisions as people use the network. Currently, there are there are lots of museum exhibits that allow visitors to register an opinion or a sensation, but rarely is

that data compiled and used for creating a Collective Intelligence experience. Social media can tap the Collective Intelligence of a museum's community to uncover facts and stories that would otherwise be lost, so it represents an opportunity to reach new audiences and to create communities around museum collections [279].

This research work will enhance the Collective Intelligence in the museum environment by using the information and experiences shared by visitors in the museum private social network and the activities of the visitors as they move inside the museum.

- Explicit Collective Intelligence will be gathered and recorded from the users through questionnaires or using information posted by the user on the museum social network, where visitors can share their experiences, impressions and information obtained in the virtual exhibits with other visitors.
- Implicit Collective Intelligence will be obtained from the data generated by the visitors as they move inside the museum (for example, the places that the user visited, the average time of visit, etc.).

This approach will help museums to raise awareness about user data (user interests/actions), to classify a visitor in a certain group according to her profile (nationality, cultural level, age, art preferences, etc.) and to suggest some places to visit by using the preferences of that group, i.e. provide more personalised tours inside the museum. The Collective Intelligence of a museum can also be shared with other museums; in fact this technology is a great example of the potential for collaboration among museums and can help to aggregate data shared across numerous organizations.

2.5 Applications for Smart Living Spaces

2.5.1 Entertainment & Learning in Smart Living Spaces

The Philips HomeLab [5] is mainly meant for testing and evaluating new entertainment and household devices and applications. New movie experiences or personal care services (open/closed window, elderly monitoring) are typical applications. iCAT [63], a physical avatar available as a playfellow, has been tested and evaluated in the HomeLab. The EasyLiving room of Microsoft Research focuses on the collaboration of sensor techniques (e.g., positioning devices, identification sensors) and their interplay with input and output devices for media output [15]. For

example, positioning sensors in the sofa affects the choice of the output device to be used for information presentation, e.g., power point slides or photos (in general the output device that is located opposite to the user).

Mixed reality is exploited both for enabling the augmentation of traditional board games and for allowing the combination of modern technology and traditional face to face communication in the context of collaborative gaming. To this end, research has been focused both on developing frameworks for the development of tabletop collaborative games [17] and on the actual development of games that combine augmented tables together with mobile devices [16]. RFID technology has been proposed for the creation of mixed reality games which allow the existence of various augmented physical objects in the game's space [80].

Existing approaches regarding the use of cultural resource in the context of games include games based on exhibits, as well content creation or manipulation from the user inspired by artists' work. Although such approaches are really entertaining and have a measurable impact, there are currently no systematic approaches allowing the reusability of knowledge across various game setups. This research work will elaborate an extensive knowledge base which will facilitate the development of games and learning applications, including, for example, art quizzes, memory games and art tutors, supporting in depth understanding of art. To this end, the knowledge used is not static but enriched by museum experiences while interaction with games is enriched through augmented objects, natural interaction techniques, and user and context monitoring. All these are achieved in an ambient yet non-intrusive environment.

2.5.2 Art in the context of Smart Living Spaces

2.5.2.1 Informative art

Informative art is computer augmented, or amplified, works of art that not only are aesthetical objects but also information displays, in as much as they dynamically reflect information about their environment [87]. The presentation of art has been used as a means of visualizing information by altering its appearance. For example, the Andy Warhol's paintings of Campbell soup cans have been employed for visualizing a count-down clock or "egg-timer" [34]. In the same context, InfoCanvas is a personalized peripheral display where the user can select the information she wants to monitor (e.g., stock portfolio information, weather, traffic data, news

headlines, etc.) via a web-based interface and map it to a pictorial representation on the display [67]. A collage of such pictorial representations is then displayed on a peripheral display in the users surrounding, e.g., on the wall in an office, where it provides the user with information "in a calm, unobtrusive manner". Unlike ambient information visualization, informative art moves ahead into investigating the aesthetics of the visualization metaphors trying to ensure the acceptability of such techniques by their target audience. This concept was applied to the domain of dynamic paintings following several different approaches, such as:

a) employing visualization techniques to convey data to imagery (e.g., the data portraits in PeopleGarden [199], the artificial life example in [88]);
b) creating dynamic compositions by adding predefined items on a canvas using predefined criteria and then altering their characteristics such as their size, colour, position, etc. based on related data values (e.g., InfoCanvas [67], Stone Garden [33]);
c) mimicking the style of famous painters in order to create novel paintings that have similar visual characteristics (e.g., the Mondrian-like and Klein-like paintings in [88], the Motion Painting and the Soup Clock in [33]);
d) mapping specific information semantics to some parts or characteristics of an existing painting and then changing the composition as related information is received (e.g., the "Stilleben" in [23]);

2.5.2.1.1 Design recommendation for presenting Informative Art

Taking into account that the concept of informative art is used for presenting non crucial background information to users without disrupting their major tasks, there are a number of considerations that arise. According to [24], the following design criteria are crucial when designing and developing informative art:

- **Cultural Background:** Cultural background and understanding to a high degree determines individual appreciation of visual designs and the aesthetic appeal of artwork. It is therefore essential to provide a number of choices between deferent artwork metaphors relating to the cultural context of use.
- **Aesthetic Appeal:** To provide means for a personal emotional expression, informative art applications should allow the modification of the appearance of colour, light, smoothness, shininess, etc.

- **Environmental Context:** The aesthetic appreciation of a piece of artwork is always based on its context of exposure. Different settings of exhibit (e.g., living room, office, public cafeteria, etc.) conceivably raise different levels of comfort with a specific display theme. This consideration poses the need for offering the option to adapt the themes used so as to satisfy the respective environmental requirements.
- **Comprehension and Continuity:** From prototypical installations has been learnt that spontaneous changes of the modes of display or the displayed emblems or symbols severely disrupts the continuity of comprehension. To minimize distraction generated by the occurrence of status changes, very soft blending and smoothing techniques have to be deployed in the visuals and graphics. Updates in information must be encoded in subtle changes of the respective visuals.
- **Periphery of Perception:** A critical affordance of Informative Art displays happens to be unobtrusiveness with respect to the primary task of the user, i.e., the display must not draw the focus of the users attention (by e.g., alerting), but stay calm in the background. The flow from the periphery to the focus of the users' attention (and back) should be user controlled.

2.5.2.1.2 Discussion

Is the information readable?

The usage of art for information visualization has been criticised in the literature. It is argued that users can't understand that they are looking at data and conceive the visualization as a mere picture. This is especially true when the metaphor is too literal, and therefore the viewers need to be forced out of the usual way they look at similar images [36]. There is no meaning that the user could discern. Research on Evaluating the Comprehension of Ambient Displays has proven that the viewer must take three steps: realize that data is being visualized, what data is being shown, and how the visualization works in order to read it. In this context, the most important step is to realize that what you are looking at is, indeed, visualization.

But is it Art?

One of the main concerns of creating amplified artworks for ambient information visualization is whether Informative Art is a form of art, as created by professional or

amateur artists. If the answer is based on what the scientific community has produced to date, the answer is clear and straightforward, no. People decorate their personal space to make it more "livable", and the configuration of furniture, plants, photos, posters, etc., directly reflects and influences the personality of the inhabitants. Informative Art must be able to fill the same role. Since the concept is based on the idea that Informative Art should occupy the same kind of places that paintings and posters currently do, it is crucial to make such applications visually appealing [97]. To this end, it can be argued that informative art applications are not meant for creating art themselves but presenting art for informative purposes. A number of alternative ways of using art created by famous artists over the centuries are presented in subsequent sections in this report, allowing the production of applications that are both visually appealing and informative.

This research work proposes innovative way of presenting informative art based on actual artefacts and through the facilitation of structured knowledge. To this end the ways that traditionally informative art is presented (mainly through amplified artworks for ambient information visualization) will be enriched. This is achieved by presenting famous art within the living environments, and augmenting the meaning of art to convey information. Several visualisation techniques will be employed through mixing art and traditional UIs for creating informative art displays that are readable, aesthetically appealing and capable to be used for various purposes.

2.6 Applications of technology for Creativity

2.6.1 Digital Art & Digital Artistis

The evolution of computing technology was rather influential for art creation. Novel forms of art have risen such as digital painting and digital architecture. The most important aspect of digital art is that it makes the creative act explicit as it has never been before in any kind of art, indeed, in the entire history of art. The computer has enormously expanded creativity by allowing for a greater exploration of chance, and thus the creation of more complex esthetic "permutations", different combinations of identical elements, than traditional art has ever created, indeed, allowed or even thought of. It has also given us a more efficient means of manufacturing art that never existed before2. This digital revolution has resulted into the emergence of a new

[2] http://www.artnet.com/magazineus/features/kuspit/kuspit8-5-05.asp

group of digital artists. David Hockney is a well-known artist facilitating modern technology for creating digital paintings. Every few days he creates a painting with his iPad's Brushes application, then emails it to identical devices on display at Paris's Pierre Berge-Yves St. Laurent Foundation, where his "Fresh Flowers" exhibition runs through January 303.In the same context entire galleries and art foundations have focused on digital art. Since 1979, Ars Electronica has sought out interlinkages and congruities, causes and effects. The ideas circulating here are innovative, radical, eccentric in the best sense of that term. They influence our everyday life, our lifestyle, our way of life, every single day4. For those interested in the field several journals of digital arts have been created. Leonardo was founded in 1968 in Paris by kinetic artist and astronautical pioneer Frank Malina. Malina saw the need for a journal that would serve as an international channel of communication between artists, with emphasis on the writings of artists who use science and developing technologies in their work. Today, Leonardo is the leading journal for readers interested in the application of contemporary science and technology to the arts5.

2.6.2 Combination of digital and physical media

Moving to state of the art of computing, research conducted in the field of Ambient Intelligence and ubiquitous computing has experimented on the combination of digital and physical media such the medium of paper and the medium of computation. Several prototypes of laboratory notebooks that combine PDAs and graphics tablets with paper notebooks to permit users to (e.g.) annotate, store, and evaluate their handwritten paper notes with computational tools have been created [355]. Still other efforts have employed alternative types of integration: the HyperGami and Popup Workshop programs [356, 357], for example, permit users to design paper polyhedral and popup cards (respectively) on the computer screen, print out templates on a colour printer, and assemble a tangible folded object. Coelho et al. explored “pulpbased computing” embedding electronics into lovely hand-made papers and the group Graffiti Research Labs conducted a variety of playful experiments with conductive paints and paper (Graffiti Research Labs) [358]. Buechley et al 2009

[3] http://www.hockneypictures.com/home.php

[4] http://www.aec.at

[5] http://www.leonardo.info/leoinfo.html

created a construction kit for paper computing that enables people to, relatively quickly and easily; meld the creative affordances of paper and computation to make interactive paintings and sketches [359].

2.6.3 Novel forms of Art in public spaces

In the same context research has proposed novel forms of Art in public spaces. Creating art with mobile phones in public spaces is an emerging form of artistic expression. Especial in the research topic of light art or light graffiti (for example, Blinkenlights6) research has targeted to the development of mobile interactive art such as the MobiSpray. MobiSpray provides a novel, portable, gesture-controlled art tool for creating large-scale, full-color projections in the environment in real time. In the same context several drawing interfaces have been proposed such as Cho's motion-sensitive brush [360], whose big movements result in big strokes while smaller ones produce thinner lines. In Drawn [361], painted ink forms appear to come to life, rising off the page to interact with the very hands that drew them. Remote interactive graffiti [362] invites distributed internet participants to "draw" via a browser-enabled interface on a common (installation based) canvas such as a white board or a projection on the sidewalk of a street. In the same context land art7 or environmental art8 (for example, Christo9), in which the landscape and the artwork are inextricably linked, and the intention of the artist is to cause no harm to nature or environment through the artwork.

[6] Blinkenlights: http://www.blinkenlights.net/

[7] Land art: http://en.wikipedia.org/wiki/Land_art

[8] Environmental art: http://en.wikipedia.org/wiki/Environmental_art

[9] Christo and Jeanne-Claude: www.christojeanneclaude.net/

3 User groups and requirements

This section aims at specifying the target user groups that benefit from the usage of ambient intelligence technologies for the development and dissemination of art. These user groups contain both people involved in the creation of art and any individual that could benefit from using art in the context of various daily activities (work, entertainment, education, living etc.). This user base sets specific requirements for the applications to be developed especially in relation to aesthetics, usability, learnability, etc. Each of these requirements encompasses a specific user goal that should be achieved through the usage of these applications.

The methodology used for collecting and elicitating requirements includes browsing exhaustively the currently published literature (paper or electronic), in reports, journals, conference proceedings, and books. Keywords and key subject titles, relative to the problem area, were identified and used to initiate and drive a search that was carried out, mostly, in two distinct pools of information:

- on-site libraries and records, and
- the World Wide Web (WWW)

The initial list of used keywords and subjects is: Art, Painting, Painting techniques, Painting material, Painting styles, Art styles, Painting tutorials, Bachelor in painting, Master of fine arts, Artist's workshop, Interactive exchibits, Museum interactive applications, Art games, Ambient Intelligence, Informative Art, Ambient Information Visualization, Ambient assisted Living Ambient Games, etc.

3.1 Stakeholders

This section identifies the stakeholders to be addressed by the research work to be conducted, by analysing the basic fields of interest and making an in depth analysis of the target user groups involved in each of these fields.

3.1.1 The Art Creation Process

Traditionally, art Masters, namely the accomplished artists, were running large workshops where a number of different people were involved in the production process. An engraving by an unknown artist that presents the daily tasks that took place in such a workshop in Early Modern Europe is presented in Figure **1**. Typically, the people involved in these workshops were:

1. **The Master:** An accomplished and well known artist in the society
2. **Apprentices**: Young persons learning art techniques in these workshops. The system of apprenticeship first developed in the later middle Ages and came to be supervised by craft guilds and town governments. A master was entitled to employ young people as an inexpensive form of labour in exchange for providing formal training in the craft [117]. The task of a person carrying out an apprenticeship in the workshop of a painting Master involved grinning pigments, mixing paints, etc. In many cases, because apprentices were considered a burden, parents used to pay the Masters for accepting their children for apprenticeships.
3. **Journeymen**: Persons who have evolved from apprentices to artists. Their tasks involved working on the less important parts of a painting, such as backgrounds, clothing, etc. In some cases the amount of effort carried out by the master itself and from several journeymen was the result of negotiations between the Master and the art patron. These persons were also called journeymen because, among other duties, they travelled a lot for gaining experience and getting contact with art in other settings.

Figure 1: Engraving presenting an overview of a painter's workshop in Early Modern Europe

Nowadays, the activities involved in the process of producing art has radically changed, but the terms described above can still be used to describe the steps needed to become an accomplished artist. In this context, an **apprentice** can be thought of as the art student or anyone learning art. On the other hand, a **journeyman** is the young artist who is learning new methods and techniques and therefore creating a personal art style. Based on the aforementioned analysis, the following user groups can be defined:

- **UG1 - Master**
- **UG2 - Young artist**
- **UG3 - Art student**

3.1.2 Teaching art

In education, a teacher is a person who educates others. A teacher who educates an individual student may also be described as a personal tutor. The role of teacher is often formal and on-going, carried out by way of occupation or profession at a school or other place of formal education. People involved in the process of teaching art are included in the list of stakeholders for this research work mainly due to their role on educating people about art and therefore bringing them one step closer on

understanding art. The derived user roles from the process of teaching art are the roles that are typically in charge of the process of educating people about art:

- **UG4 - Art teacher**
- **UG5 - Art historian**

3.1.3 Enjoying Art

In the context of this research work, taking into account that art as a social medium implies the need to be access by all, any individual who is fond of getting informed about art by visiting museums, art galleries, studying history of art, etc., is considered as a stakeholder:

- **UG6 - Art lover**
- **UG7 - The recipient of an Ambient Intelligent Environment**

3.2 User Goals

The various roles identified in the preceding analysis are considered stakeholders of this approach. More specifically, the User Goals set for each or the aforementioned roles are:

UG1: Master

- **UG1-G1:** Be creative
- **UG1-G2:** Be able to get the most of his experience
- **UG1-G3:** Spend his time creatively (minimise the time need for performing tasks not related to art creation)
- **UG1-G4:** Be proactive not reactive
- **UG1-G5:** Achieve a sense of mastery and feel that his work is unique.
- **UG1-G6:** Reuse working solutions
- **UG1-G7:** Keep a sense of continuous learning and improvement in the field
- **UG1-G8:** Enjoy his work
- **UG1-G9:** Be able to use art techniques and practices in the optimum way
- **UG1-G10:** Facilitate his experience in art creation in the most optimum way
- **UG1-G11:** Access reference material essential from his work
- **UG1-G12:** Get access to art related information such as auction and sales catalogues, exhibition and collections catalogues (from museums, galleries and private collections), core journal and serial publications, image collections (digital and analogue), historical surveys and chronologies, catalogues

raisonnés, visual dictionaries, art films, sources of electronic art, artists books, archival materials, product reviews, patents, product catalogues, exhibition and show reviews, museum and gallery directories and calendars, etc.

- **UG1-G13:** Obtain an overall understanding of the application's mechanics quickly without having to know/learn details about its content or functionality
- **UG1-G14:** Perform tasks as quickly as possible.
- **UG1-G15:** Produce solid and pleasant compositions

UG2: Young artist

- **UG2-G1:** Have the ability to learn using various sources of knowledge such as books photos videos etc.
- **UG2-G2:** Grow its creativity by studying various art styles by being into constant contact with art through museums, galleries etc.
- **UG2-G3:** Grow the ability of identifying major movements, periods, exemplary works, and "masters" in the fields of art, architecture, and design.
- **UG2-G4:** Acquire knowledge of the materials and techniques employed in the fields of art, architecture, and design
- **UG2-G5:** Get in touch with the terminology of artists, architects, and designers
- **UG2-G6:** Get the best out of various art mediums
- **UG2-G7:** Use colour properties efficiently
- **UG2-G8:** Use a number of different painting techniques
- **UG2-G9:** Master perspective
- **UG2-G10:** Produce solid and pleasant compositions
- **UG2-G11:** Reuse working solutions
- **UG2-G12:** Keep a sense of continuous learning and improvement in the field
- **UG2-G13:** Enjoy artistic work
- **UG2-G14:** Obtain an overall understanding of the application's mechanics quickly without having to know/learn details about its content or functionality
- **UG2-G15:** Perform tasks as quickly as possible.
- **UG2-G16:** Get educated in a number of important aspects of painting (such as composition, lights and shadows)

UG3: Art student

- **UG3-G1:** Have the ability to learn using various sources of knowledge such as books photos videos etc.
- **UG3-G2:** Grow its creativity by studying various art styles by being into constant contact with art through museums, galleries etc.
- **UG3-G3:** Learn the various properties of art mediums
- **UG3-G4:** Learn everything about colour such as colour properties (transparency, opaqueness etc.), mixing colours, rendering shadows, etc.
- **UG3-G5:** Learn a number of different painting techniques (wet on wet, venetian red glazing, scrambling etc.) and effects (rendering textures, clothing etc.)
- **UG3-G6:** Learn the way items are presented into space (perspective) and the variations occurring by using different perspectives (one point, two point, three point etc.)
- **UG3-G7:** Learn the attributes of composition and the different variation and effects that can be achieved through different composition styles
- **UG3-G8:** Obtain an overall understanding of the application's mechanics quickly without having to know/learn details about its content or functionality
- **UG3-G9:** Get educated in a number of important aspects of painting (such as composition, lights and shadows)
- **UG3-G10:** Produce solid and pleasant compositions

UG4: Art teacher

- **UG4-G1:** Produce training material such as videos, html tutorial slide shows
- **UG4-G2:** Grow creativity by studying various art styles by being into constant contact with art through museums, galleries etc.
- **UG4-G3:** Be constantly in contact with art students via the net
- **UG4-G4:** Enjoy teaching work
- **UG4-G5:** Keep a sense of continuous learning and improvement in the field
- **UG4-G6:** Obtain an overall understanding of the application's mechanics quickly without having to know/learn details about its content or functionality

UG5: Art historian

- **UG5-G1:** Constantly enrich knowledge
- **UG5-G2:** Get in touch with art across the world
- **UG5-G3:** Keep a sense of continuous learning and improvement in the field
- **UG5-G4:** Obtain an overall understanding of the application's mechanics quickly without having to know/learn details about its content or functionality
- **UG5-G5:** Access personalised information from Art

UG6: Art lover

- **UG6-G1:** Access art from various sources (galleries, museums and art stores)
- **UG6-G2:** Get informed about the new art trends

UG7: The recipient of an Ambient Intelligent Environment

- **UG7-G1:** Obtain access to art through various sources
- **UG7-G2:** Enjoy art
- **UG7-G3:** Get Entertained
- **UG7-G4:** Get informed about art
- **UG7-G5:** Decorate his personal space
- **UG7-G6:** Be constantly informed
- **UG7-G7:** Exploit the alternative meanings of art
- **UG7-G8:** Feel comfortable in his personal space
- **UG7-G9:** Have access to various sources of information
- **UG7-G10:** Make good use of leisure time
- **UG7-G11:** Avoid distractions

3.3 User Requirements

System Requirements capture the intended functionality and behaviour of the system so as to drive architectural decisions and validate the architecture. In general, requirements are partitioned into *functional requirements* and *non-functional* requirements. Functional requirements are associated with specific functions, tasks or behaviours that the system must support, while non-functional requirements are constraints on various attributes of these functions or tasks associated with the user's goals. In other words, functional requirements clarify the functionality required by the system towards supporting effectively (an agreed set of) user tasks, whereas non-

functional requirements specify the required behaviour of the system towards supporting efficiently the user goals. It can be helpful to think of non-functional requirements as adverbially related to tasks or functional requirements: how fast, how efficiently, how safely, etc., is a particular task carried out through a particular system.

3.3.1 Functional Requirements

This section presents the functional requirements of an ambient facility to serve as an environment for enabling (a) the development of art by artists, (b) the dissemination of art through an ambient art gallery, and (c) the use of art for education, entertainment and informative purposes. These requirements constitute the basis of the alternative set-ups and interactive applications proposed in this report.

UG1: Master

- **UG1-R1:** UG1-G1 implies the provision of facilities that allow the artist to constantly be informed – educated – influenced by art trends and therefore enhance his creativity
- **UG1-R2:** UG1-G2 implies that the incorporated facilities should be flexible for allowing the artist to use them in parallel with the knowledge stemming from his experience
- **UG1-R3:** UG1-G6 implies that the system should be aware of the artist work and monitor art creation in order for already existing working solution to be reused by the artist (for example recall the technique used for creating a background of a painting that no longer exists on the artists collection).
- **UG1-R4:** UG1-G7 and UG1-G9 implies that the artist should be constantly able of being educated having access to a vast collection of knowledge produced within the workshop or accessed through external sources such as the internet.
- **UG1-R5:** UG1-G8 implies that all the facilities incorporated in the workshop should be pleasant in order for the artist to be able to enjoy his work.
- **UG1-R6:** UG1-G11 implies that the facilities offered by the workshop should be usable and easy to learn allowing the artist to focus on the creative process. To this end these facilities should be able to run on the background of user perception in order to avoid unwanted distractions.

- **UG1-R7:** UG1-G12 implies that specific input techniques should be employed allowing the user to perform tasks as quick as possible by requiring minimal input from the user.
- **UG1-R8:** UG1-G10 implies the existence of a knowledge base containing a vast collection of information together with mechanisms for retrieving content for several sources such as the internet.

UG2: Young artist

- **UG2-G1:** Have the ability to learn using various sources of knowledge such as books photos videos etc.
- **UG2-G2:** Enhance creativity by studying various art styles by being into constant contact with art through museums, galleries etc.
- **UG2-G3:** Enhance the ability of identifying major movements, periods, exemplary works, and "masters" in the fields of art, architecture, and design.
- **UG2-R4:** UG2-G4 implies the existence of training facilities that allow student to get in touch with and get trained on materials and techniques employed in various fields of art, architecture and design. Such facilities include educational games, training applications etc.
- **UG2-R5:** UG2-G6 requires for the system to offer facilities the users are familiar with and can support the use of a wide collection of different art mediums
- **UG2-R6:** UG2-G7 implies the existence of applications that can assist young artists understanding colour (mixing, complementariness, shadow rendering etc.) and using the qualities of colour for improving their art skills
- **UG2-R7:** UG2-G8 implies that the system should be operational together with various painting techniques
- **UG2-R8:** UG2-G8 implies the existence of facilities that can assist artists on creating their own compositions by manipulating material from various sources such as pictures, videos, 3D models, etc.
- **UG2-R9:** UG2-G11 implies the existence of facilities that record existing solutions to be used by the artist as a source of inspiration for future work allowing him to build from his prior experience

- **UG2-R10:** UG2-G14 and UG2-G15 implies that the facilities offered by the virtual workshop should be usable and easy to learn allowing the artist to focus on the creative process while interacting with the system as quickly as possible.

UG3: Art student

- **UG3-R1:** UG3-G1 and UG3-G2 implies the existence of facilities for browsing knowledge through various sources, creating personalised collections of knowledge, combining knowledge from various sources and in general the provision of the maximum possible ability to use distributed knowledge in a centralised manner. At the same time the existence of personalisation is required for allowing the transformation of knowledge
- **UG3-R2:** UG3-G3 and UG3-G4 can be facilitated through the existence of a training framework that can allow young artists and art students to experiment on the qualities and attributes of the various art mediums and colour.
- **UG3-R3:** UG3-G5 implies the existence of applications that are not restricted to a specific technique or style but offer a wide range of possibilities for expanding to a wide range of different art styles.
- **UG3-R4:** UG3-G6 and UG3-G7 can be facilitated through the existence of applications that can assist on employing perspective and various attributes of objects for creating dynamic and pleasant compositions.
- **UG3-R5:** UG3-G8 is achieved through designing and developing applications that are usable and self-explainable requiring minimum effort from the user's side and simultaneously offering maximum outcome.

UG4: Art teacher

- **UG4-R1:** UG4-G1 can be facilitated through applications that enable the transformation of the material collected through the tracking of art creation sessions to training material that can be automatically created analysed and used by the system.
- **UG4-R2:** UG4-G2 and UG4-G5 implies the existence of applications that can facilitate the collection and presentation of knowledge through various sources such as libraries, e-books, internet, museums, galleries etc.

- **UG4-R3:** UG4-G3 can be facilitated through the existence of various facilities for communicating with people through alternative channels such as video, voice text and through a common network (internet)
- **UG4-R4:** UG4-G4 can be achieved by offering applications that are usable and enjoyable offering increased output with the minimum possible effort.
- **UG4-R5:** UG4-G6 can be achieved through designing and developing applications that are usable and self-explainable requiring minimum effort from the user's side and simultaneously offering maximum outcome.

UG5: Art historian

- **UG5-R1:** UG5-G1 and UG5-G2 implies the existence of training facilities that allow people to get in touch with, and get trained on, materials and techniques employed in various fields of art, architecture and design. Such facilities include educational games, training applications etc. In the same context the existence of applications that can facilitate the collection and presentation of knowledge through various sources such as libraries, e-books, internet, museums, galleries etc. is also considered important.
- **UG5-R2:** UG5-G3 implies the existence of applications that can facilitate the collection and presentation of knowledge through various sources such as libraries, e-books, internet, museums, galleries, etc.
- **UG5-R3:** UG5-G7 can be achieved through designing and developing applications that are usable and self-explainable requiring minimum effort from the user's side and simultaneously offering maximum outcome.

UG6: Art lover

- **UG6-R1:** UG6-G1 and UG6-G2 can be achieved through the existence of applications that can facilitate the collection and presentation of knowledge through various sources such as libraries, e-books, internet, museums, galleries, etc., is also considered important.
- **UG6-R2:** UG6-G3 can be achieved through designing and developing applications that are usable and self-explainable requiring minimum effort from the user's side and simultaneously offering maximum outcome.

UG7: The recipient of an Ambient Intelligent Environment

- **UG6-R1:** UG7-G1 and UG7-G5 implies that an ambient environment should provide facilities for presenting art from various sources in different contexts and for different purposes (e.g. informative art, art for setting the mood etc.).
- **UG6-R2:** UG7-G2 implies the existence of every day facilities that employ art in order to assist the daily activities of Ami recipients.
- **UG6-R3:** UG7-G3 and UG7-G10 implies that entertainment should be one of the goals of the provided facilities offering support for single or multiplayer games that entertain while having significant educational value.
- **UG6-R4:** UG7-G4, UG7-G6 and UG7-G9 imply facilities able of collecting information from various internal or external sources.
- **UG6-R5:** UG7-G8 and UG7-G11 implies that the incorporated facilities should run on the background allowing minimum user distraction, and maximum privacy making the user feel comfortable in his personal space.

3.3.2 Non Functional Requirements

Although the provision of the above mentioned functionality is of high value to the user, the user might end up disliking the system if some of his/her goals (e.g., to perform administrative tasks as quickly as possible; to stay away from big mistakes, to be consistent) are violated while using the system. Thus, identified user goals have been translated into non-functional requirements as follows:

<keyword> : <non-functional requirement>

Non-functional keywords include, but are not limited to: Usability, in terms of Learnability, Efficiency, Memorability, Errors, Satisfaction; Security; Reliability; Maintainability; Portability; Extensibility; Reusability; Resource utilisation; Operability; and Accessibility.

- **<Learnability>:** It is essential for each application incorporated in the Ambient Environments to be developed to require a minimum level of learning from the user side. To this end the provision of easy to used self-descriptive and intuitive User Interfaces in though a fundamental requirement. This is extremely important in the case of this research work so as to cope with the diversity of the target users' population. Artists are usually non-

experts in technology and in the context of CHIs the population of visitors could contain children, elderly and people with disabilities.

- **<Efficiency>:** Efficiency implies the existence of applications that perform tasks more efficiently from their counterparts. This is a very important issue when designing for ambient intelligence, especially based on the fact that the evolution of technology is not carried out through impression but via offering more efficient ways of performing specific activities. Especially in the case of the artist's workshop allowing the artist to perform daily activities easier, with less effort and as efficient as before will determine the success of the proposed approach.
- **<Memorability>:** This requirement implies the provision of applications containing simple and self-descriptive operations not relying on the user's ability to remember sequences of actions. This may achieved by allowing the user to perform operation in a way similar to actions performed in the context of his every day activities. This is important for all the areas targeted by this research work. The artist's workshop should function with minimum artist intervention. At the same time CHIs and smart living spaces should provide added value facilities.
- **<Errors>:** The ability to minimize errors and recover for system and user errors is vital. The applications should avoid the typical attitude of living the impression that the user is responsible for application errors and at the same time be in position to recover "silently" without the need for user input. In the same context user errors should be foreseen and avoided through the appropriate run time user assistance.
- **<Satisfaction>:** Offering satisfaction to the user accessing an interactive application is considered primary requirement especially when speaking about applications suitable for environments focusing on work and entertainment. More specifically this is achieved by offering support for recovering from user errors and furthermore via offering and overall feeling of smooth operation and facilitating the user to perform complex operation through and intuitive and usable interface.
- **<Security>:** Security is considered a major requirement especially for applications facilitating ambient intelligence where the existence of cameras,

intensive user profiling, management of sensitive user data (bank accounts, credit cards) etc. is thought as fundamental. To this end the usage of such data in a way that sensitive user information are shield for unauthorized access is most important for allowing these technologies to spread and get accepted by people in their everyday life. In this context sensitive user information should be stored by the system only in cases where the computing environment is isolated and secured (e.g. smart home, artist's workshop). It is important to keep such information confidential and don't submit them over the network especially in the case of CHIs.

- **<Reliability>:** Although the above requirements are important nothing can be achieved by relying on an unreliable system. Fault tolerance, consistent operation, tolerance to loss of network connectivity, ability to recover for power loss etc. are major requirements for an ambient environment. All these issues should be identified and solved transparently. It is not wise to depend upon the average user on identifying and manually solving such issues especially in environments created for non IT experts such the ones presented in the context of this research work.
- **<Maintainability>:** It is traditionally derived from the field of human computer interaction that users should pay time for performing their tasks than managing and maintaining the interface offered for performing these tasks. To this end it is important to create applications that are self-maintained with the minimum feedback from the user.
- **<Extensibility>:** The provision of a framework that offers the option for the incorporation of new applications is essential. This although partially addressed by this research work requires further investigation from the field of standardization for offering common hardware and software standards for allowing the cooperation of applications developed for specific Ambient Infrastructures.

4 Scenarios of Use

This chapter describes a number of "personas" which are imaginary users with specific expertise, goals, desires and expectations from an Ambient Environment. These "personas" are in turn used for presenting alternative interaction scenarios that allow to highlight the structure of the environment to be developed, the applications offered and how environment, applications and intelligence are combined towards addressing the requirements of each "persona" in the optimum possible way.

4.1 Gerard the Art Master

Gerard is a well-known and respected artist. He has successfully completed numerous painting commissions over years, but remains open minded concerning the involvement of modern technology in his work. Recently, Gerald moved from his old Workshop to a new one that offers ambient technologies for supporting him in his work.

4.1.1 A walk to the national garden

Gerard the Art Master during a morning walk in the national garden gets fascinated by the view of a beautiful arrangement of flowers. Using his mobile phone, he takes some pictures of the flowers together with various interesting objects in the garden, such as benches, flower amphora, etc. Feeling the anxiety of the artistic inspiration he heads towards his workshop. On the doorstep he uses the iris-scanner to identify himself. The workshop door opens and a familiar voice welcomes him. Gerard moves quickly to his study and gets seated. His presence is caught and the lights of the

workshop are open while his study initiates the studying agent. Gerard puts his mobile phone on the study area and all the recently taken pictures appear on the design area. At the same time, Gerard asks from the system access to his collection of reference material and browses several sources such as pictures, paintings, items, etc. He drags some of this material on the design space.

Figure 2: Gerard is creating a composition in the design space

Using his pen he starts editing his photos and the material selected from his library in order to test several composition schemes. At the same time, he uses his pen to quickly insert some comments on the collected material. When he is satisfied with the initial sketches for his new composition, he asks the system to save his data with the name “expression flowers of spring” and to initiate a painting session. The lights in his study are closed and the attention is moved to the art creation area. Gerard moves towards the shelves used for storing his painting material. He browses through his painting supports and selects a painting canvas. Then he is suggested to use oil painting. A number of colours suitable for his subject matter are presented to him together with a number of applicable paint brushes. Gerard accepts some of the recommendations and ignores some others. He selects a number of paint tubes and brushes. He wishes to create a much paler variation of the flowers, so he prefers Cadmium Yellow pale rather than medium, Cadmium red light rather than the standard one, while he agrees on using titanium white, sap green, ultramarine blue, cobalt violet, burnt umber and raw umber. On the other hand, he totally agrees on the brush types and sizes for the selected subject and support type, so he just collects those from the brush container (a green led is lit on these brushes).

Figure 3: Gerard is browsing Art Supplies

Moving to his work area, he places the painting support on his tripod and the projection is dynamically adjusted to the canvas size. At the same time, when he places the painting supplied on the desk, the real time assistant applications are loaded such as texture editor, colour chart, colour wheel using dynamic information such as the colours used for the painting, brush types, etc. The composition has been already loaded on the projection screen.

Figure 4: Gerard is working on the Art Creation Area

Gerald asks to present the composition in grey scale in order for him to test different variations of colour on his subject matter. Using the colour wheel and colour chart he virtually mixes colour and applies the results on the canvas together with textures. Although this computerised work is not art, it allows him to test several colouring and

texturing schemes before proceeding. When satisfied by this process, Gerald saves his coloured and textured composition and dedicates one of the screens of his working area to constantly presenting his composition while painting. The other screen displays the colour mixes used. Using these virtual colour mixes he starts making some real work mixing actual paints to complete his painting.

4.1.1 A Portrait commission

Gerard sits on his workshop browsing some of the portraits he has created in the past. He is waiting for Monett, a girl that commissioned to him her portrait. Making a portrait was always challenging for him, basically because it requires an in depth understanding of the subject matter in terms of facial characteristics, personality, etc. Monett arrives at the door step of the workshop and Gerard is notified that his client has arrived and requests the doors to open. He welcomes Monett and invites her in the workshops living room where they are seated for a relaxed introductory discussion. Meeting the requirements of a portrait commission is never an easy task so Gerald uses their discussion with Monett to study her facial expression and characteristics and more importantly to understand her personality. After some time Gerald asks Monett if she would like to see some other portrait commissions he has painted in order to understand the feelings she wants to express through her portrait. Gerald uses the interactive table in front of them to browse his previous works.

Figure 5: Gerard and Monett are browsing some of his past works

They spend some time browsing the portraits while Gerald asks Monett to express her feelings for each of the portraits browsed. Gerald knows that light and subject matter positioning is extremely important for depicting various emotions to the viewer, so he

is going to use this session with Monett to understand her wishes for her portrait. Suddenly, Monett sees a three quarter view portrait of a young lady and says that this is her favourite one, so Gerald having in mind that this is a suitable setup for a young lady such as Monett asks for the workspace to adopt the setting of the selected portrait. The lights of the model's plane are automatically adjusted to meet these requirements and the frame projected in front of the model's plane is adjusted to a 2/4 ratio that is suitable for such a portrait. Gerard leads Monett to the model's plane where she is seated in the middle and requests her to lean to her left so as to achieve a three quarter view. Then Gerald move outside in order to further adjust lights, gesture and framing from the artist's view of the model's plane.

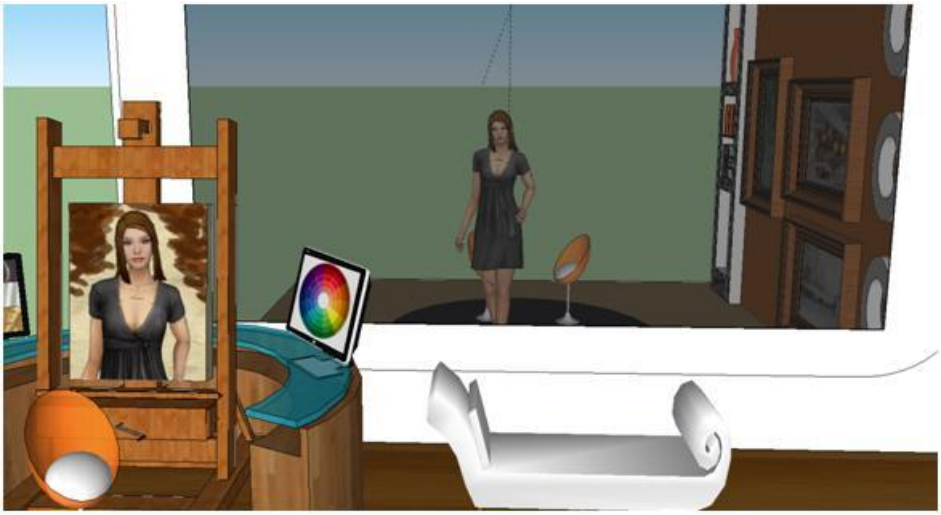


Figure 6: Monett is posing in the model's plane while Gerald is making the appropriate for the composition adjustments

After taking some time to fine tune these settings, Gerald asks Monett whether she has time to pose for the whole painting session or she would like to examine her current portrait setup and allow him to work offline. Monett has some business to attend to so she prefers to allow Gerard to work offline. Gerald asks the system to save Monett portrait settings and requests a preview of these settings inside the model's plane, asking Monett whether she is satisfied with what see sees. Monet really likes these settings so she leaves the workshop allowing Gerard to work offline. Gerald requests the portrait to appear on his canvas and uses a charcoal stick to outline Monet's portrait. Then he moves to select some painting supplies among the ones already outlined based on his subject matter.

4.2 Jack Luis the Art Student

Jack Luis is studying Art at the local University. From his first years he had realised his interest in art and his significant skills in expressing himself through art. He has recently taken the decision to become a professional artist, so he subscribed to the school of arts in the local university.

4.2.1 Preparing for the exams

Jack Luis is sitting at home using his personal computer to study for his mid-term exams. He also has a number of painting assignments. One of his assignments is the experimentation on perspective through the usage of geometric forms such as the cube, the cone, the sphere, and the cylinder. At the same time he is requested to create and paint a physical still life composition using objects of modern technology. The main concept of this assignment is to experiment on the application of modern painting techniques used by the impressionists to create a non-naturalistic still-life containing modern subject matter. His uncle Gerald a well-known and accomplished artist was always supportive on his vision to become an artist himself and has welcomed him to use his brand new Ami workspace for studio practice. Jack Lui calls his uncle and asks him if he can use his workshop for creating his paintings and arranges a meeting for later this afternoon. Jack Luis steps in his uncle's workshop and explains the concepts of his assignments to his uncle. Gerald makes a quick introduction of the workshop and explains how several aspects of his assignments can be facilitated through his workshop. Gerald is living his nephew to work and Jack Luis sits on the design space to start working on his assignment. He is using the 3D composition suite to test on the creation of compositions using pure geometric shapes. At the same time he is using several colours and lighting schemes to achieve the desired light and shadow scheme for the created composition. After being satisfied with the result he save the composition and uses the surface to select some painting supplies. He is new into oil painting so he spends some time exploring the qualities of paints before selecting them. He is interested on opacity (getting a very opaque and brilliant white for highlights) but also on transparency (laying over transparent colour over opaque hues). Then he is using the Paint Lab for young artist to experiment on colour theory and mixing for preparing himself for painting. After the selection of colour he moves to the augmented painting surface, places a canvas and adjusts the size of the virtual canvas to the actual one. Then he projects the created composition

on the side of the canvas and uses a charcoal stick to duplicate the composition on canvas. Then he creates the appropriate colour mixtures and moves into painting his assignment. After finishing the composition he lives the painting to dry and call his uncle to renew his appointment for tomorrow. The next day Jack Lui visits his uncle's workshop having with his an old projector, a painting frame, a computer screen cleaning spray, a leather bag and a red strap. He is planning on using these items for creating a composition for his other painting assignment. He first uses the design space to learn more about the impressionists. He is using a tag presenting a famous impressionist painting of Monet to access more information about the movement while using the web browser to get information from the net. After spending some time reading he moves to the models plane. He places a table that his uncle keeps handy for still-life painting in the middle of the models plane and places the items on the model plane. The framing agent is already running on the augmented painting surface. He spends some time rearranging the items to achieve a pleasant composition while also previewing the projection of his composition. He is also thinking about framing in order to select the part of the composition that should be painted. When being confident about his set-up he moves to the augmented painting surface and frames the composition. He in turns loads this composition to the painting surface selects a painting canvas. He decides to use the painting assistants to create colour mixtures and when satisfied by the result creates actual mixtures. He transfers the composition on the surface using a grid (a grid is presented on both the canvas and the composition) in order to get the visual arrangement of elements correctly and then moves into applying the created mixtures on the surface. After finishing painting his uncle arrives and helps him select the correct frame for his finished work. When back at home Jack Luis feels quite tired from studying all day and he would like a break with his friends. He decides to call his friends at home for some educative art game that would allow them to be informally tested for their knowledge on the topic of renaissance which is the first subject of their exams.

4.3 Christian the Art Teacher

Christian is an Art Teacher on the Open University and an artist. He enjoys teaching mainly through the possibility it provides for transferring his knowledge and experience to new artists. Recently, he moved to a new apartment that was specially designed to meet both his requirements as an artist and as an art teacher.

4.3.1 An online course

Christian is planning to create an online demonstration on impressionism for his class on the Open University. His intentions include creating instructional material that present a brief overview of the history of this art trend focussing on the initiators of the movement. To this end, he uses the interactive table located in his study area to start browsing resources about Monet, the initiator of the Impressionist movement (the movement was names upon a painting of Monet namely "Impression sun rise"). While browsing among the collection of painting by Monet, he selects the ones to be the included in his demonstration, arranged in chronological order, and uses the voice recording facility for describing to his students the creation process. The same process is used for inserting information about several other members of the group and other artists that inspired or were inspired by the group, such as Manet. Christian intends to finish his demonstration presenting a real life scenario of creating an impressionistic painting, so he saves his progress on the interactive-table and request the initiation of a painting process. To this end, he requests the system to load a painting by Vincent Van Gogh, a very important impressionist whose work was critical for the later evolution of impressionism to expressionism. Based on the analysed colour values and hues of the painting, the system makes concrete recommendations to Christian as long as the colour palette is concerned while extracting information from the knowledge base to make proposals regarding the brush types to be used, etc. Christian after selecting the material moves to the art creation process and requests the production of educational material to be included in his demonstration such as video screen-shots sound files etc. To this end, the recording application appears on the application screen on the left side of the art creation area. Christian starts the painting process and requests the system to take snapshots of the canvas at specific moments, allowing him to record instructions representing the step in question while having also the ability to use the text entry component for including notes. When the painting is completed, Christian can use the video recording of the painting session, the snapshots taken, audio recording and notes to complete the demonstration or just request the system to automatically incorporate this data to the demonstration created and saved through the i-table. The manual editing of this material is carried out on the design where Christian can use the incorporated facilities to edit the available material for generating instructional material such as presentations, html pages, video tutorials, etc. Upon completion of this process, Christian requests the submission of this

information to his personal web site on the web in order for it to be instantly available to his students.

4.4 Monett the Art lover

Monett is a decorator working for a company which provides decoration services for households, stores, businesses, etc. Although decorating for most people is not related to art, Monett is aware that especially virtual art can teach a decorator among others the power of balance, harmony, and colour and in general the quality of living that can be achieved through integrating art in everyday environments. She also, although not common for a person of her occupation, loves modern technology and she is interested in taking the most of technology as long as it can harmoniously coexist with art. To this end, she uses modern technology installed in every modern house-hold to improve her quality of living through art.

4.4.1 A stressful day

Monnet gets home from work after a quite difficult day. She had a presentation to a very important client and she was quite nervous and stressed. After entering her home, the space adopts her personality. The lights are automatically adjusted to the optimum conditions and soft classical music starts playing. The space gets aware of her stressful day mainly through the intense movement of her nape, so pale relaxing paintings appear on the art displaying screens.

Figure 7: Monett enters her home and the space adopts her personality

Monett sits on her couch and uses some video casts to get informed about the news.

Figure 8: Monett gets informed about the news

After a while Monett moves to her office. Her gaze sees the informative screen display where new items have appeared in one of her favourite paintings, the Botticelli's "Birth of Venus", so she requests her e-mailer application to appear on the screen in-front of her laptop. While she is browsing her mail, the informative display presents a stormy seascape. She gets worried because her son is travelling home tomorrow from a short trip to his grandmother.

Figure 9: Monett notices that new flowers have appeared on her favourite painting

Monett requests to access weather forecasts and gets informed that tomorrow the weather will be quite bad, so she decides to place a call to her son. Her call gets accepted and her son appears on the screen in front of her. She suggests him to stay another day with his grandmother until the weather gets better and kisses him

goodbye. The last thing she notices before getting asleep in her couch is a scheme of prosperity on her informative art display having in mind that at least her financial status is still ok.

4.5 Anna the Art Tourist

Anna works for a law firm in the human relations department. She is a very social person. Her interest in art is non-professional, but she really enjoys learning about art through her visits to various museum, galleries, etc. She does not have much free time, but she spends some of her vacation time travelling and visiting art museums. She is also interested in and likes using modern technologies.

Anna decides to take a visit to the National Gallery of Art. While entering the museum towards the exhibition, a notification appears on her mobile device prompting her to select one of the available virtual tours. She takes some time browsing the available tours and selects the one most related to her favourite art style. She requests to purchase an unlimited download option. She also gets informed that the museum provides the option to personalise the information presented according to her interests and knowledge, so she takes a minute to fill in an anonymous profile.

Figure 10: Anna is using her mobile device to select one of the virtual tools and for filling in her profile

Finally, she receives an invitation to enter into the museum network on her Smartphone. Through this network, she is able to share with other visitors her experiences, impressions and information obtained from the virtual exhibits. She can also ask questions to other visitors and answer other people's questions as well in real

time. Furthermore, Anna can post all this information in her Facebook or Twitter account sharing it with her friends. After completing the transactions, she enters the main museum hall. Her mobile device is used as a navigator allowing her to visit the exhibits based on her selected tour in a number of different ways (based on chronological order, influence on art, value, dates etc.). When Anna approaches an exhibit, she notices that information is projected on the periphery of the painting, while a tablet is unobtrusively located in front as an interactive sign. Anna can use multi-touch gestures for navigating and browsing the vast collection of information available for the specific exhibit using the tablet. The peripheral projections present information to other people in proximity to the painting. She can also download the displayed information on her mobile device.

Figure 11: Anna is in front of a physical painting augmented with information

Although Anna knows that the National Gallery does not have the complete collections of her favourite artist, she gets informed by her mobile device that she can access the complete life and works of this artist by either interacting with the artist's timeline or by using the digital augmented painting located within the room. She gets in front of a wall where a timeline of the artist is presented. She can view information regarding the life and works of this artist by performing simple gestures. She gets really fascinated by this novel form of interaction and definitely wishes to try the digital augmented painting too. She also learns that several works of her favourite painter and related to the one she is seeing are located in other museums in the same

region. When she stands in front of the digital painting, an interactive menu appears allowing her to start interacting with the specific exhibit.

Figure 12: Anna is using her hands to locate points of interest within a virtual exhibit

She can use her right hand to indicate points of interest within the painting to have information regarding the selected point of interest displayed on the digital painting. She can also use gestures for zooming in and out specific regions of the painting and therefore accessing details that are typically lost when digitised artefacts are presented in their entirety at low resolution. The displayed information is personalised according to her profile, as well as the preferences and behaviour of previous visitors with a profile similar to Anna's. Technical information for a moderate expertise level is displayed, and the option is offered to dig into more information if desired.

Anna also wonders what happens when more than one person is accessing the same exhibit. In the room she sees several people standing in front of a large painting and all seem to be actively engaged. Information is displayed in different languages for different visitors. When she approaches this exhibit a welcome note appears and she notices that her hand is mapped within the exhibit. While moving her right hand, several points of interest within the painting are highlighted (allowing her to access information) without that having an effect to other people currently interacting with the exhibit. At the same time she can use gestures for zooming in and out specific regions of the painting, but she can also point at specific regions in the painting using her mobile phone camera and view augmented information on the phone display.

Figure 13: Anna is using gestures and hand tracking for navigating (Deep Zooming) within a virtual exhibit while other users are active on the periphery of the same artefact

Alternatively, she can also use the tablet size cardboard which she was given at the entrance. Information is projected on the cardboard, and she can interact by touching the projected buttons to view information. She gets really excited, “It is like having a tablet that costs two cents!” she thinks.

Figure 14: Anna is using a cardboard provided by the museum to access more information about the exhibit

Anna decides to also visit the museum floor where classic paintings are displayed. There, another interactive exhibit captures her attention. In this exhibit she can use a number of objects, representing the application of several restoration techniques, for performing the virtual restoration of a painting. When she finishes the restoration, her

mobile phone application asks whether she would like to contribute to art restoration in the museum through a small donation, and she accepts.

Figure 15: Virtual art restoration, before (left) and after (right)

Anna enters another hall of the Gallery and a notification appears on her mobile device asking whether she would like to participate to the Treasure Hunt game organised by the museum using her mobile device. Anna finds this idea quite interesting, so she accepts to download on her mobile device the treasure hunt application. A notification appears on her mobile device that in order to begin the treasure hunt she should locate a specific painting in order to collect the first clue. As a subsequent step she must answer a number of questions prompted by her device. Anna finds this new way of interacting with art very attractive and exciting. After playing for some time, she is prompted that in order to get the next clue she should score 100 points in the Painting Lab game located in the multimedia room. She moves within the room where an interactive setup is located. The game requests Anna to select among a number of available objects the one that should be applied for digitally reproducing a painting displayed in front of her and she selects a charcoal. Then the game selects a colour from the painting and requests her to use the palette in front of her to mix this colour.

Figure 16: Anna is using physical brushes and a palette for mixing colours in the Lab Game

After completing several tasks Anna finally scores 100 points and gets the final clue to the treasure, which is the digital copy of a famous painting of her favourite artist ready to view, experience and download. The game can also be played collaboratively. In fact, Anna notices that the pupils of a school visiting the museum have formed four teams whose members collaborate to find the treasure. Each team shares a common area in the museum game site, where the team players distribute the missions, put information and clues, discuss among themselves, etc. The team with the highest score wins the game, and each player obtains a digital painting of his/her favourite artist. After spending about two hours in the Gallery, Anna leaves the museum with a positive attitude towards new ways of interacting with art.

After entering her home, the space adopts her personality. The lights are automatically adjusted to the optimum conditions and soft classical music starts playing. The painting that she liked most and on which she spent more time viewing during her visit to the museum appears on the art display screen in her living room.

Figure 17: Anna enters her home and the space adopts her personality

The smart home system asks her if she would like to see more details about the paintings that she visited. She enthusiastically agrees, and a virtual assistant appears on the screen in front of her couch. The virtual assistant presents a personalised documentary on the specific paintings she saw at the museum. She can navigate the presented information through hand gestures. At the same time she can also have a closer look at the paintings on her tablet in a synchronized way and interact with them through multi-touch gestures. She will never forget today's visit to the museum, she thinks. Of course she also has the option to view information about other interesting paintings she did not have time to see at the museum, and she starts thinking that perhaps it would be worth planning a second visit soon.

Figure 18: Anna sits on her couch while a virtual assistant is presenting a personalised documentary on the paintings she saw at the museum

Afterwards, Anna places a call to her friends to invite them for playing their favourite art board game tomorrow, and informs them that the game will certainly raise their competition as brand new artefacts are available.

Figure 19: Anna and her friends are playing an augmented art game on the coffee table

5 Ambient Design

The goal of Ambient Intelligence is to be mixed in the fabric of human activities acting as a non-visible computerized framework. From this point of view, Ambient Intelligence must and should be incorporated in to human space gracefully in order to achieve non-intrusiveness. Therefore, it is essential to investigate not only the technological aspects, but also to move to the analysis of the structure and architecture of the physical space where human activities take place and are facilitated by the technological environment. One of the basic questions posed is: "What are the requirements in terms of hardware infrastructure and which is the architectural setup of the space hosting these technologies?"

This section presents the envisioned by this research work setups in terms of structure and architecture aiming to facilitate the usage of the proposed technologies in the context of real life scenarios. To this end, specific attention is paid to understanding the space, designing prototypes of floor plans, 3D representations and presenting the affordances of the resulting prototypes.

5.1 Envisioned Set – ups

This work proposes the creation of applications that facilitate the development and dissemination of art and investigates the main areas of interest of such an approach. The alternative physical spaces that are analysed in this work for hosting the proposed infrastructure are:

- **The Ambient Workshop:** Is defined as the physical place where art is conceptualised, designed and created

- **The Smart Home:** The Home of tomorrow enriched with applications where art is facilitating for information, education, entertainment and beauty
- **The Ambient Art Gallery:** The physical space where art is exhibited

5.1.1 The Ambient Workshop

The Ambient Workshop is defined as the physical place enriched with ambient technologies where the creative process is carried out. In this physical space the traditional methods of creating art meet with the state of the art of computing technology aiming at solving fundamental design issues and problems and therefore allowing the artists creativity to evolve. It is argued that this ambient intelligence oriented approach allows the artist to easily carry out tasks not closely related to the actual creative process, and therefore spending more time on revealing his talent on his subject matter than carrying out non creative tasks (like finding literature, selecting the appropriate paints, browsing material, testing composition schemes, etc.). The process of setting up the ambient workshop entails the need to define the planes needed and the infrastructure provided for enabling the artist to unfold his creativity. The setup proposed in this context contains two planes the plane of the model (the physical subject-matter of art) and the plane of the artist (the artists working environment). This concept is derived from the traditional scheme used successfully by artists across the centuries. The evolution of technology offers today the option of an indirect relation between the subject matter and the artists (e.g., painting and composing with the help of computer aided facilities and digital material). These new approaches to art creation can also be applied in parallel with traditional methods and techniques. The floor plans of a proposed setup of the workshop are presented in Figure 20, while Figure 21 presents a 3D representation of this setup.

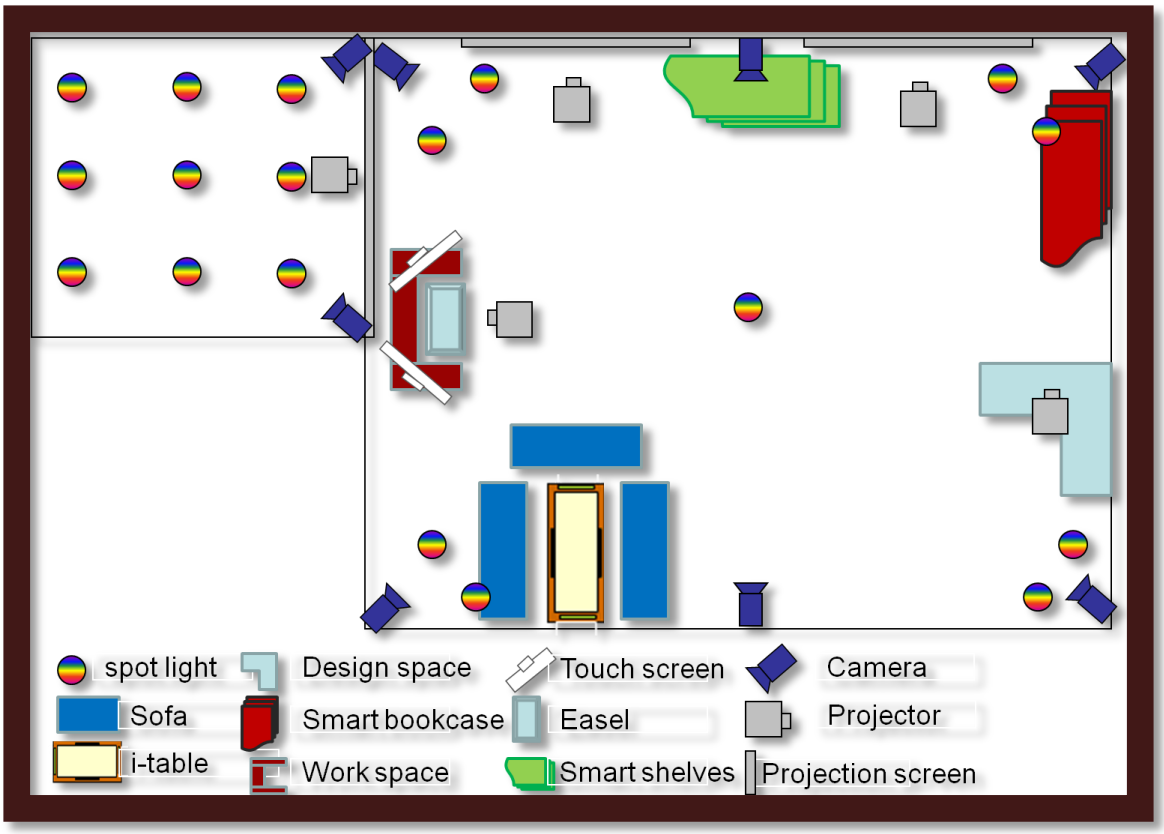


Figure 20: Floor plans of the artist's workshop

1

Figure 21: A three dimensional representation of the Workshop (Artist's plane on the right and Model's plane on the left)

5.1.1.1 The artist's plane

The artist's plane presented in Figure 22 is the physical place where the artists creativity is unfold. To this end, the artist's plane consists of:

- **Design Space:** The space where a new composition is created using a mix of modern graphics design technologies and traditional paper based media.
- **Bookcase:** Is the place where reference material can be browsed using computerised searching facilities together with augmented physic objects (e.g., books, magazines etc.).
- **Smart shelves:** Selecting painting supplies from smart shelves that can analyse subject matter, technique and style and make specific proposals.
- **Meeting Area:** The physical space where the artist meets his patrons for browsing art, discussing and selecting among alternative composition schemes.
- **Work space:** The place where the creativity, knowledge, and compositions come to life. This space introduces both the traditional art creation schemes and modern technology for allowing the creation of new mixed techniques that facilitate the creation of art.

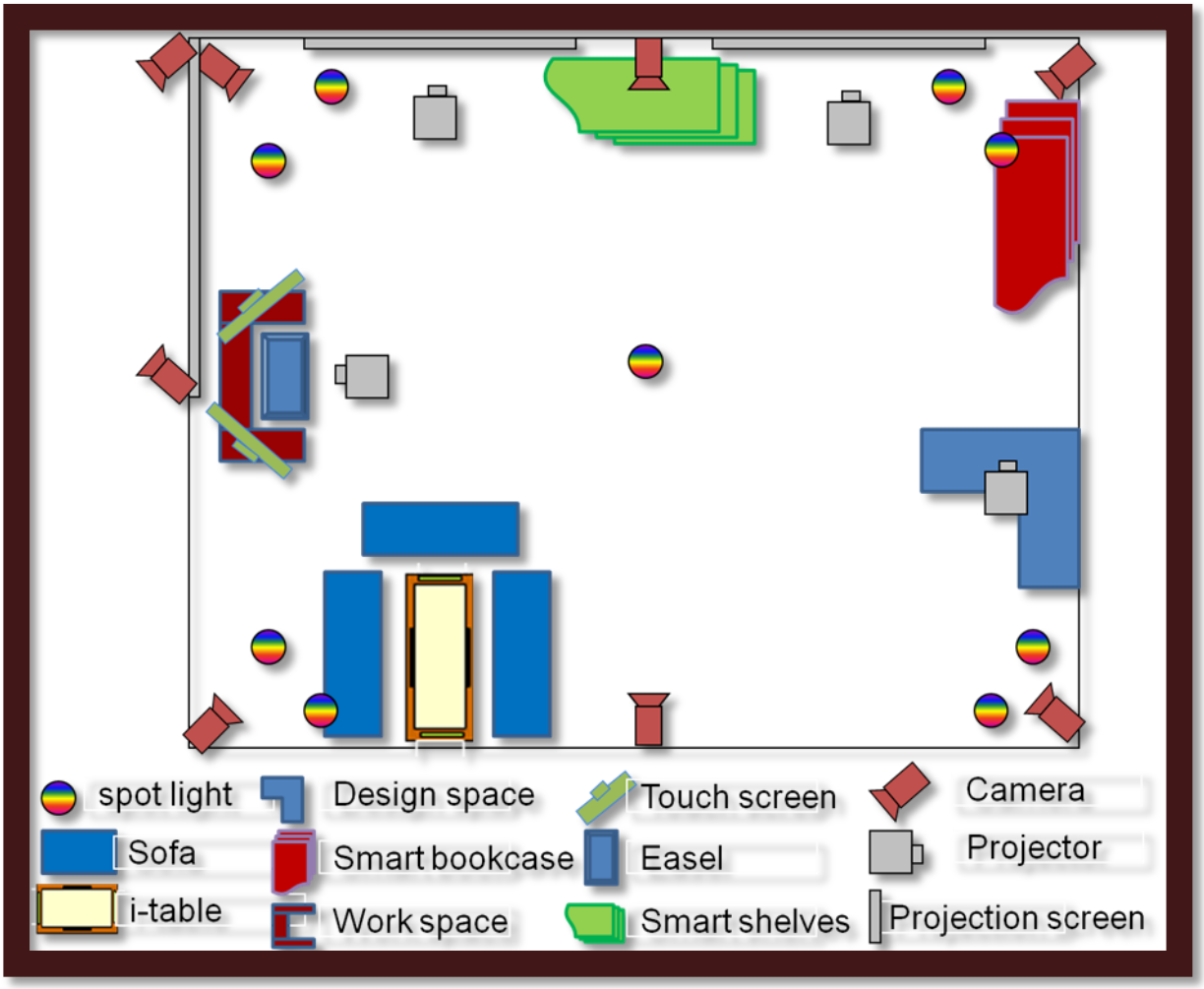


Figure 22: Floor plans of the artist's plane

5.1.1.1.1 Design Space

A detailed representation of the Design Area is presented in Figure 23 while Figure 24 presents the design space as incorporated in the unified workshop prototype. As shown in this figure, the design area consists of an augmented table where the artist using assistive design technologies (Mixed reality with integration of physical and virtual objects) creates the preparatory sketches. These sketches are at runtime digitized and presented in the art controller. The art controller works together with design support applications such as colour and texture wizards. Using these applications specific effects can be applied to the preparatory sketches. The touch screen on the right of the design area is used for rendering design time support applications.

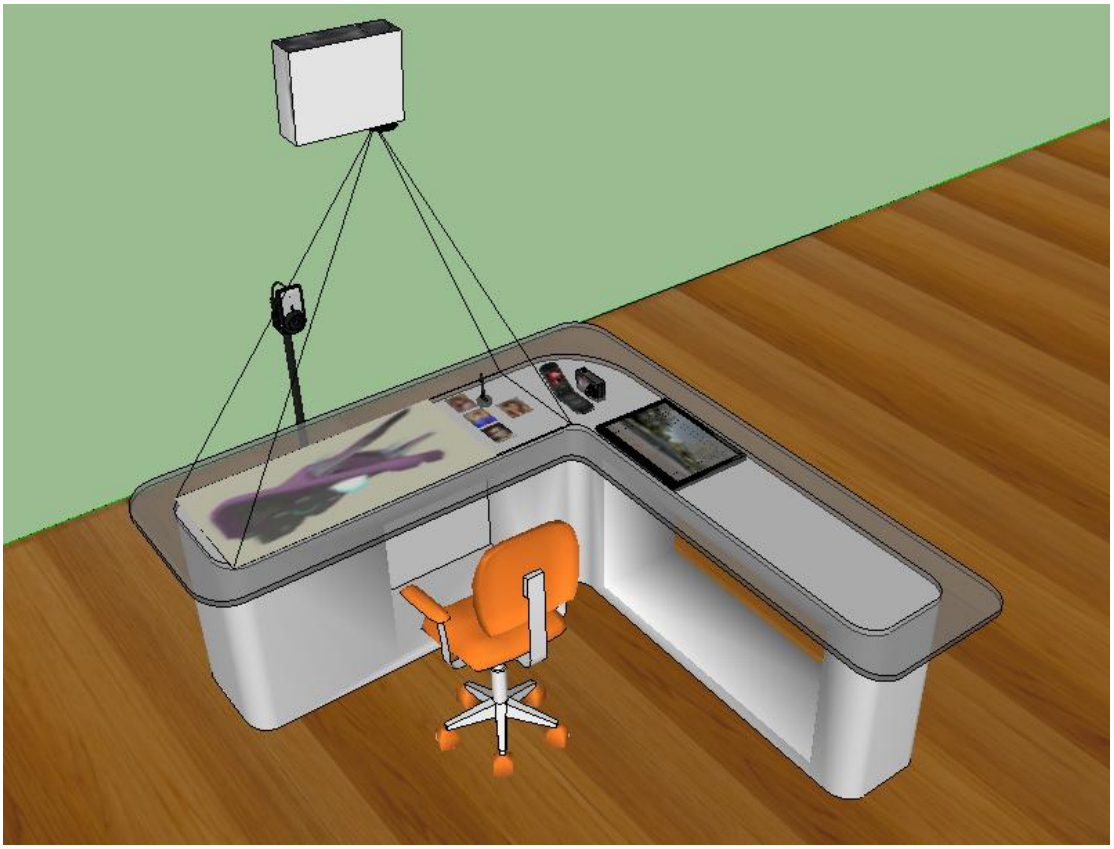


Figure 23: A detailed 3D representation of the artist's design area

Figure 24: The Artist's Design area

5.1.1.1.2 Bookcase

The Ambient Bookcase is a place where physical reference material in the form of books, magazines, museum guides are augmented and used. These physical materials can be browsed through the ambient applications and referenced in the same way as virtual reference material. This new form of organisation allows the simultaneous usage of virtual and physical reference material through a common infrastructure.

Figure 25: The Ambient Book Case

5.1.1.1.3 Smart shelves

Browsing through painting material is a task closely coupled with the artist's experience and knowledge. Selecting the most appropriate support paints and in

general art supplies is essential for the success of the creative process. The smart shelves incorporated in the Ambient Workshop allow the system to analyse the subject matter and make specific proposals for selecting among available art supplies. These proposals can in turn used by the artist for performing his final selection employing both his experience and the analysis performed by the system.

Figure 26: Smart shelves

5.1.1.1.4 Meeting Area

The meeting area tries to facilitate the human to human relations between the artist and the patron allowing them not only to communicate in a comfortable environment but also use this area of informal communication for making specific decisions about the patronage. To this end, the incorporated technologies facilitate the browsing of resources, selection of composition, etc.

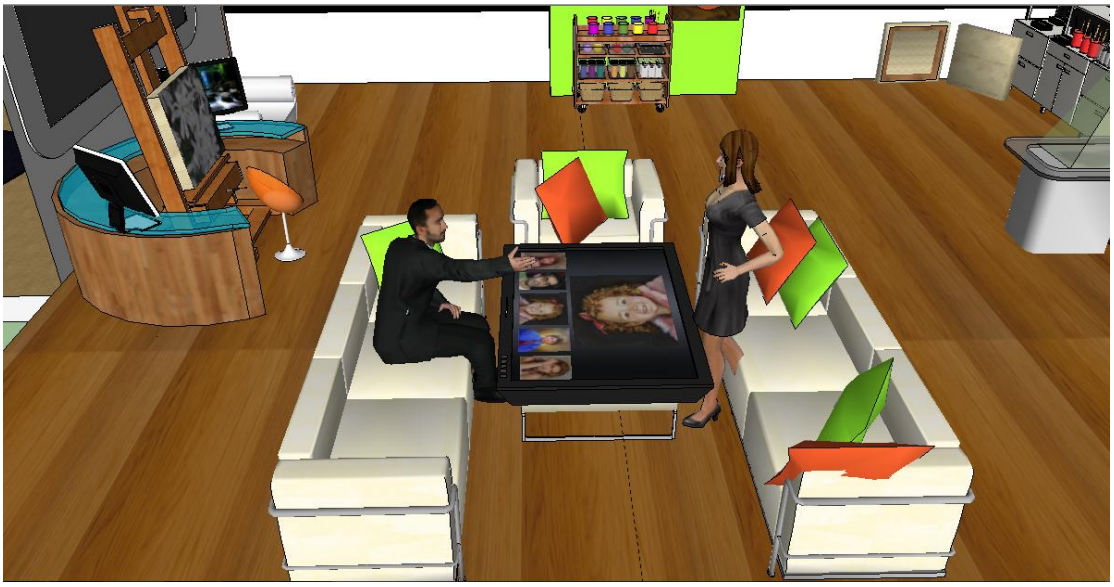


Figure 27: Browsing paintings through the interactive table

5.1.1.1.5 Work space

Represents the place where the artist subject matter is transformed to the final product using advanced facilities for providing design and creation time support.

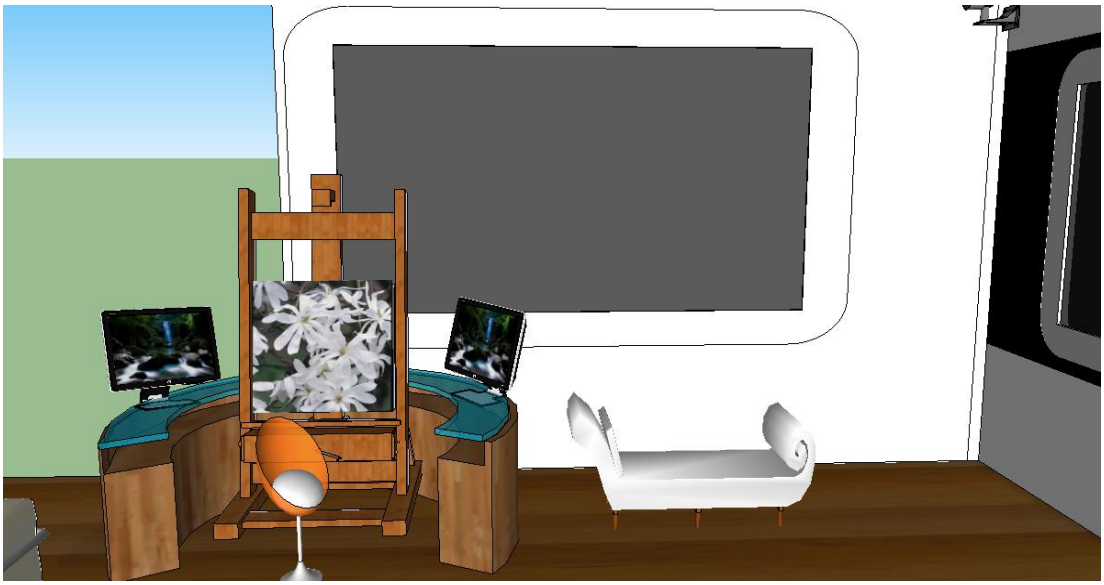


Figure 28: The Artist's Work Area

5.1.1.2 The model's plane

The model's plane presented in Figure 29 is the studio where the subject-matter of art is placed. As presented in this figure, this space is structured around the model. Controllable lights are placed in several locations of the room for enabling the

production of unlimited variations of lighting. The central screen is the place through which the subject matter of art is projected to the artist and at the same time as a physical screen for projecting information such as composition schemes, grids, framing shapes, etc. Figure 30 presents a prototype representation of the model's plane showing the process of posing for a painting.

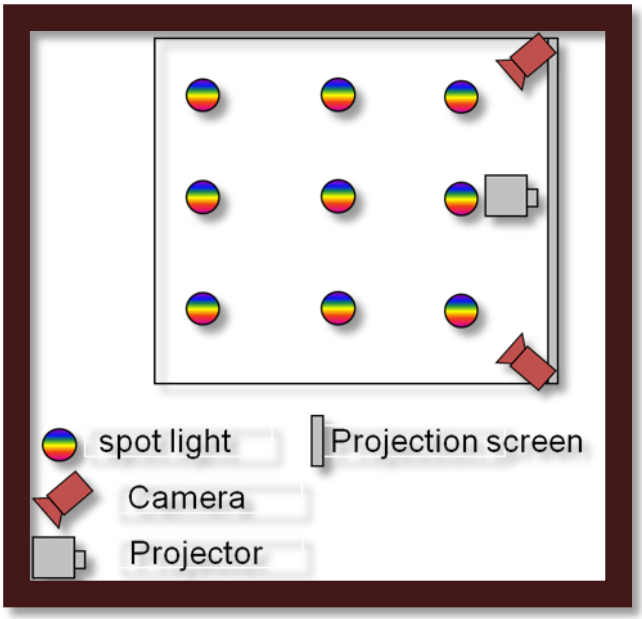


Figure 29: A three dimensional representation of the model's plane

Figure 30: A three dimensional representation of the model's plane

5.1.1.3 Hardware infrastructure

For facilitating the presented setup of the Ambient Workshop several hardware requirements must be met. To this end, Figure 31 presents a detailed representation of

the hardware infrastructure that should be installed for facilitating the requirements set both from the space and from the applications incorporated for making the space functional. In this figure the following hardware infrastructure is outlined:

- **Spot lights:** adjustable spot lights that can be operated via the ambient software infrastructure for setting the lighting both in the workshop and model plane.
- **I-table:** An interactive table used in the meeting area for allowing the collaborative browsing of resources between the patron and the artist.
- **Touch screens:** For presenting design and creation time support applications to the artist
- **Projection screens:** Areas where projections can be carried out both for informative purposes (two projection screens on the main area of the workshop) and for art creation purposes (one projection screen in front of the model's plane)
- **Cameras:** Installed both in the artist's and model's area.
- **Projectors:** for projecting on the projection screens and the design space.
- **Distance sensors:** For offering context information (proximity).
- **Speakers:** For TTS purposes.
- **RFID:** For allowing the usage of augmented objects through the Workshop
- **Bluetooth:** For communicating with mobile devices possessed by the artist or the patron.

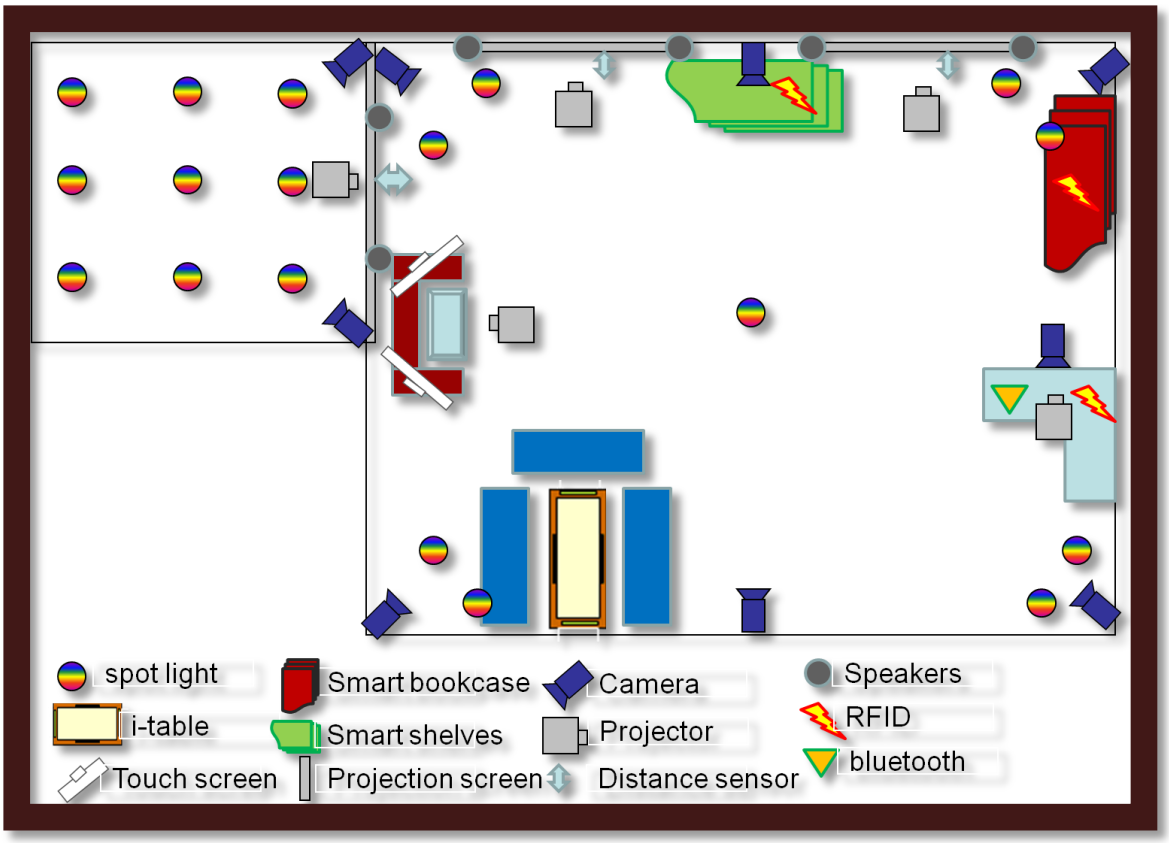


Figure 31: Workshop floor plans with detailed hardware specification

5.1.2 The Smart Home

Home automation is an emerging trend that the public looks for is currently finding its way in residential houses, apartments, and commercial businesses. Although many techniques used in building automation (such as light and climate control, control of doors and window shutters, security and surveillance systems, etc.) are also used in home automation, additional functions in home automation can include the control of multi-media home entertainment systems, automatic houseplant watering and pet feeding, automatic scenes for dinners and parties, and a more user-friendly control interface [140]. In the same context the smart home although building on facilities offered by home automation goes forth in offering ambient facilities that aim at entertainment, education, etc.

5.1.2.1 Architecture

This section presents the architecture proposed for setting-up a smart home environment which facilitates the fruition of art in various ways, such as:

- informative art (e-mailer, weather forecast)

- art for aesthetic purposes (smart canvas, etc.)
- entertainment (games on the i-table, and on the back screen projection area)
- education and learning

Figure 32 presents the floor plans of the proposed set-up, while Figure 33 presents a 3D representation of the proposed architecture for allowing the presentation of the affordances offered through the proposed structure.

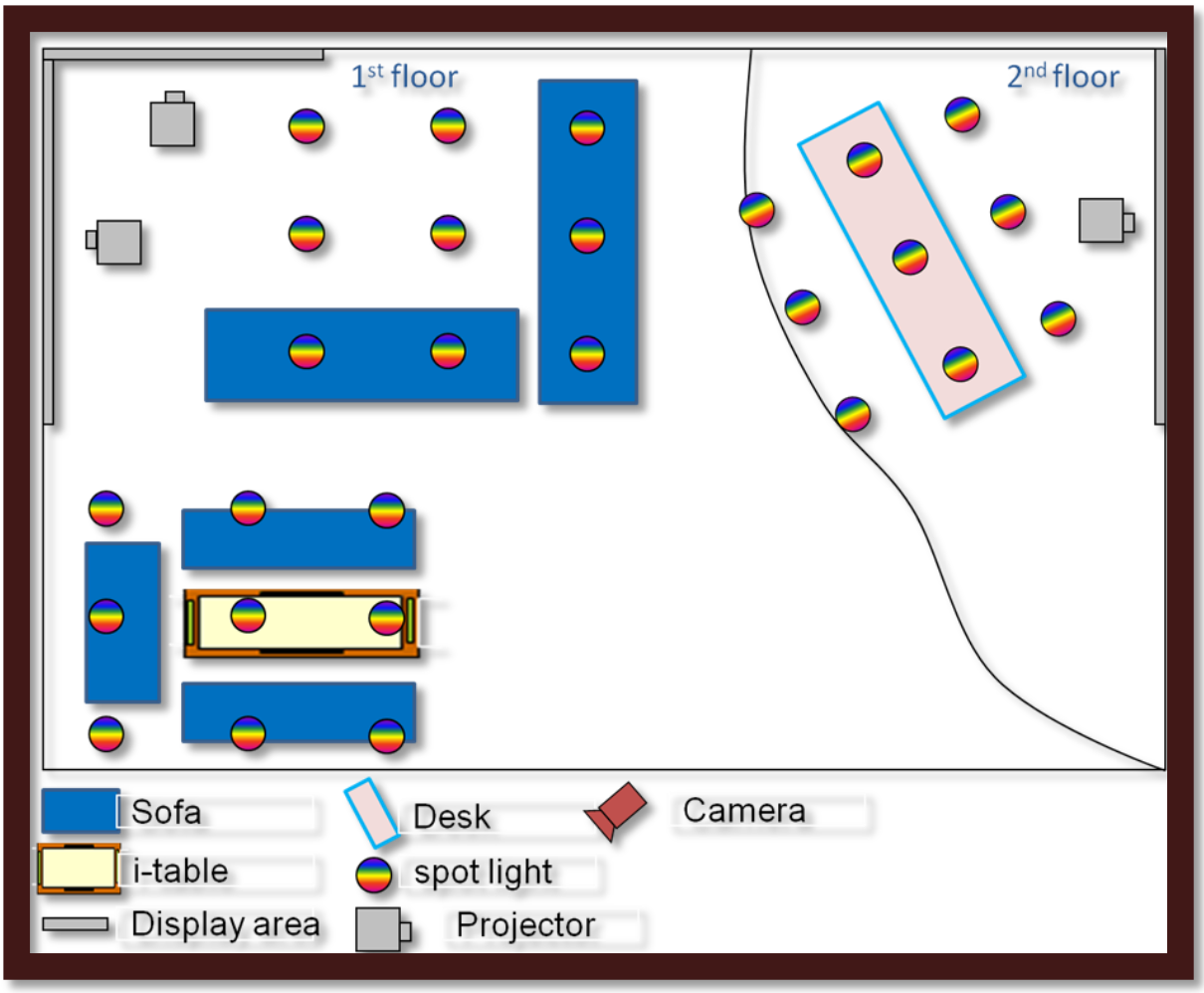


Figure 32: Floor plans for the smart home setup

Figure 33: The smart home in 3d

5.1.2.1.1 The office

On the second floor of the smart home resides the office allowing the fruition of art for informative purposes as presented in Figure 34. This figure presents a prototype representation of the office in 3D. The projection screen in front the office presents the e-mailer application utilizing a painting by Sandro Botticelli named "The birth of Venus" while other facilities are outlined, such as adjustable lights, etc.

Figure 34: 2nd floor: the office

5.1.2.1.2 Living-room: Entertainment area

The entertainment area contains a large projection screen as shown in Figure 35 together with a small informative art display as presented in Figure 36. In this area, applications related to art can be presented in the periphery of user's attention using

the informative art display or at the core of user's entertainment centre using the large projection screen. The first setup is used when art is meant to inform users, while the second is used where art is used for entertainment in the context of games, etc.

Figure 35: View to the home entertainment area

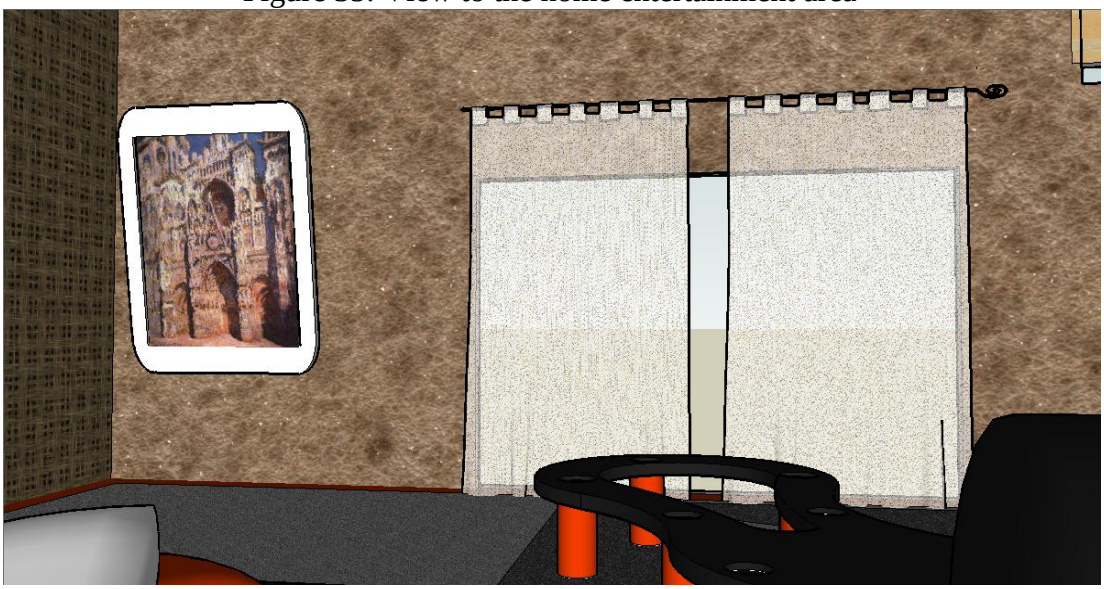


Figure 36: An informative art display mounted on the wall

5.1.2.1.3 Living-room: Games spot

The Games spot is the physical place of the living room where the inhabitant of the smart home can be gathered together with friends and enjoy a number of educative games. The set-up of this area makes it suitable for collaborative platform or role playing games while allowing the simultaneous usage of mobile devices for keeping player oriented information.

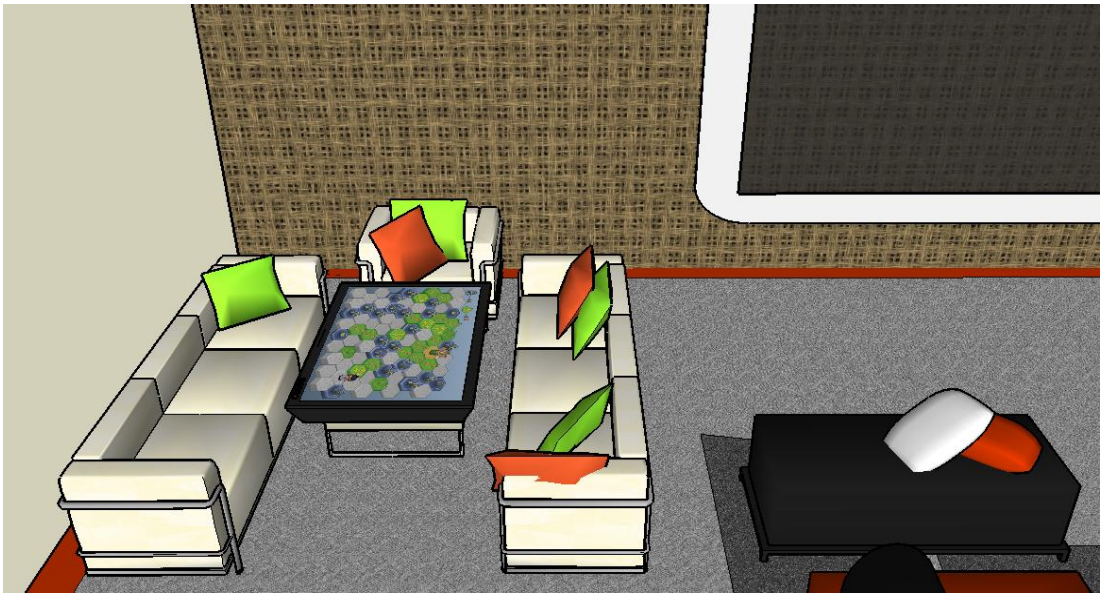


Figure 37: The games spot

5.1.2.2 Hardware infrastructure

As presented in Figure 32, the smart home setup contains:

- **Spot lights:** adjustable spot lights that can be operated via the ambient software infrastructure for setting the lighting at the various spaces of the smart home such as the office, entertainment and games space.
- **I-table:** An interactive table used on the Games spot for presenting collaborating games and allowing the augmentation of physical objects to the game's space.
- **Projection screens:** Areas where projections can be carried out both for informative purposes (two projection screens one on the office and another one on the entertainment area) and for general projection purposes (one projection screen in the entertainment area).
- **Cameras:** Installed on both floors.
- **Projectors:** for projecting on the projection screens.
- **Distance sensors:** For offering context information (proximity).
- **Speakers:** For TTS purposes and audio purposes.
- **RFID:** For allowing the usage of augmented objects through the Games spot.
- **Bluetooth:** For communicating with mobile devices possessed by the house owners.

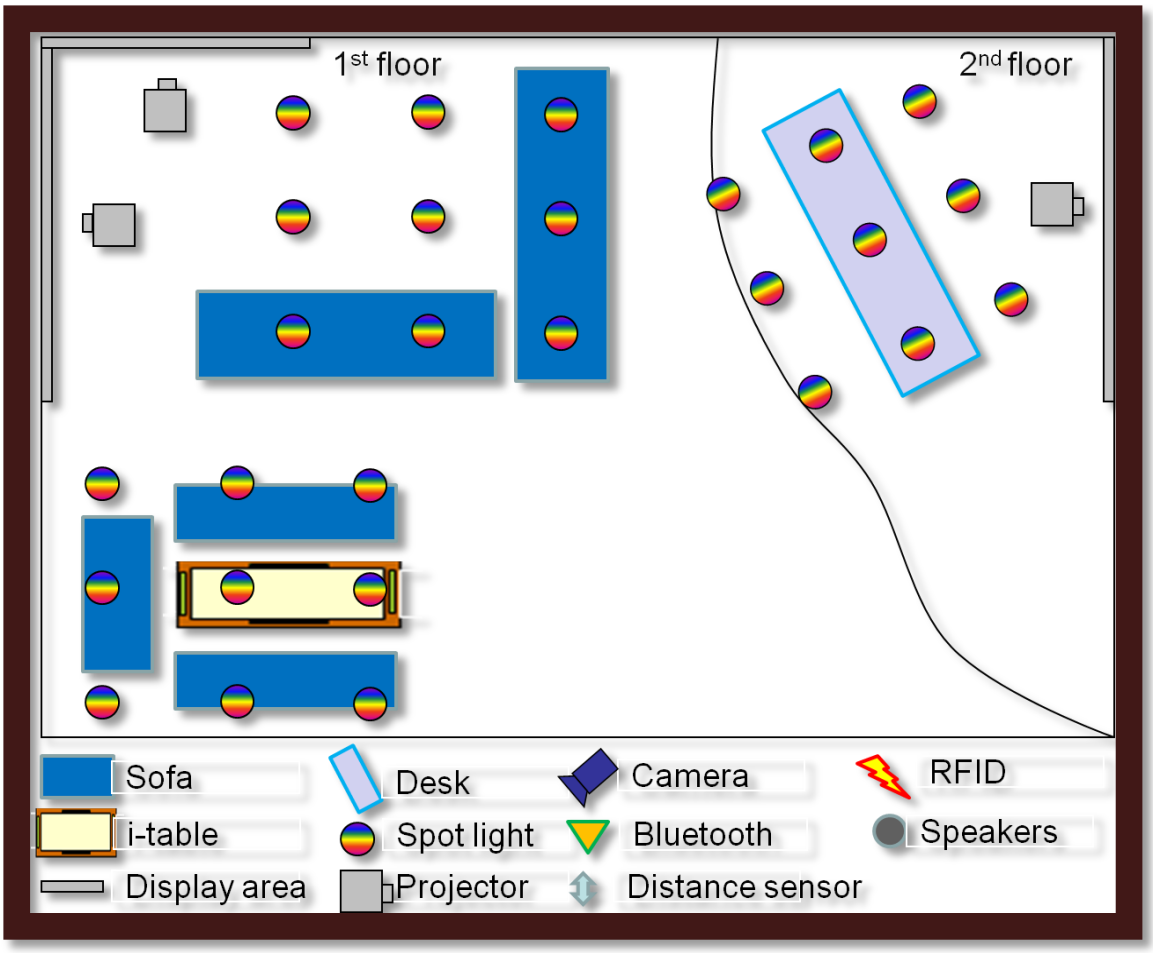


Figure 38: Floor plans of the Smart Home with detailed hardware specification

5.1.3 The Ambient Art Gallery

Art is today accessed by the public in more or less the same manner as in the previous centuries. Museums and art galleries are the most common places where art is exhibited. The main evolution in the way that art is exhibited using the aforementioned ways is the existence of new technology driven ways for guiding visitors, such as electronic voice guides. At the same time, the evolution of the internet has made it possible for people to access art via online galleries which in turn serve commercial or non-commercial purposes. The main drawback of this approach is mainly that a two dimensional representation of art through pictures cannot produce the same effect or provide the same educational information as the art itself. For example, Rembrandt used to create clothing by applying flat colour to the surface while exaggerating detail such as features and patterns with bright textured application of paint. It is therefore essential to enrich the information offered view

pictures but at the same time keep the same feeling that result from visiting the art itself.

5.1.3.1 Architecture

This section presents an indicative setup of an Ambient Intelligence Facility acting as an Ambient Art gallery as presented in Figure 39. The goals of this architecture are to allow the presentation of art both as a physical entity and as a virtual entity. In both cases the existence of ambient technology focuses on enhancing the ways that art is perceived both by employing intelligent paradigms for presenting art specific information but furthermore for allowing the usage of appropriate lighting, navigation, etc. At the same time, a prototype setup of an ambient art gallery in 3D is presented in Figure 40.

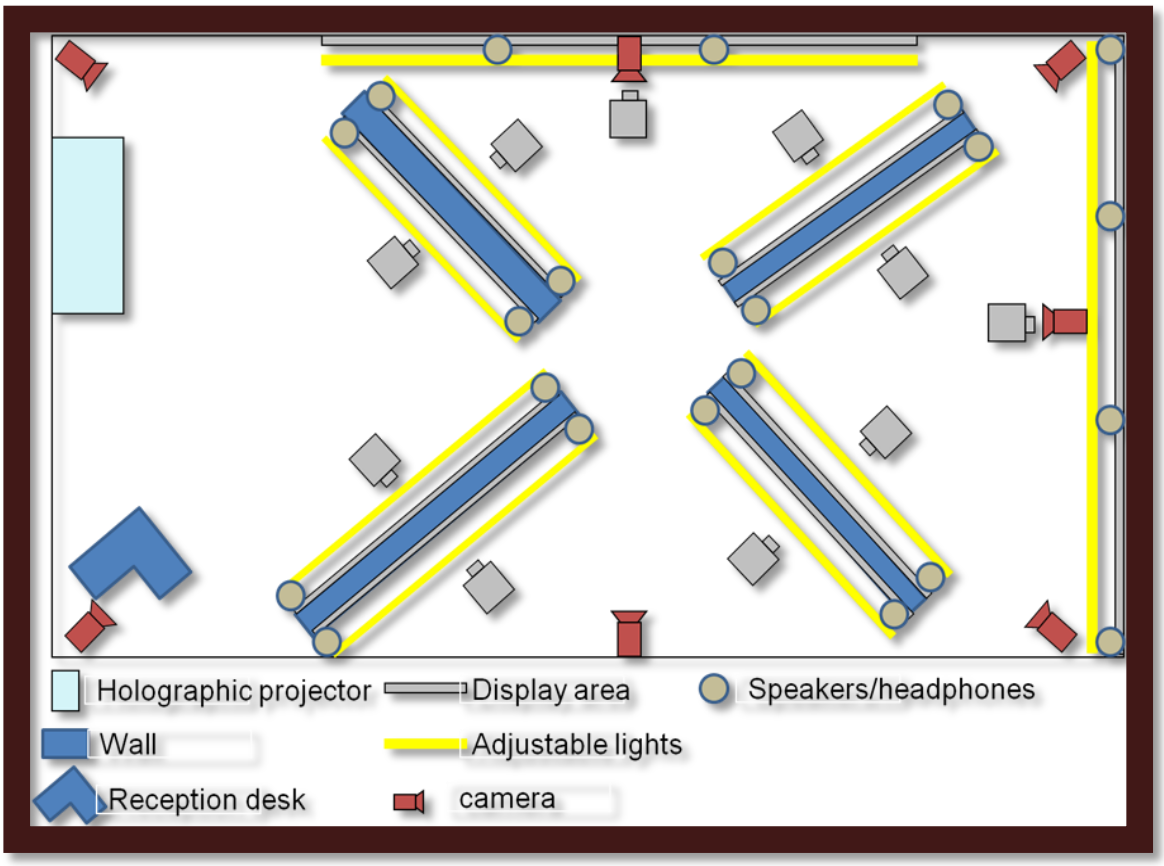


Figure 39: Setup of the Ambient Art Gallery

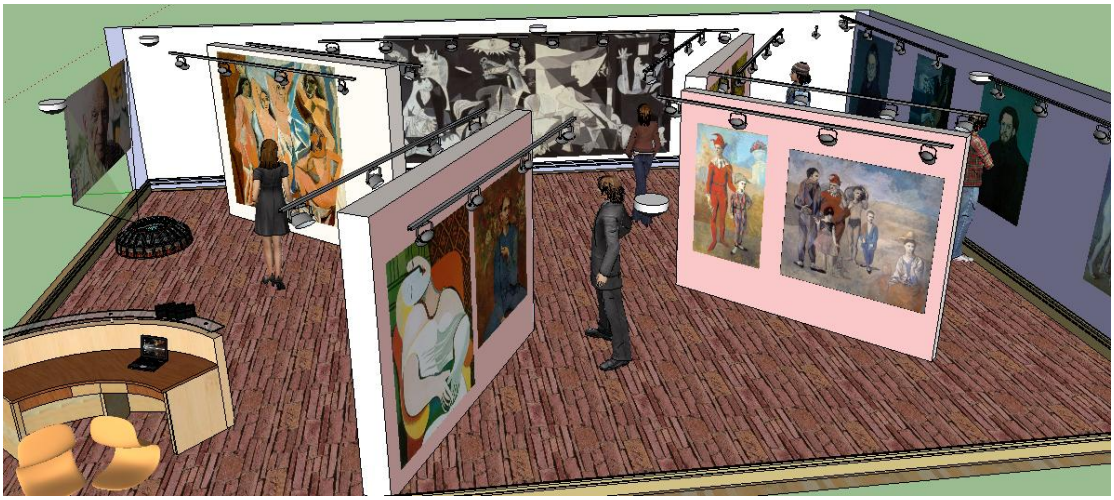


Figure 40: An overview of the exhibition in 3D

The main area of interest in this prototype art gallery are the holographic display screen appearing in the entrance of the gallery, allowing the presentation of information that advertise the exhibition while employing contextual information for presenting user specific information .

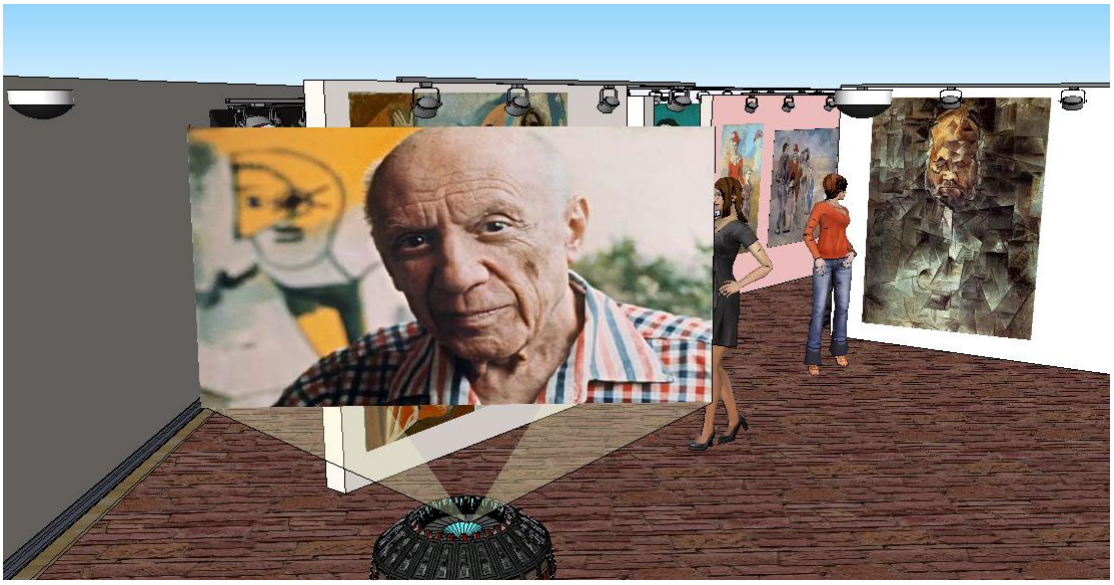


Figure 41: A holographic projection screen presenting information for the exhibition

The reception desk of the exhibition (see Figure 42) is the physical place where customers are introduced to the concept of the exhibition allowing the payment of tickets, the selection of guiding schemes, etc. In this space mobile devices can also be used for allowing the visitors to synchronise their devices for allowing the interactive browsing of exhibits (downloading pictures, reference material, historical information etc.).

Figure 42: The reception desk

Figure 43 presents a screenshot of a visitor accessing an interactive exhibit of the ambient art gallery.

Figure 43: An interactive exhibit

5.1.3.2 Hardware Specifications

As presented in Figure 39 the hardware infrastructure used includes:

- **Art Displays:** these are the areas where art is presented to the user either on a virtual or physical form
- **Spot lights:** Adjustable spot lights are mounted on the ceiling over the areas of interest for allowing the applications to produce the desired lighting

- **Distance sensors:** These sensors are mounted below the displays for collecting proximity information
- **Cameras:** Cameras are used both for tracking visitor positions on the gallery area and for getting user inputs via gestures
- **Helio display:** Is a device used to simulate a hologram style presentation of information. It is used for displaying pure three dimensional object (like sculptures) facilitating user interactive with these objects via gestures (rotation, scale, zoom etc.)
- **Holographic projector:** For allowing the presentation of information that advertises the exhibition.
- **RFID sources:** These sources are used for propagating to mobile devices information regarding the projection area currently viewed by a visitor in order to present the appropriate information on the mobile device
- **Speakers:** For TTS purposes and audio purposes.
- **Bluetooth:** For communicating with mobile devices possessed by the house owners.
- **Hardware controls:** For allowing the manipulation of virtual artefacts (zooming, rotation etc.)

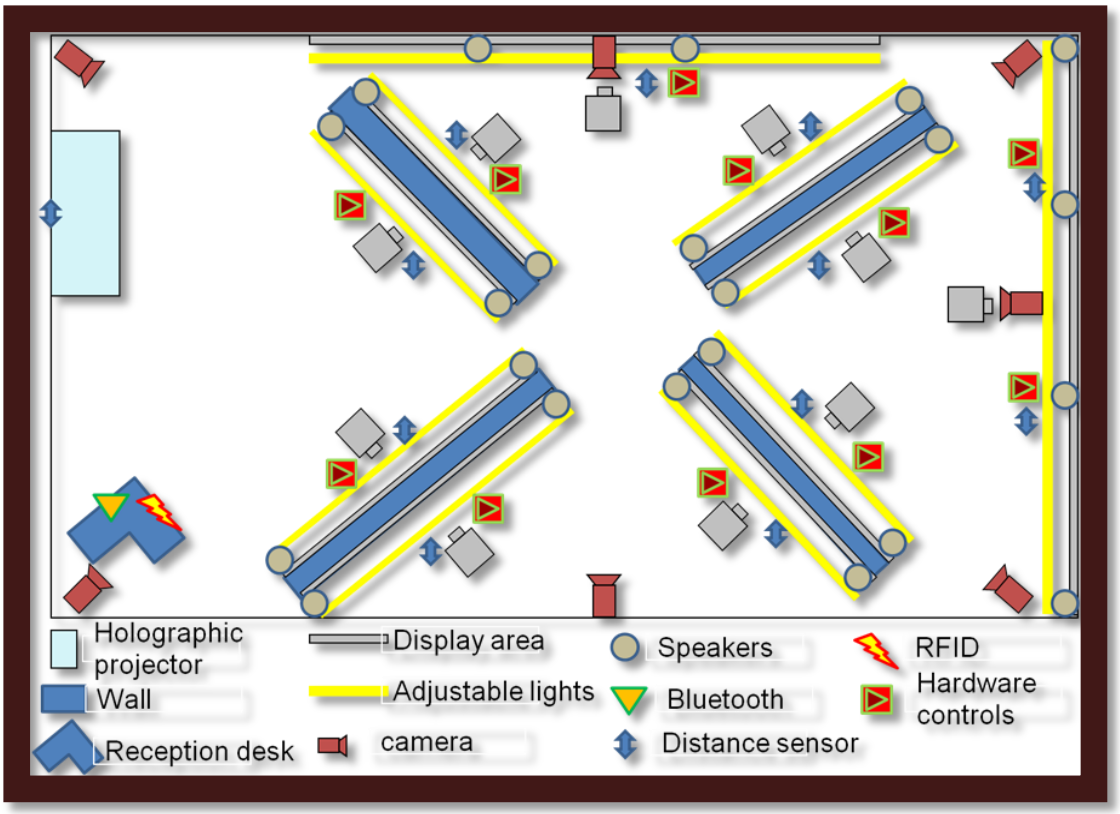


Figure 44: Floor plans of the Art Gallery with detailed hardware specification

5.2 From vision to reality: The Ami simulation space

For the deployment of the proposed architectural structures in the context of a real life Ami environment a simulation space has been setup within the FORTH's Ami facility [304]. This simulation space has been set-up in order to meet the needs of all the spaces presented in the previous sections. To this end according to the scenario implemented within the space locations and devices act in accordance to the requirements of this scenario. In this section the general structure of this space will be presented together with the deployed hardware. At the same time the way that this hardware acts in the context of simulating the environments presented by this research work is presented. It is important to highlight that the previous sections present the optimum configuration of the spaces facilitated by this research work. The adaptations presented in this section foster the need to simulate three different spaces within the same unified Ami simulation space.

Figure 45 presents the floor plans of the Ami simulation space employed by this research work together with the deployed hardware. At the same time in Figure 46

pictures of the final simulation space as adjusted for the needs of this research work are shown.

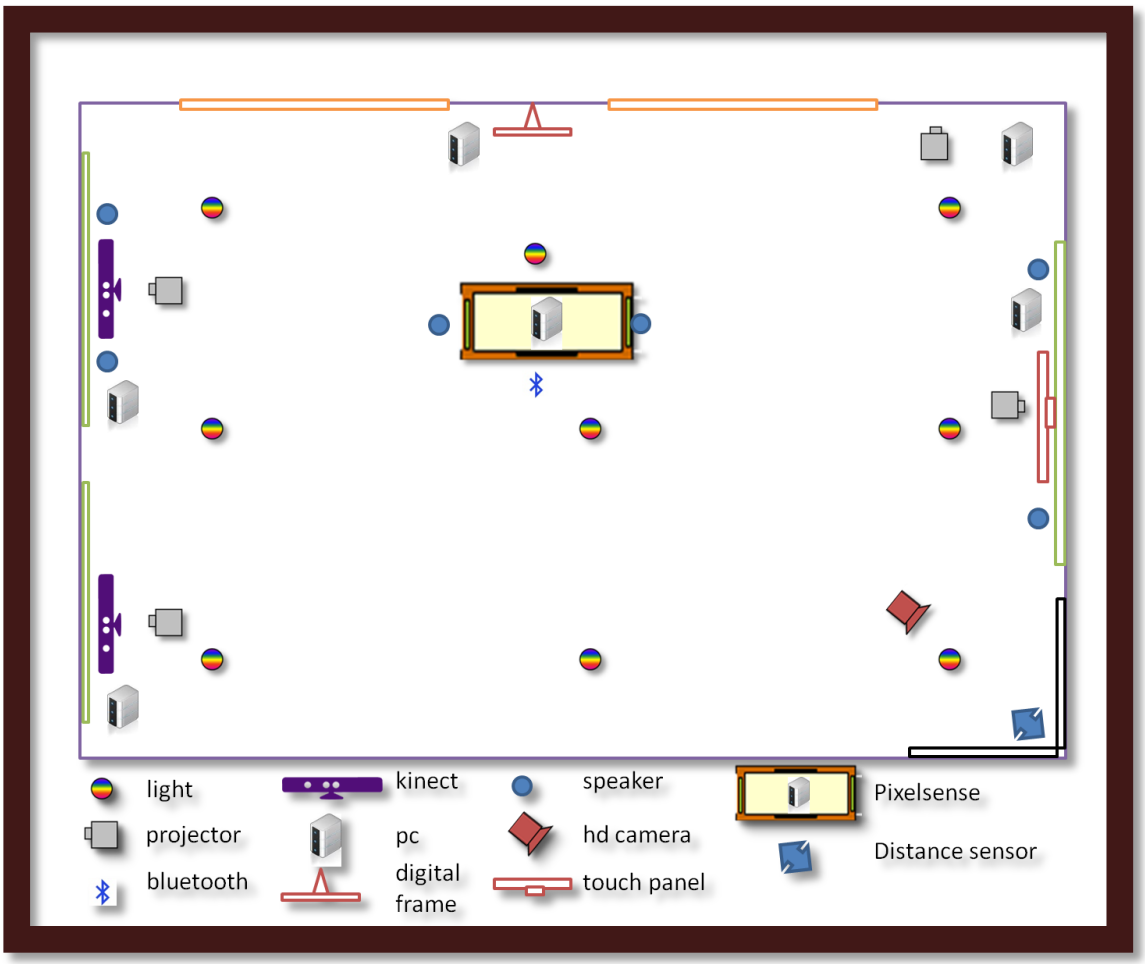


Figure 45: Floor plans of the Ami Simulation space

Figure 46: A panorama view of the Ami Simulation space

5.2.1 The Artist's Workshop

In order for the simulation space presented above to act as a full featured Ambient Workshop the deployed infrastructure is used to map the different spaces and facilities identified during the design of the workshop. To this end Figure 47 presents the mapping between the initial design of the workshop and its required adaptation. As shown in this figure the meeting space and the design space has been unified and facilitated by the Pixelsense device contained within the space. At the same time the

model plane has been transferred within the same room allowing the artist to have direct contact with his subject matter.

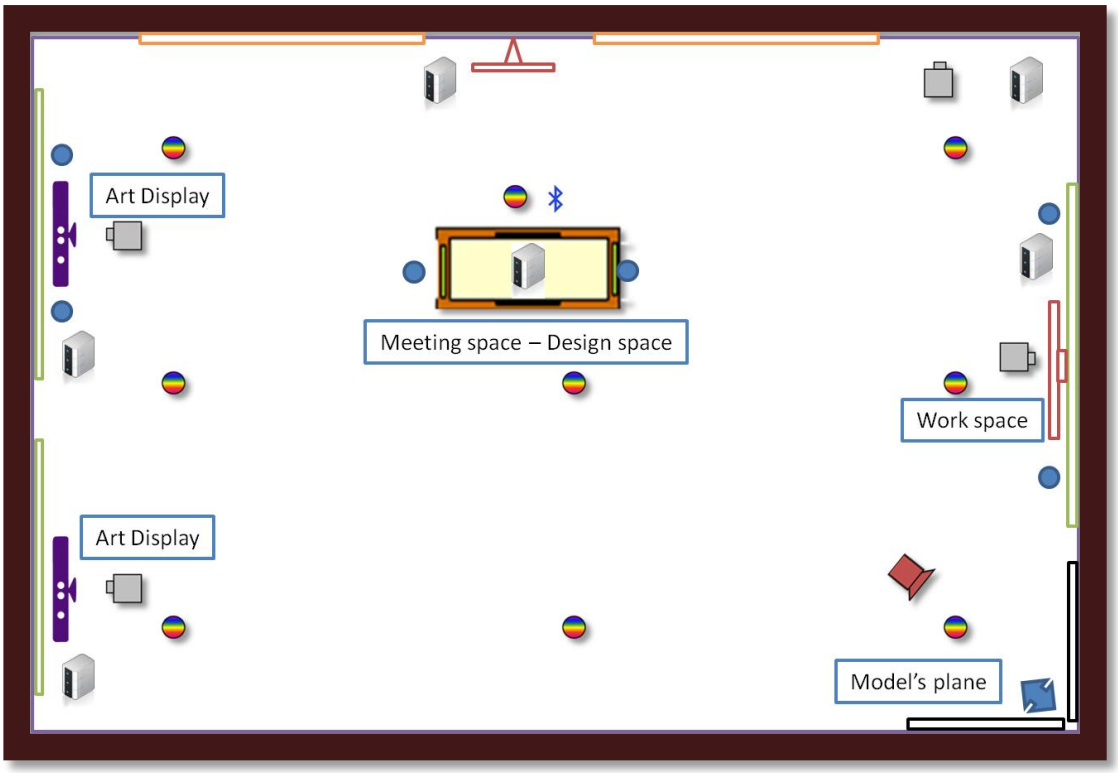


Figure 47: The Artist's workshop within the Ami simulation space

The physical arrangement of the aforementioned envisioned areas of the artist workshop within the Ami simulation space are presented in Figure 48.

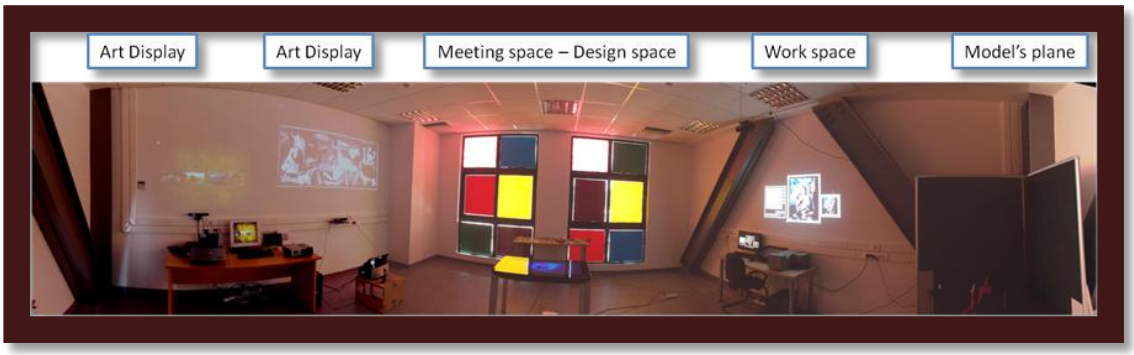


Figure 48: The physical arrangement of areas within the Ami simulation space

5.2.2 The Ambient Art Gallery

For the art gallery a more abstract deployment of technology, in conjunction to the one proposed in the context of the design, has been followed. The approach followed here was to be able to deploy most of the developed by this research work facilities

within the same space for displaying the entire museum experience at once. The mapping of the museum experience within the simulation space is presented in Figure 49. As shown in this figure in the same space two different interactive exhibits can be presented (a digital and a physical one). The Pixelsense table acts as a device for presenting application within museum leisure space or unoccupied spaces (corridors, entrances etc.). There is also a projection area dedicating for exhibition advertising while the reception is the place to get a mobile device to be used while browsing through the museum collection of artefacts.

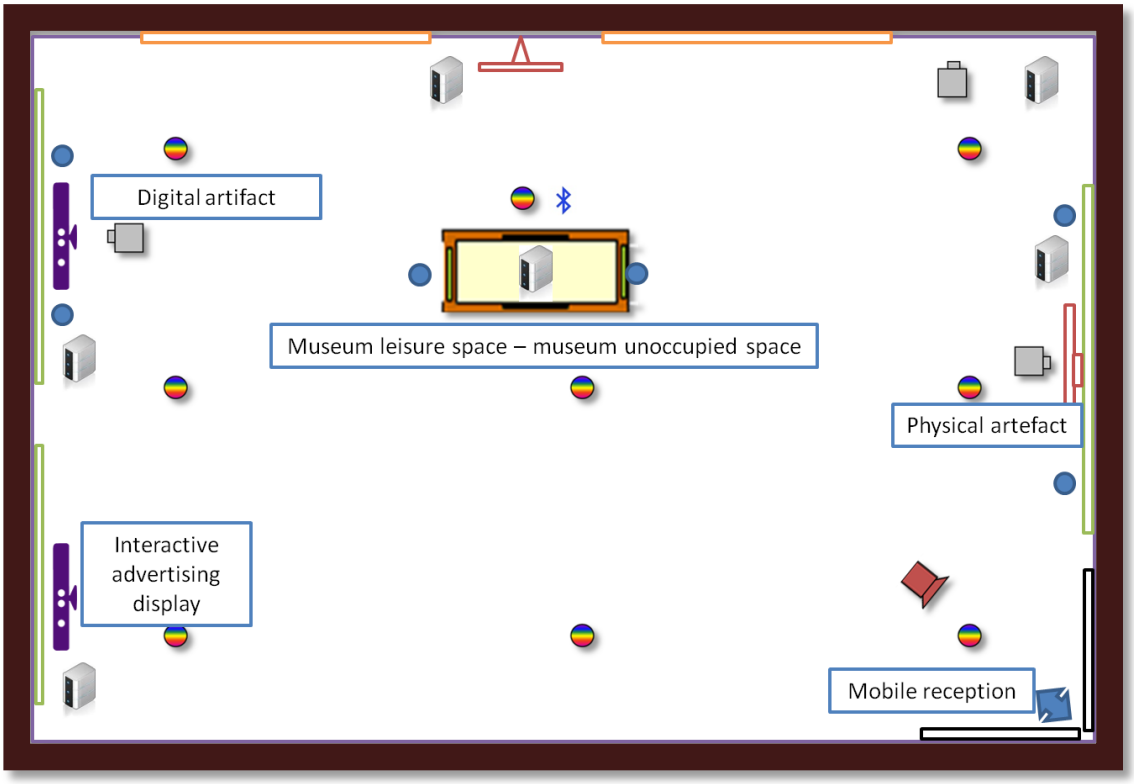


Figure 49: The Ambient Art Gallery within the Ami simulation space

The physical arrangement of the aforementioned envisioned areas of the art gallery within the Ami simulation space are presented in Figure 50.

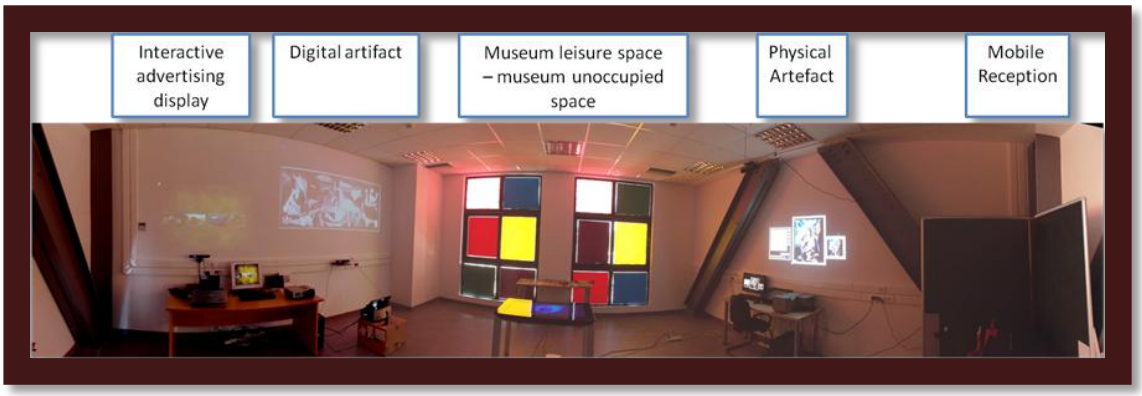


Figure 50: The physical arrangement of art gallery areas within the Ami simulation space

5.2.3 The Smart Home

The smart home is mapped to the Ami simulation space in the way presented in Figure 51. As shown in this figure two augmented paintings are located within the living room. At the same time the interactive table is acting as the games spot of the smart home. The digital frame has also found its spot within the living room allowing the final projection are to act as the spot for education and entertainment.

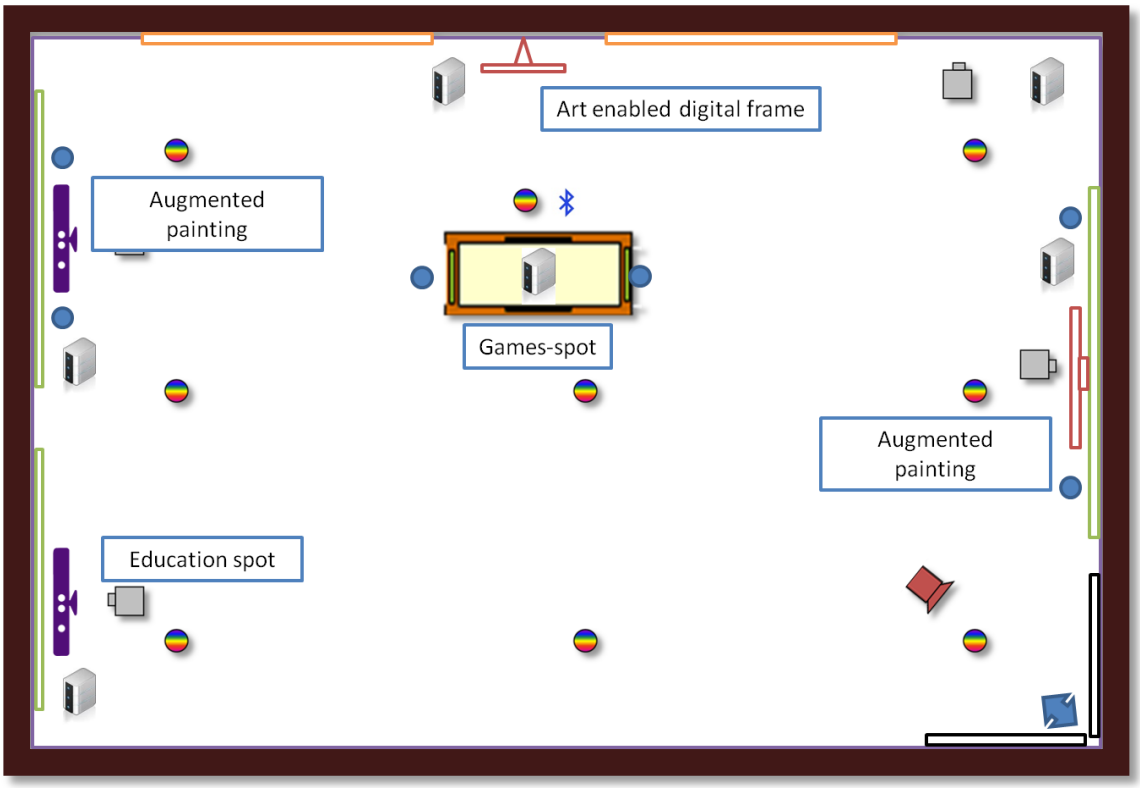


Figure 51: The Ambient Art Gallery within the Ami simulation space

The physical arrangement of the aforementioned envisioned areas of the smart home within the Ami simulation space are presented in Figure 52.

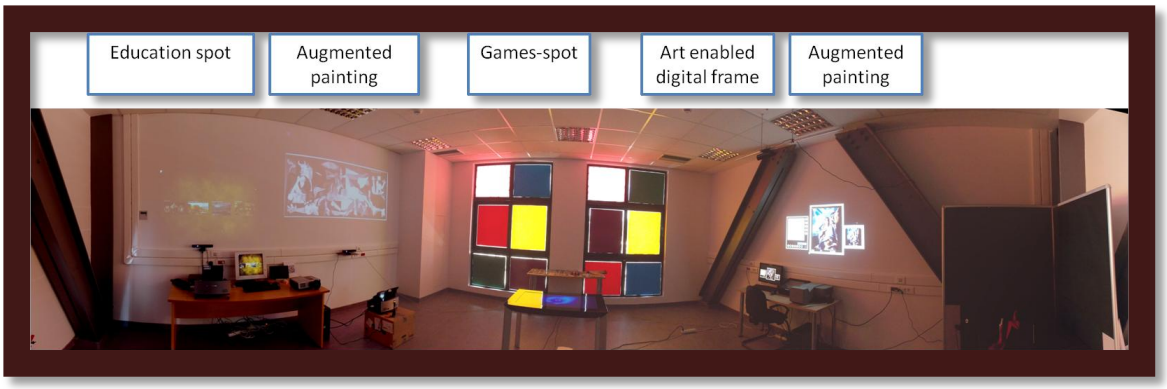


Figure 52: The physical arrangement of smart home's areas within the Ami simulation space

6 Defining a Model for Visual Arts

This section describes the process of defining and implementing the knowledge infrastructure used by this research work so as to enable the creation and exploitation of art in the context of diverse smart environments. Taking into account that the implemented applications should be operated under various contexts and for various purposes, it was essential to envision a common infrastructure to facilitate their development without the need for context related specialisations. To this end, this is achieved by this research work through the implementation of a common for all interactive applications **ontology meta-model**.

6.1 A Model for Visual Arts

The creation of universal art ontology can be thought as having fundamental importance for allowing the manipulation of art under various contexts and for various purposes. The importance of such ontology is the ability offered via its usage to answer to a number of theoretical and practical questions about an art object such as:

- **Theoretical issues:**
    - What kind of art is it
    - When it was created
    - What does it depicts
    - What are the main points of interest
    - Who is the artist responsible for its creation

  - What was the artists intentions
  - What are its cultural information
- **Practical issues:**
  - How was created
  - What mediums were used
  - What is the ideal lighting setting for presenting it
  - Where it is located

Having the ability to answer to a multitude of questions via the universal art ontology is important for allowing the use of art objects as educational material (in the context of games, tutorials), as gallery objects with advanced instructional facilities (in the context of art galleries), or for informative purposes (in the context of ambient informative art applications), etc. To this end, the ontology specification should contain an extended classification of art, in order for each artefact to be classified on the ontology.

6.1.1 Classification of Visual Arts

Visual arts are art forms that focus on the creation of artefacts which are primarily visual in nature, such as traditional plastic arts (drawing, painting, sculpture, architecture, and printmaking), modern visual arts (photography, video, and filmmaking), and design and crafts. Many artistic disciplines (performing arts, language arts, textile arts, and culinary arts) involve aspects of the visual arts as well, so these definitions are not strict [114]. In this context, a first attempt to classify visual arts can be based on the collection of alternative artistic expressions [114]:

- **Drawing:** Drawing is a means of making an image, using any of a wide variety of tools and techniques. It generally involves making marks on a surface by applying pressure from a tool, or moving a tool across a surface using dry media such as graphite pencils, pen and ink, inked brushes, wax colour pencils, crayons, charcoals, pastels, and markers.
- **Painting:** Painting taken literally is the practice of applying pigment suspended in a carrier (or medium) and a binding agent (a glue) to a surface (support) such as paper, canvas or a wall. However, when used in an artistic sense it means the use of this activity in combination with drawing, composition and other aesthetic considerations in order to manifest the expressive and conceptual intention of the practitioner.

- **Printmaking:** Printmaking is creating for artistic purposes an image on a matrix which is then transferred to a two-dimensional (flat) surface by means of ink (or another form of pigmentation). Except in the case of a monotype, the same matrix can be used to produce many examples of the print. Historically, the major techniques (also called media) involved are:
    - woodcut
    - line engraving
    - etching
    - lithography
    - and screen-printing (serigraphy, silk-screening)
- **Photography:** Photography is the process of making pictures by means of the action of light. Light patterns reflected or emitted from objects are recorded onto a sensitive medium or storage chip through a timed exposure. The process is done through mechanical, chemical or digital devices known as cameras.
- **Filmmaking:** Filmmaking is the process of making a motion-picture, from an initial conception and research, through scriptwriting, shooting and recording, animation or other special effects, editing, sound and music work and finally distribution to an audience; it refers broadly to the creation of all types of films, embracing documentary, strains of theatre and literature in film, and poetic or experimental practices, and is often used to refer to video-based processes as well.
- **Computer art:** Visual artists are no longer limited to traditional art media. Computers may enhance visual art from ease of rendering or capturing, to editing, to exploring multiple compositions, to printing (including 3D printing). Computer art is any art in which computers played a role in production or display of the artwork. Many traditional disciplines are now integrating digital technologies and, as a result, the lines between traditional works of art and new media works created using computers have been blurred. This type of art is beginning to appear in art museum exhibits, though it has yet to prove its legitimacy as a form unto itself and this technology is widely seen in contemporary art more as a tool rather than a form as with painting.

- **Sculpture:** Sculpture is three-dimensional artwork created by shaping or combining hard and/or plastic material, sound, and/or text and or light, commonly stone (either rock or marble), metal, glass, or wood. Some sculptures are created directly by finding or carving; others are assembled, built together and fired, welded, moulded, or cast.

6.1.1.1 Visual Arts across the ages

In terms of time-line, visual art may be classified as follows [51]:

- **Pre-Historic:** Pre-historic art is the artwork produced by the nameless early humans from the edge of the epoch when homo sapiens came to being (cave paintings, pottery and other utensils, and early tools)
- **Ancient:** This class of art refers to the different visual artworks that are remains of ancient civilizations from Egypt, Mesopotamia, Greece and Rome.
- **Medieval:** Medieval art, though stated among the classification based on the time-line, also refers to the artwork produced in basically in Europe, and also in North Africa and Middle East, during the early period of one and a half millennia after Christ.
- **Renaissance:** Renaissance can be said to be based around Italy, and it refers to the artwork produced during the period of 1300 to 1600.
- **Romanticism:** This class of artworks is around the year 1700 and 1900. The style is similar to Renaissance Art but the key difference is the choice of subjects.
- **Modern:** This class of artworks started in the late 19th century. The movement has an international scope and is not bound by borders of countries.
- **Contemporary:** This class of art is overlapped with the Modern Art. The time period is 1960 to current time. Almost anything visual can be classed as Contemporary Art if it can be classed as art and a commentary on it can be made in descriptive terms.

6.1.1.2 A cultural classification of virtual arts

In terms of culture, one may classify visual art as follows [51]:

- **Western:** This class of artworks originated from the continent of Europe.

- **Islamic:** This class of art originated in the Middle East, and revolves around Islam religion.
- **Eastern:** This is an encompassing category for the diverse artworks that may be further classified as Buddhist, Chinese, Japanese, Indian Art and several other classes that were influenced by specific cultures.

6.1.1.2.1 Western Art Styles

Western art styles can be classified as follows:

- **Abstract art** [126] in its many forms has been a dominant mode in the visual arts for the better part of a century. Popular histories usually trace "abstraction" as a succession of style or "isms," each set within it particular art-historical context, assuming a general familiarity with this kind of critical narrative. Abstract art uses a visual language of form, colour and line to create a composition which may exist with a degree of independence from visual references in the world. Abstraction indicates a departure from reality in depiction of imagery in art. This departure from accurate representation can be only slight, or it can be partial, or it can be complete.
- **Abstract expressionism** [116] was an American post–World War II art movement. It was the first specifically American movement to achieve worldwide influence and put New York City at the centre of the western art world, a role formerly filled by Paris. The most important art movement since the Second World War, Abstract Expressionism revolutionized the way Americans viewed art and culture alike.
- **Art Deco** [118] was a popular international art design movement from 1925 until the 1940s, affecting the decorative arts such as architecture, interior design, and industrial design, as well as the visual arts such as fashion, painting, the graphic arts, and film. The movement was a mix of many different styles and movements of the early 20th century, including Neoclassical, Constructivism, Cubism, Modernism, Art Nouveau, and Futurism [197].
- **Baroque** [120] is a period of artistic style that used exaggerated motion and clear, easily interpreted detail to produce drama, tension, exuberance, and grandeur in sculpture, painting, architecture, literature, dance and music. The

style began around 1600 in Rome, Italy and spread to most of Europe. The popularity and success of the Baroque style was encouraged by the Roman Catholic Church, which had decided at the time of the Council of Trent that the arts should communicate religious themes in direct and emotional involvement.

- **Body painting** [123], or sometimes body painting, is a form of body art, considered by some as the most ancient form of art. Unlike tattoo and other forms of body art, body painting is temporary, painted onto the human skin, and lasts for only several hours.
- **COBRA** (or **CoBrA**) [125] was a European avant-garde movement active from 1949 to 1952. The name was coined in 1948 by Christian Dotremont from the initials of the members' home cities: Copenhagen (Co), Brussels (Br), Amsterdam (A). COBRA was formed by Karel Appel, Constant, Corneille, Christian Dotremont, Asger Jorn, and Joseph Noiret on 8 November 1948 in the Café Notre-Dame, Paris.
- **Colour Field painting** is a style of abstract painting that emerged in New York City during the 1940s and 1950s. It was inspired by European modernism and closely related to Abstract Expressionism, while many of its notable early proponents were among the pioneering Abstract Expressionists. Colour Field painting is characterized primarily by large fields of flat, solid colour spread across or stained into the canvas; creating areas of unbroken surface and a flat picture plane. In colour field painting "colour is freed from objective context and becomes the subject in itself [**Error! Reference source ot found.**].
- **Constructivism** was an artistic and architectural movement that originated in Russia from 1919 onward which rejected the idea of "art for art's sake" in favour of art as a practice directed towards social purposes. Alexei Gan used the word as the title of his book Constructivism, which was printed in 1922 [127]
- **Contemporary art** [128] can be defined variously as art produced at this present point in time or art produced since World War II. The definition of the word contemporary would support the first view, but museums of contemporary art commonly define their collections as consisting of art

produced since World War II. The classification of "contemporary art" as a special type of art, rather than a general adjectival phrase, goes back to the beginnings of Modernism in the English-speaking world.

- **Cubism** [129] was a 20th century avant-garde art movement, pioneered by Pablo Picasso and Georges Braque, that revolutionized European painting and sculpture, and inspired related movements in music and literature.
- **Digital painting** [130] is an emerging art form in which traditional painting techniques such as watercolour, oils, impasto, etc. are applied using digital tools by means of a computer, a digitizing tablet and stylus, and software. Digital painting differs from other forms of digital art because the artist uses painting techniques to create the digital painting directly on the computer.
- **Expressionism** was a cultural movement originating in Germany at the start of the 20th-century as a reaction to positivism and other artistic movements such as naturalism and impressionism [27]. It sought to express the meaning of "being alive" [108] and emotional experience rather than physical reality [108, 106]. It is the tendency of an artist to distort reality for an emotional effect; it is a subjective art form.
- **Les Fauves** [134] (French for The Wild Beasts) were a short-lived and loose grouping of early 20th century Modern artists whose works emphasized painterly qualities and strong colour over the representational or realistic values retained by Impressionism.
- **Figuration Libre** [135] (Free figuration) is a French art movement of the 1980s. It is the French equivalent of Bad Painting and Neo-expressionism in America and Europe, Junge Wilde in Germany and Transvanguardia in Italy. The term was coined by Fluxus artist Ben Vautier.
- **Folk art** [136] encompasses art produced from an indigenous culture or by peasants or other labouring trades people. In contrast to fine art, folk art is primarily utilitarian and decorative rather than purely aesthetic [112].
- **Futurism** was an art movement that originated in Italy in the early 20th century. It was largely an Italian phenomenon, though there were parallel movements in Russia, England and elsewhere. The Italian writer Filippo Tommaso Marinetti was its founder and most influential personality [137]. The Futurists admired speed, technology, youth and violence, the car, the

airplane and the industrial city, all that represented the technological triumph of humanity over nature, and they were passionate nationalists.

- **Graffiti** [138] (singular: graffito; the plural is used as a mass noun) is the name for images or lettering scratched, scrawled, painted or marked in any manner on property. Graffiti is sometimes regarded as a form of art and other times regarded as unsightly damage or unwanted. Graffiti is any type of public markings that may appear in the forms of simple written words to elaborate wall paintings.
- **Hard-edge** [139] painting is painting in which abrupt transitions are found between colour areas. Colour areas are often of one unvarying colour. Colour transitions often take place along straight lines, though curvilinear edges of colour areas are also common.
- **Hyperrealism** [141]. Hyperrealism is a genre of painting and sculpture resembling a high resolution photograph. Hyperrealism is a fully-fledged school of art and can be considered as an advancement of Photorealism by the methods used to create the resulting photorealistic paintings or sculptures.
- **Impressionism** [142] was a 19th-century art movement that began as a loose association of Paris-based artists exhibiting their art publicly in the 1860s. The name of the movement is derived from the title of a Claude Monet work, Impression, Sunrise (Impression, soleil levant). Characteristics of Impressionist paintings include visible brush strokes, open composition, emphasis on light in its changing qualities (often accentuating the effects of the passage of time), and ordinary subject matter, the inclusion of movement as a crucial element of human perception and experience, and unusual visual angles.
- **Lyrical Abstraction refers** to two related but distinctly separate movements in Post-war Modernist painting. European Lyrical Abstraction is an art movement born in Paris in 1945. The French critic Charles Estienne created its name in 1946.
- **Mannerism** [149] is a period of European art that emerged from the later years of the Italian High Renaissance around 1520. Mannerism encompasses a variety of approaches influenced by, and reacting to, the harmonious ideals and restrained naturalism associated with artists such as Leonardo da Vinci,

Raphael, and early Michelangelo. Mannerism is notable for its intellectual sophistication as well as its artificial qualities.

- **Minimalism** [151] describes movements in various forms of art and design, especially visual art and music, where the work is stripped down to its most fundamental features.
- **Modernism** [152], in its broadest definition, is modern thought, character, or practice. The term encompasses the activities and output of those who felt the "traditional" forms of art, architecture, literature, religious faith, social organization and daily life were becoming out-dated in the new economic, social and political conditions of an emerging fully industrialized world.
- **Naïve art** [155] is characterized by a childlike simplicity. (See also outsider art, to which it bears many similarities.) It is a gross oversimplification to assume that Naïve art is created by people with little or no formal art training**.**
- **Neoclassicism** [156] Neoclassicism is a revival of the styles and spirit of classic antiquity inspired directly from the classical period, which coincided and reflected the developments in philosophy and other areas of the Age of Enlightenment, and was initially a reaction against the excesses of the preceding Rococo style.
- **Op art** [157], also known as optical art, is a genre of visual art that makes use of optical illusions. "Optical Art is a method of painting concerning the interaction between illusion and picture plane, between understanding and seeing." [50].
- **Orientalism** [158] refers to the imitation or depiction of aspects of Eastern cultures in the West by writers, designers and artists. An "Orientalist" may be a person engaged in these activities, but it is also the traditional term for any scholar of Oriental studies.
- **Orphism** [159] or Orphic cubism is a term coined by the French poet Guillaume Apollinaire in 1912. He used the French term Orphisme to label the paintings of Robert Delaunay, relating them to Orpheus, the poet and symbol of the arts of song and the lyre in Greek mythology. Founded by Jacques Villon, the orphists were rooted in cubism but moved toward a pure lyrical abstraction, seeing painting as the bringing together of a sensation of bright colours.

- **Outsider art** [161] was coined by art critic Roger Cardinal in 1972 as an English synonym for art brut, a label created by French artist Jean Dubuffet to describe art created outside the boundaries of official culture; Dubuffet focused particularly on art by insane-asylum inmates [89].
- **Painterly** [162] is a translation of the German term malerisch, one of the opposed categories popularized by Swiss art historian Heinrich Wölfflin (1864 - 1945) in order to help focus, enrich and standardize the terms being used by art historians of his time to characterize works of art. The term painterly has been applied to styles such as Venetian painting (as opposed to the Florentine), Baroque (as opposed to Renaissance) and the Rubenistes (as opposed to the Poussinistes). An oil painting is "painterly" when there are visible brush strokes, and/or a rough impasto surface.
- **Photorealism** [164] is the genre of painting based on making a painting from a photograph. The term is primarily applied to paintings from the United States photorealism art movement that began in the late 1960s, early 1970s. More recently, a splinter art movement called hyperrealism has developed.
- **Pin striping** [165] is the application of a very thin line of paint or other material called a pin stripe, and is generally used for decoration. Freehand pin stripers use a specialty brush known as a pin striping brush. Fine lines in textiles are also called pin stripes.
- **Pointillism** [166] is a style of painting in which small distinct dots of colour create the impression of a wide selection of other colours and blending. Aside from colour "mixing" phenomena, there is the simpler graphic phenomenon of depicted imagery emerging from disparate points.
- **Pop art** [167] is a visual art movement that emerged in the mid 1950s in Britain and in the late 1950s in the United States [57]. Pop art challenged tradition by asserting that an artist's use of the mass-produced visual commodities of popular culture is contiguous with the perspective of fine art.
- **Postmodern art** [168] is a term used to describe an art movement which was thought to be in contradiction to some aspect of modernism, or to have emerged or developed in its aftermath. The traits associated with the use of the term postmodern in art include bricolage, use of words prominently as the

central artistic element, collage, simplification, appropriation, depiction of consumer or popular culture and Performance art.

- **Post-painterly Abstraction** [169] is a term created by art critic Clement Greenberg as the title for an exhibit he curated for the Los Angeles County Museum of Art in 1964, which subsequently travelled to the Walker Art Centre and the Art Museum of Toronto (which later became the Art Gallery of Ontario).
- **Precisionism** [166]**,** also known as Cubist Realism, was an artistic movement that emerged in the United States after World War I and was at its height during the inter-War period. The term itself was first coined in the early 1920s.
- **Realism** [173] in the visual arts and literature is the depiction of subjects as they appear in everyday life, without embellishment or interpretation. In its most specific sense, Realism was an artistic movement that began in France in the 1850s, after the 1848 Revolution.
- **Regionalism** [174] is an American realist modern art movement that was popular during the 1930s. The artistic focus was from artists who shunned city life, and rapidly developing technological advances, to create scenes of rural life.
- **Rococo** [176] (less commonly roccoco) is a style of 18th century French art and interior design. Rococo rooms were designed as total works of art with elegant and ornate furniture, small sculptures, ornamental mirrors, and tapestry complementing architecture, reliefs, and wall paintings.
- **Romantic realism** is an aesthetic term that usually refers to art combines elements of both romanticism and realism. Although the terms "romanticism" and "realism" have been used in varied ways, [98] they are typically seen as opposed to one another. Romantic realists combine elements from each tradition.
- **Romanticism** [178] is a complex artistic, literary, and intellectual movement that originated in the second half of the 18th century in Western Europe, and gained strength during the Industrial Revolution. The movement stressed strong emotion as a source of aesthetic experience, placing new emphasis on such emotions as trepidation, horror and awe—especially that which is

experienced in confronting the sublimity of untamed nature and its picturesque qualities, both new aesthetic categories.

- **Socialist realism** [182] is a style of realistic art which has as its purpose the furtherance of the goals of socialism and communism. Although related, it should not be confused with social realism, a type of art that realistically depicts subjects of social concern.
- **Street art** is any art developed in public spaces — that is, "in the streets" — though the term usually refers to unsanctioned art, as opposed to government sponsored initiatives. The term can include traditional graffiti artwork, stencil graffiti, sticker art, wheat pasting and street poster art, video projection, art intervention, guerrilla art, flash mobbing and street installations. Artists attempt to have their work communicate with everyday people about socially relevant themes in ways that are informed by esthetic values without being imprisoned by them. [184]
- **Stuckism [**185] is an international art movement that was founded in 1999 in Britain by Billy Childish (who left in 2001) and Charles Thomson to promote figurative painting in opposition to conceptual art.
- **Superflat** [186] is a postmodern art movement, founded by the artist Takashi Murakami, which is influenced by manga and anime [72]. The term is used by Murakami to refer to various flattened forms in Japanese graphic art, animation, pop culture and fine arts, as well as the "shallow emptiness of Japanese consumer culture."[44].
- **Surrealism** [187] is a cultural movement that began in the early 1920s, and is best known for the visual artworks and writings of the group members. Surrealist works feature the element of surprise, unexpected juxtapositions and non sequitur. Leader André Breton was explicit in his assertion that Surrealism was above all a revolutionary movement.
- **Tachisme** [200] was a French style of abstract painting in the 1940s and 1950s. It is often considered to be the European equivalent to abstract expressionism. The Cobra group artists are also related to Tachisme, as is Japan's Gutai group.
- **Tonalism** [201] (1880 to 1915) is an artistic style that emerged in the 1880s when American artists began to paint landscape forms with an overall tone of

coloured atmosphere or mist. Dark, neutral hues, such as grey, brown or blue, would usually dominate such compositions.

6.1.1.2.2 Eastern Art Styles

Eastern styles:

- **Chinese**
  - **Bird-and-flower painting** [122] is a kind of Chinese painting named after its subject matter. Normally, most bird-and-flower paintings belong to the scholar-artist style of Chinese painting. According Chinese tradition, bird-and-flower painting covers "flowers, birds, fish, and insects".
  - **Ink and wash painting** is an East Asian type of brush painting. Only black ink, the same as used in East Asian calligraphy, is used, in various concentrations. Wang Wei is generally credited as the painter who applied colour to existing ink wash paintings [143].
  - **Shan Shui** [180] refers to a style of Chinese painting that involves or depicts scenery or natural landscapes, using a brush and ink rather than more conventional paints. Mountains, rivers and often waterfalls are prominent in this art form.
  - During the **Ming Dynasty** (1368-1644), Chinese painting [150] developed greatly from the achievements in painted art during the earlier Song Dynasty and Yuan Dynasty. The painting techniques which were invented and developed before the Ming period became classical during this period. More colours were used in painting during the Ming Dynasty.
  - During the **Tang Dynasty,** as a golden age in Chinese civilization, Chinese painting developed dramatically, both in subject matter and technique [189].
  - The **Southern School** [183] of Chinese painting, often called "literati painting", is a term used to denote art and artists which stand in opposition to the formal Northern School of painting. Generally, Southern School painters worked in monochrome ink, and focused on expressive brushstrokes and a somewhat more impressionistic approach than the Northern School's formal attention to detail and use of colour and highly refined traditional modes and methods.

- **Wu School** [192] is the term applied to a group of painters of the Southern School during the Ming period of Chinese history, and was not an academy or educational institution, but instead was largely by artistic theory of its members. A Wu School painting is characterized by inscriptions describing either, the painting, the date, method, or reason for the work, which is usually seen as a vehicle for personal expression.
- The **Zhe School** [194] was a school of painters, and part of the Southern School, which thrived during the Ming dynasty. The school was not a school in the proper sense of the word in that the painters did not formulate a new distinctive style, preferring instead to further the style of the Southern Song.

- **Japanese**
  - **Emakimono** [132], often simply called emaki, is a horizontal, illustrated narrative form created during the 11th to 16th centuries in Japan. Emakimono combines both text and pictures, and is drawn, painted, or stamped on a hand-scroll. They depict battles, romance, religion, folk tales, and stories of the supernatural world. It is seen as the origin of modern manga.
  - The **Kanō** school [144] is one of the most famous schools of Japanese painting.The school's works are the paragons of Momoyama period art, and while most schools specialize in one style, medium, or form, the Kanō school excels at two. Kanō painters often worked on a large scale, painting nature scenes of birds, plants, water, or other animals on sliding doors or screens, covering the background with gold leaf. Some of the most famous examples of these can be found at the Nijō Castle in Kyoto.
  - **Rimpa** [175], is one of the major historical schools of Japanese painting. It was created in 17th century Kyoto by Hon'ami Kōetsu (1558-1637) and Tawaraya Sōtatsu (d. c.1643). Roughly fifty years later, the style was consolidated by brothers Ogata Kōrin and Ogata Kenzan.
  - The **Shijō** school [181], also known as the Maruyama-Shijō school, was an offshoot school of the Maruyama school of Japanese painting founded by Maruyama Ōkyo, and his former student Matsumura Goshun in the late 18th century. The school's style focuses on a Western-influenced objective realism, but achieved with traditional Japanese painting techniques.

- **Yamato-e** [193] is a style of Japanese painting inspired by Tang Dynasty paintings and developed in the late Heian period. It is considered the classical Japanese style. The Yamato-e often tells narrative themes with text along with them, show the beauty of nature.

- **Korean**
  - **Korean painting** [146] includes paintings made in Korea or by overseas Koreans on all surfaces. It includes art as old as the petro-glyphs through post-modern conceptual art using transient forms of light. Calligraphy rarely occurs in oil paintings and is dealt with in the brushwork entry, Korean calligraphy.
- **Islamic**
  - **Ottoman Miniature** [160] was an art form in the Ottoman Empire, which can be linked to the Persian miniature tradition [25] as well as strong Chinese artistic influences. It was a part of the Ottoman Book Arts together with illumination (tezhip), calligraphy (hat), marbling paper (ebru) and bookbinding (cilt). The words taswir or nakish were used to define this art in Ottoman language. The studios they worked in were called Nakkashane.
  - A **Persian miniature** [163] is a small painting, whether a book illustration or a separate work of art intended to be kept in an album of such works. The techniques are broadly comparable to the Western and Byzantine traditions of miniatures in illuminated manuscripts, which probably had an influence on the origins of the Persian tradition. Although there is an equally well-established Persian tradition of wall-painting, the survival rate and state of preservation of miniatures is better, and miniatures are much the best-known form of Persian painting in the West.
- **Indian**
  - The **Bengal** School of Art [121] was an influential style of art that flourished in India during the British Raj in the early 20th century. It was associated with Indian nationalism, but was also promoted and supported by many British arts administrators.
  - **Madhubani** painting [148] or Mithila Painting is a style of Indian painting, practiced in the Mithila region of Bihar state, India. Madhubani

painting has been done traditionally by the women of villages around the present town of Madhubani (the literal meaning of which is forests of honey) and other areas of Mithila. The painting was traditionally done on freshly plastered mud wall of huts, but now it is also done on cloth, hand-made paper and canvas.

- **Mughal** painting [153] is a particular style of Indian painting, generally confined to miniatures either as book illustrations or as single works to be kept in albums, which emerged from Persian miniature painting, with Indian Hindu, Jain, and Buddhist influences, and developed during the period of the Mughal Empire (16th -19th centuries).
- **Mysore** painting [154] is an important form of classical South Indian painting that originated in the town of Mysore in Karnataka. These paintings are known for their elegance, muted colours, and attention to detail. The themes for most of these paintings are Hindu gods and goddesses and scenes from Hindu mythology.
- **Rajput** painting [172], a style of Indian painting, evolved and flourished during the 18th century in the royal courts of Rajputana, India, flowing from the style of Mughal painting, itself derived from the Persian miniature. Rajput paintings depict a number of themes, events of epics like the Ramayana and the Mahabharata, Krishna's life, beautiful landscapes, and humans.
- **Samikshavad** [179] is the first indigenous Art movement in modern India, which started in north India in 1974. It has a different identity from the western movements of art. It is neither affected nor inspired by the western art. Its main source of inspiration is the present social, political, cultural and economical conditions. By this style, the artist tends to expose the corruption prevalent in the society and politics, with a language that is symbolic and satirical.
- **Tanjore** painting [190] is an important form of classical South Indian painting native to the town of Thanjavur in Tamil Nadu. Tanjore Paintings are known for their surface richness, vivid colours and compact composition. Essentially serving as devotional icons, the themes of most of these paintings are Hindu gods and goddesses, and saints as well.

6.1.1.3 Art and religion

In terms of religion art can be classified as follows:

- **Christian Art [38]**
  - **Catholic Art**
    - Church Architecture
    - Fresco
    - Paintings
    - Stained Glass
    - Sculptures.
  - **Orthodox Art**
    - Church Architecture
    - Icons: paintings that follow a specific style
    - Stained Glass. Sculptures are forbidden: Raised relief metal on an icon is not forbidden
  - **Protestant Art**
    - Church Architecture
    - Stained Glass

6.1.1.4 Material used on Visual Arts

In terms of material used for creating art:

- **Paints:** Acrylic Paints, Watercolour Paints, Oil Paints, Coloured Pencil, Pen and Ink, Soft Pastels, Hard Pastels, Oil Pastels, Graphite, Chalks, Charcoal, Tempera
- **Colours:** Naples Yellow, Lemon Yellow, Cadmium Yellow Pale, Chrome Lemon, Cadmium Yellow, Chrome Yellow, Cadmium Yellow Deep, Chrome Orange ,Cadmium Orange, Chrome Orange Deep, Vermillion, Cadmium Red Light, Cadmium Red, Cadmium Red Deep, Permanent Geranium, Scarlet Lake, Crimson Alizarin, Carmine, Napthol Crimson, Rose Madder, Permanent Magenta, Cobalt Violet, Permanent Mauve, French Ultramarine, Permanent Blue, Cobalt Blue, Phthalo Blue, Prussion Blue, Cerulean Blue, Prussian Green, Phthalo Green, Hookers Green, Viridian, Emerald Green, Sap Green,

Terre Verte, Yellow Green, Permanent Light Green, Yellow Ochre, Raw Sienna, Buff Titanium, Flesh Tint, Light Red, Venetian Red, Indian Red, Burnt Sienna, Raw Umber, Burnt Umber, Vandyke Brown, Payne's Grey, Ivory Black, Lamp Black, Flake White, Titanium White, Zinc White, Mixing White, Under painting White

- **Painting mediums:** Gesso, Mod Podge, PVA, Texture Paste, Gel Medium, E-6000, Polymer Medium, Crystal Lacquer, Painting medium, Glassing Medium, Poppy oil, Linseed oil
- **Painting surfaces:** Canvas, Panel, Watercolour paper, Pastel paper, Sketch book
- **Brushes**
    - **Brush types:** Colour Shapers, Varnishing Brush, Cheap Decorating , Brush/Stencil Brush, Filbert Brush, Round Brush, Flat Brush, Rigger Brush / Liner Brush, Mop Brush, Fan Brush
    - **Brush hair type**: Badger Hair, Camel Hair, Hog Bristle, Kevrin/Mongoose Hair, Kolinsky Sable, Ox Hair, Pony Hair, Red Sable, Zibeline, Squirrel Hair, Synthetic

6.1.1.5 Visual art techniques

In terms of the techniques used for creating art:

- Impasto, scrambling, glazing, cross hatching, pointillism, wet on wet, wet on dry, collage, dry brush, fat over lean, feather lines, frottage, grading, abstraction, sponge technique, tonking, wash off, broken colour, breaks

This indicative list of data to be classified must be further enriched with information such as:

- Historical information
    - Creation date (estimated or actual)
    - Artist
    - Style (cubism, impressionism etc.)
    - Current available at (museums, galleries)
- Information about art itself

- Techniques used (glassing, texturing)
- Meaning of art
- Social or political context

6.1.2 Ontology bindings to Specific qualities found in art creations

6.1.2.1 The Alphabet of Art

In this section the main axes that form the alphabet of art are presented in order to get an insight on the basic tools that every artist uses when creating art for achieving the underling meaning that he wishes to convey through his creativity. At the same time, the fundamental principles that affect the way that art is perceived by people shall be analysed focusing on understanding the invisibles lines existing between subject matter, artist's intentions and viewer interpretation. It is argued that a deeper understanding of the aforementioned issues can allow modern technology not only to coexist with, but also facilitate the creation of art. The Alphabet of Art was developed by the late Robert J. McKnight, a sculptor, designer, and theoretician of art. McKnight believed that the historical development of communication systems paralleled the development of the senses in the individual. Just as a new-born child orients itself to the world first by touch, then hearing, and only later by eyesight, so objective systems of communication developed in that order. First was the numerical system, based on our fingers and the sense of touch. Next was the alphabet, based on our sense of hearing. McKnight saw the evolution of a visual notation system as the next logical step—hence the Alphabet of Art [202]. This visual notation system can be used for presenting and/or inferring information about an art object based on the manual specification or the computerised extraction of such information from an art object. The Alphabet of Art is made up of Elements (Line, Line Direction, Shape, Size, Texture, Value, and Colour) and Attributes that are defined as the qualities that the art or design conveys to the observer. In any notation system there must be a method of making comparisons. In the Alphabet of Art, the Elements and Attributes are viewed as having a range of contrast, from minimum to maximum. The range of contrast provides the ground for making visual comparisons and judgments. Table summarizes the entire Alphabet of Art.

PRINCIPLE	Maximum Contrast	Minimum Contrast
ELEMENTS	-	-

Line (see Table 3)	**Curved**	**Straight**
	Emotionally Active Aesthetically dynamic Spatially in depth	Emotionally passive Aesthetically decorative Spatially static
Line Direction (see Table 4)	**Diagonal**	**Horizontal or Vertical**
	Emotionally Active Aesthetically dynamic Spatially in depth	Emotionally passive Aesthetically decorative Spatially static
Shape (see Table 4	**Naturalistic**	**Geometric**
	Emotionally Active Aesthetically dynamic Spatially in depth	Emotionally passive Aesthetically decorative Spatially static
Size (see Table 6)	**Large**	**Small**
	Emotionally Active Aesthetically dynamic Spatially in depth	Emotionally passive Aesthetically decorative Spatially static
Texture (see Table 7)	**Rough**	**Smooth**
	Emotionally Active Aesthetically dynamic Spatially in depth	Emotionally passive Aesthetically decorative Spatially static
Value (see Table 8)	**Light, Dark**	**Greyed**
	Emotionally Active Aesthetically dynamic Spatially in depth	Emotionally passive Aesthetically decorative Spatially static
Colour (see Table 9)		
Hue	**Primary**	**Secondary**
	Emotionally Active Aesthetically dynamic Spatially in depth	Emotionally passive Aesthetically decorative Spatially static
Chroma	**Strong**	**Weak**
	Emotionally Active Aesthetically dynamic Spatially in depth	Emotionally passive Aesthetically decorative Spatially static
Value	**Light, Dark, Bright**	**Grey, Dull**
	Emotionally Active Aesthetically dynamic Spatially in depth	Emotionally passive Aesthetically decorative Spatially static
Composition (see Table 10**)**	**Asymmetrical**	**Symmetrical**
	Emotionally Active Aesthetically dynamic Spatially in depth	Emotionally passive Aesthetically decorative Spatially static
ATTRIBUTES		
Emotional	Active	Passive
Aesthetic	Dynamic	Decorative
Spatial	In Depth	Static

Table 2: Minimum and Maximum Contrast for each Element and Attribute

Attributes	Usage
○ A curved line is dynamic, ever changing. It has more contrast than a straight line and it is more naturalistic. ○ The straight line is more monotonous, has less contrast, and is more static in character.	Architects use the straight line to simplify building requirements. ○ The dynamic qualities of the curved line can be combined with the decorative qualities of the straight line by using a curved line with a continuous ratio so that it becomes repetitive and, therefore, decorative. ○ Putting horizontal lines in the bottom of a picture, vertical lines in the middle, and diagonal lines at the top increases the decorative quality of line by its multiple, repeated use.

Table 3: Attributes and usage of "Line"

Attributes	Usage
○ The diagonal line has no equal in visual intensity. It suggests depth or movement. The periphery of the eye is very sensitive to movement or to any diagonal. ○ The horizontal line is less visually intense than the diagonal and has less impact than the diagonal. Vertical and horizontal lines infer a static or decorative visual condition.	○ Parthenon in Athens is said not to have a straight line in it. In fact, curved lines are used in many cases to make the straight lines appear straighter. For example, there are three terraces at the bottom of the Parthenon. If they were not curved, they would appear to sag, as they are three inches higher in the middle than at the ends. The builders of the Parthenon placed all the horizontal lines at the bottom, the vertical lines in the middle and the diagonal lines at the top. This creates a decorative design by making the lines appear all on one plane. ○ Many modern artists have experimented with the effects of line direction. Among the most important is Piet Mondrian. By showing how to eliminate the diagonal line, he showed the way to a whole new concept of art. He said, "Any object can be interpreted in terms of horizontals and verticals

Table 4: Attributes and usage of "Line Direction"

Attributes	Usage
○ Geometric shapes express minimum contrast and are thus more decorative than naturalistic shapes. Multiple or repeated use of geometric shapes increases and enhances their decorative effects. ○ In a landscape, naturalistic shapes, such as trees, usually predominate in contrast to manmade, geometric shapes, such as houses	○ One way of making a geometric shape more decorative or less contrasting is to employ the Golden Mean Rectangle. ○ Marcel Duchamp's famous painting, "A Nude Descending a Staircase" shows the repeated use of geometric shapes. The multiple use of the same geometric shape was not only decorative, but demonstrated how a painting could show movement.

Table 5: Attributes and usage of “Shape”

Attributes	Usage
○ Large size makes things appear near and of greater importance ○ Small size makes things appear far away or less important.	○ Carol Cloar used Size in his painting "My Father Was as Big as a Tree" by painting the father large in the foreground and the tree farther away in the middle ground. Because the father is so large, he appears to be as big as the tree. ○ Leonardo da Vinci, who never painted a picture unless it was to illustrate an intellectual point, illustrates the Element of Size in the "Mona Lisa." The lady occupies the foreground while the landscape in the middle ground is moved to the background by making it smaller than it would normally appear to be imposing the lady on the faraway landscape

Table 6: Attributes and usage of “Size”

Attributes	Usage
○ Surfaces with rough texture are seen as more dynamic, emotionally active, and as having more depth.	○ Vincent Van Gogh used it successfully, making texture both a colour and design quality in his paintings. ○ The Medici Palace in Florence, Italy, is a fine example of texture in architecture. The first floor exterior of the three-story building is rough. The second story exterior employs the use of medium rough textures, and the top exterior story of the building is of smooth texture. In this example, rough texture suggests strength and smooth texture suggests lightness. ○ Rough and smooth also had psychological implications for the Egyptians. In the Great Pyramid the rough path to the rough room is considered to be Hell, while the smooth path to the smooth room is evidently Heaven.

Table 7: Attributes and usage of "Texture"

Attributes	Usage
○ Strong contrast and generally dark value implies mystery. ○ Less contrast and high values are used for happiness. ○ Maximum contrast of Value (dark and light) places objects in the foreground of a picture. Minimum contrast (grey) places objects in the background.	○ Rembrandt in the "Night Watch," he used light values for what he wanted the viewer to see, and kept the other parts of the picture in dark values. He created a dramatic effect by the maximum use of Value, in which the light comes from the figure of a child. ○ Grey is the opposite of strong contrast in Value. Grey is used to show distance, and to modify distant naturalistic forms, as in Oriental painting. In interior decoration, grey can be used to provide a more spacious feeling, especially when combined with cool colours.

Table 8: Attributes and usage of "Value"

Attributes	Usage
○ Hue is the name of the colour: red, blue, etc. ○ Chroma is the amount of intensity in a colour, whether it is intensely strong, intensely weak, or somewhere in between. ○ Value is the brightness or dullness of a colour, the amount of light in the colour.	○ Painters who want a decorative sign could paint all of the colours at the same value or intensity by using a scientific formula. ○ There has also been some study of the way colour affects how people feel and how the retina of the eye reacts to colour. ○ An application of this is the fact that doctors wear green in the operating room to rest their eyes from red. This has to do with the way the retina reacts to those two colours. ○ Hospitals sometimes put depressed people in warm-coloured rooms to make them feel less depressed and over stimulated people in cool-coloured rooms to aid in quieting them down.

Table 9: Attributes and usage of "Colour"

Attributes
○ A symmetrical composition is balanced, and has an overall equality of Size, Shape, Line, Line Direction, Texture, Value, and Colour ○ An asymmetrical composition is not balanced and does not use the Elements in equal amounts. It is not divisible into equal parts. It uses dissimilar Elements which are not often repeated.

Table 10: Attributes and usage of "Composition"

6.1.2.1 Using the alphabet for knowledge retrieval

The knowledge stemming from the usage of the art vocabulary for annotating artefacts is important for allowing the inference of facts about the artefacts without the need of providing explicit annotations (annotations that are designed so as to use an artefact in a specific manner). In this sense an artefact can be described using this vocabulary in the form presented in Table 11. Having annotated a large collection of artefacts an interactive application will be able to query the knowledge base to retrieve for examples objects that are emotionally active and aesthetically pleasant. In

this sense it would be for example easy to infer which objects are appropriate to be presented by a digital painting within a living room.

	**Line:** Curved (Emotionally Active, Aesthetically dynamic, Spatially in depth) **Shape:** Naturalistic (Emotionally Active, Aesthetically dynamic, Spatially in depth) **Texture:** Rough(Emotionally Active, Aesthetically dynamic, Spatially in depth) **Colour:** Primary (Emotionally Active, Aesthetically dynamic, Spatially in depth) **Composition:** Asymmetrical (Emotionally Active, Aesthetically dynamic, Spatially in depth)

Table 11: A subset of the vocabulary used to describe Starry Night by Vincent Van Gogh

6.2 Ontology meta-models

This section present the building blocks of the ontology backbone of the system. More specifically, three ontology meta-models are presented: (a) The Art Ontology that models all the required knowledge for presenting and using visual Art, (b) The User Profile ontology that carries out the task of representing Users and this attributes and abilities and (c) the context ontology undertaking the job of representing the proposed smart environments both in terms of space and available devices.

6.2.1 Extending CIDOC CRM: The Art Ontology

In the context of this research work the implementation of the CIDOC Conceptual Reference Model [366] (CIDOC CRM) has been extended to meet the needs for creating the Art meta-model. The Erlangen CRM / OWL is an interpretation of the CIDOC CRM in a logical framework attempting to be as close as possible to the text of the specification. The main class of the Art Ontology employed by this research work is the “Art” class, defined to present all art forms, and is specialised by the “VisualArt” class that represents all the possible variations of art forms meant to appeal the eyes. In the same context the “ArtPeriod” class represents distinctive periods of artistic creation while the “ArtStyle” class provides a globalised representation of art based on different cultures. The “Artefact” class is used to represent actual artistic creations and is specialised by classes such as “painting” and “sculpt”. Finally the artefact composition initiates the process of understanding the

underlined principles that rule a specific artistic creation. A visual representation of this group of classes as extensions of the Erlangen CRM / OWL model is presented in Figure 53.

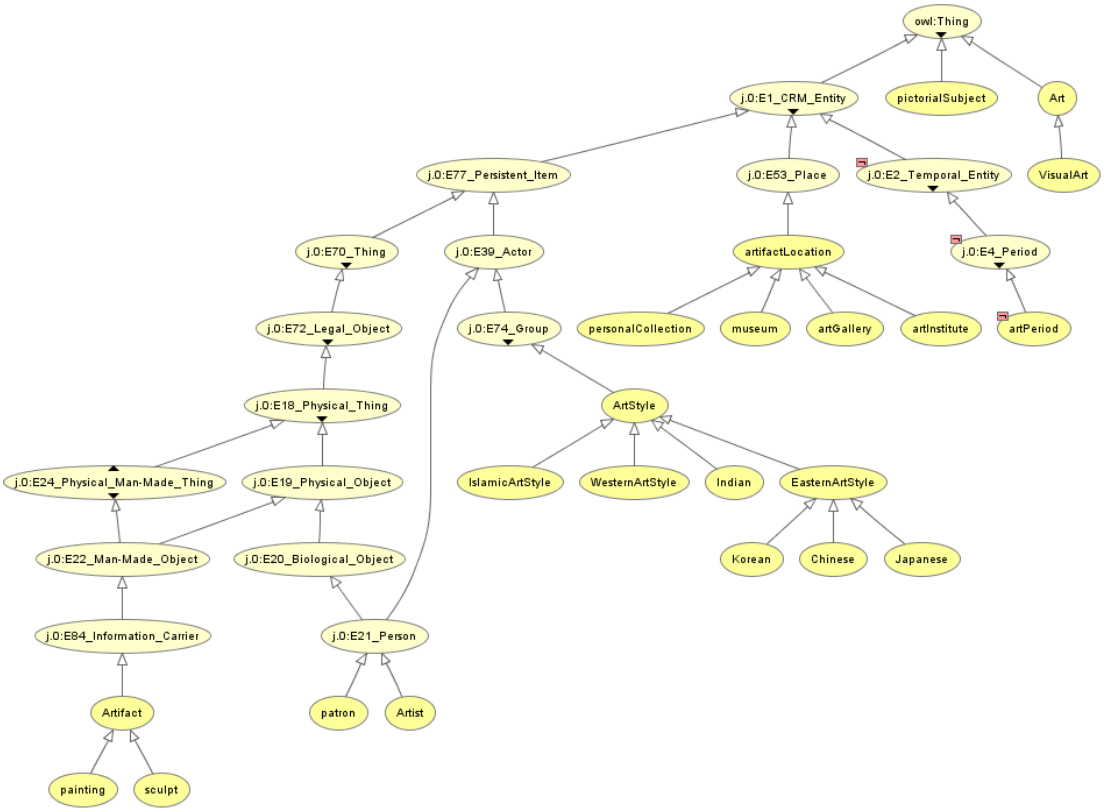


Figure 53: Ontology based representation of artefacts

In this process of understanding and thus representing artistic creations Colour plays a fundamental role. The “Paints” class represents all the different types of paints used in artistic creation while “PigmentPaints” class and its specializations are used to define pigment paints of specific manufacturer and type together with its digital representation in various colour spaces as this is defined in the “ColorSpaces” class. The fragment of the ontology dealing with colour is presented in Figure 54.

Figure 54: Representation of Colours and Paints used in Art

Paints are rarely applied as is on a painting surface. The "paintingMediums" class is used to present all these types of mediums used to dilute or alter the consistency and effects produced by a pigment. The "Surfaces" class is used to represent the support used for producing an Artefact. Surfaces are particularly important both in artistic creation and in our understanding of artistic creation (for example canvas is more suitable for large compositions while wood panels are suitable for smaller compositions). The "Techniques" class represents the methods used by artists for applying pigments on a surface (as shown in Figure 55). The technique itself can alter the visual results achieved by the artists (for example it is difficult to achieve transparencies by laying down transparent layer of paint when a "wet on wet" technique is applied). At the same time image ratio is important in artistic creation but even more important when an artefact is intended to be presented in its digital form.

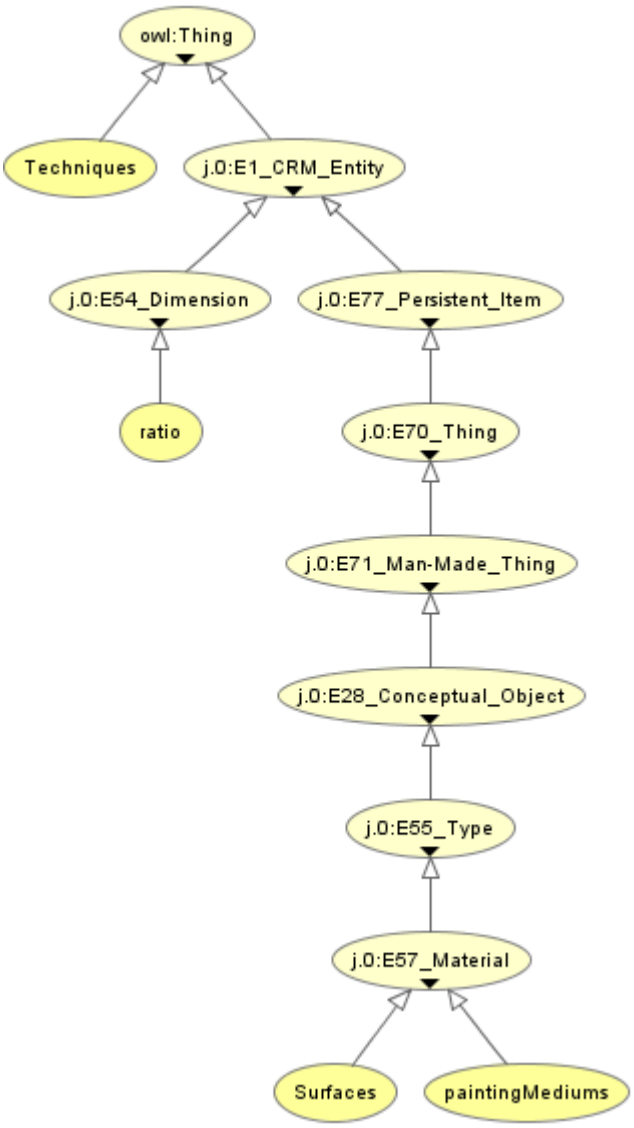


Figure 55: Techniques used in art creation and popular image ratios

Brushes are an important tool for painting. Accomplished artists use different shapes of brushes and different filaments according to the effect they wish to achieve. The "BrushTypes" class represents all the possible variations that brushes can take based on their shape while "BrushHairTypes" represent the filament used. The type of the brush together with its filament is used by the "Brushes" class for represented actual brushes with specific qualities and attributes (for example a cat's tongue brush has different qualities when sable hair is used or when a hog bristle hair is used). The ontology fragment dedicated to brushes is presented in Figure 56.

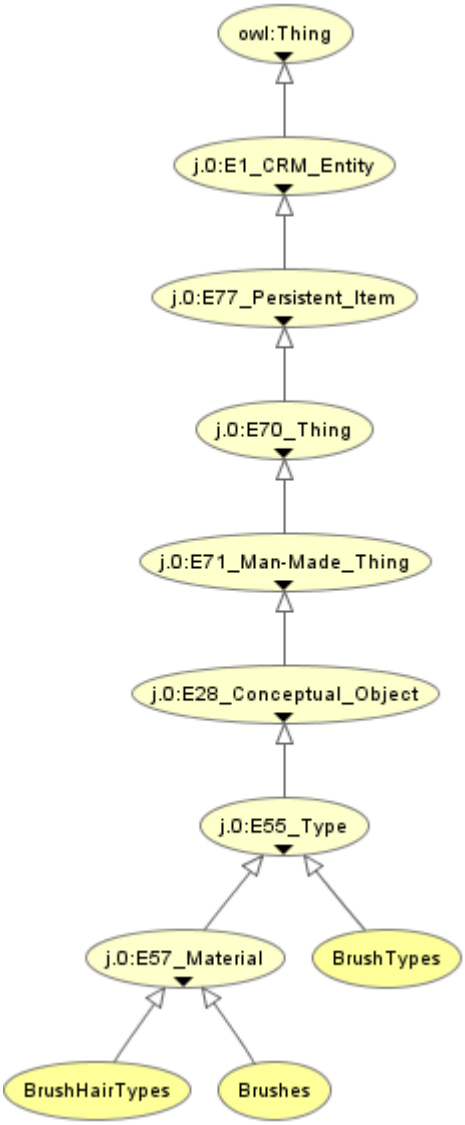


Figure 56: Ontology based representation of Artist's Brushes

In section 5.1.2 a specification of an alphabet to act as the means of understanding artistic creation has been defined. This vocabulary is represented through the classes "artVocabularyAttribute" and "artVocabularyTerm". The "artVocabularyAttribute" class is further specialised by classes that represent the emotional aesthetic and spatial qualities of an artefact. At the same context "artVocabularyTerm" class is specialised by classes that represent the collection of terms used in this vocabulary (colour hue, line, line direction etc.). The vocabulary of artistic concepts is presented in Figure 57.

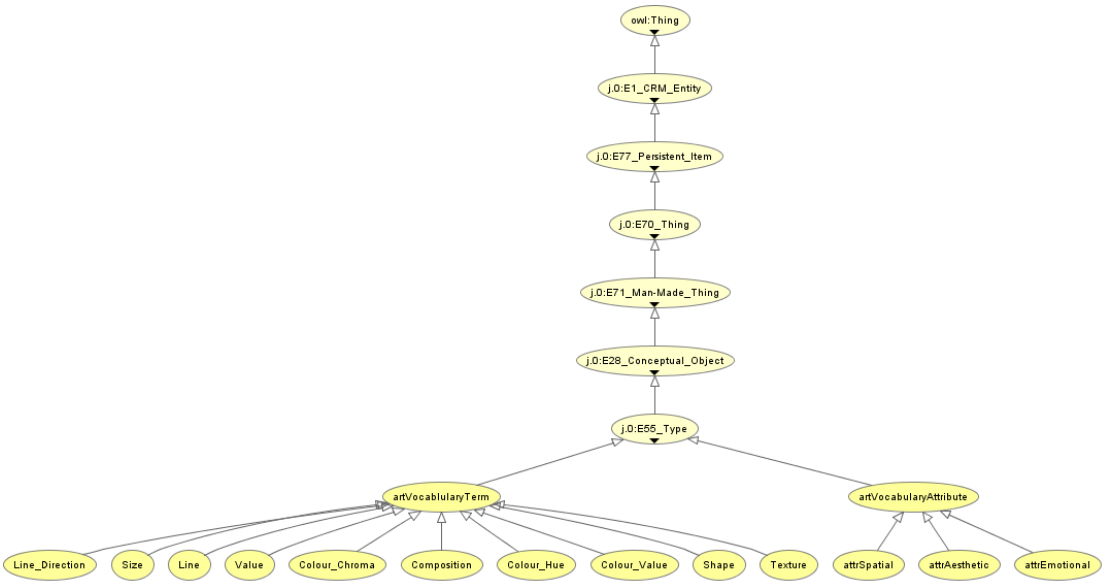


Figure 57: Representation of the Art Vocabulary

This vocabulary is further enriched with attributes that refer most to subjective understanding of an artefact than to its everlasting qualities. To this end "pictorialSubject" class is used to define what is the subject depicted by an artefact (e.g. is it a landscape or is it a mythological scene?). Classes such as "weather", "wealth" and "timeoftheday" introduce subjective knowledge to the ontology (e.g. this painting shows a storm or is it just raining?). Finally, this subjective understanding of art is further enriched by trying to define the motivated or non-motivated functions of an artefact and thus trying to interpret Artist's intentions (see Figure 58).

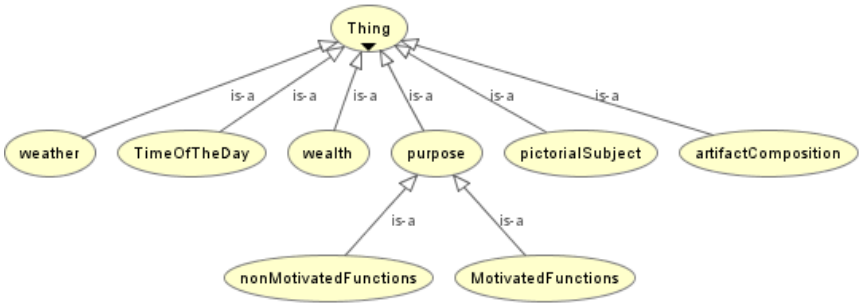


Figure 58: Classes Used for Image Annotation

6.2.2 The User Profile meta-model

The ontology meta-model employed by this research work is an extension of the User Profile Ontology [345] created in the context of Cloud4All [346]. This User Profile Ontology has been extended in the context of this research work to support the

activities, devices and interaction metaphors supported through the developed environments. The rationale for selecting to extend the User Profile Ontology created in the context of Cloud4All was based on the need to maintain cloud based user profiles that could be transferred between contexts and at the same time being capable to address the adaptation and personalisation needs of a multitude of applications. To this end the need for application specific preferences was also required so as to cope with the diversity of the implemented applications. The basic ontology structure to together with the extensions introduced by this research work is presented in Figure 59.

Figure 59: The extended User Profile Ontology

At the same time the core of the aforementioned ontology copping with the process of modelling all the aspects of user's interaction with interactive applications has been

transferred as is. This fragment of the ontology that represents users and profiles in is presented in Figure 60.

Figure 60: Users and User Profiles

6.2.3 The Context Ontology

The Context Ontology models all the required contextual information for allowing: (a) the representation of the proposed smart environments in terms of space and (b) the mapping of Devices into space. Figure 61 presents the hierarchy of Devices supported by the proposed smart environments. Devices are grouped into four main categories: (a) Input Devices, (b) Output Devices, (c) Sensors and (d) Lighting devices as shown in Figure 61.

Figure 61: The context ontology: Devices

Moving to the context itself (see Figure 62) three smart environments are defined: (a) Smart Homes, (b) Ambient Workshops and (d) Exhibitions. To model these environments lower level concepts are used such as Levels (e.g. Smart home first Level), Rooms (e.g. Ambient Workshop's Model's Plane), Walls (e.g. South wall of Model's plane) etc.

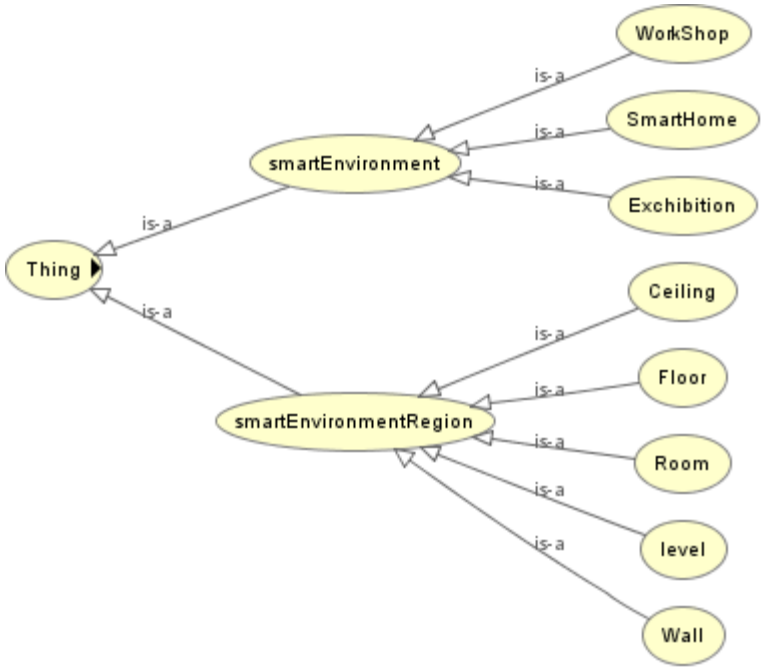


Figure 62: The context ontology: Smart Environments

6.3 Artefact annotation for using Art in the context of Smart Environments

The Art Ontology meta-model is strongly interconnected with the concept of annotations. These annotations are considered by this research work fundamental for allowing the knowledge to be manipulated in different contexts for different purposes and by different users, thus copping with diversity in a number of levels.

6.3.1 The Annotation Strategy

Image processing techniques are used for performing automated analysis of context received from various sources (a local file system, the internet, photos of artefacts just taken in a museum visit, etc.) in order to extract artistic concepts. Colour histogram processing techniques are used to determine the predominant colour scheme of a painting and for semi-automatic classification of pictorial subject (blues and sea-greens for classifying seascapes, earth browns and green for landscapes etc.). Colour palette information (primary, complementary etc.) is useful for identifying art styles. Computer vision is also of importance for classifying pictorial subjects, especially in the case of portraiture. Techniques used for identifying faces in images are used for allowing the classification of portraits and group portraits (based on the number of identified faces).

Regarding manual annotation as already stated an initial dataset has been produced via manual annotation by experts and the further population of knowledge is conducted through on demand annotation by end users. The on demand annotation scheme facilitates profile knowledge to adapt the annotation strategy to the expertise of the each specific individual and is used for the introduction of subjective user based knowledge in the ontology. At the same time annotations by end users (as shown in Table 12) are used in the context of ontology based inference for producing knowledge that populates user profile with domain specific attributes (favourite artists, periods, styles etc.). The complete set of available annotations is presented in Table 12.

Annotation scheme	
Novice User	Time of the day, Wealth-social status, Weather, Like or dislike etc.
Art lover	Artist, Art period, Art Style, Pictorial subjects, Like or dislike etc.
Art historian – teacher	Artist, Art period, Art Style , All attributes contained in the Art Vocabulary, Techniques, Artefact Location, Patrons, Purpose, Pictorial subjects, Surfaces, Time of the day, Wealth-social status, Weather etc.
Artist	Artist, Art period, Art Style, Techniques, Brushes, Colour pigments, Painting Mediums, Pictorial subjects, Surfaces etc.

Table 12. Annotation scheme based on User Expertise

Ontology of Artistic Concepts		
Art	Visual Art	Drawing, Printmaking, Photography, Filmmaking, Painting, Computer art, Sculpture
Artefact	Painting, sculpt, photo, movie, engraving	
Artefact Location	Art gallery, museum, personal collection	
Artist		
Art period	Pre-Historic, Ancient, Medieval, Renaissance, Romanticism, Modern Contemporary	
Art Style	Eastern	Chinese, Japanese, Korean
	Islamic	
	Western	
Art Vocabulary	Line	Curved, Straight
	Line	Diagonal, Horizontal or Vertical

	Direction	
	Shape	Naturalistic, Geometric
	Size	Large, Small
	Texture	Rough, Smooth
	Value	Light, Dark, Greyed
	Hue	Primary, Secondary
	Chroma	Strong, Weak
	Value	Light, Dark, Bright ,Grey, Dull
	Composition	Asymmetrical, Symmetrical
	Predominant colour	
Brushes	Type	Fans, Filberts etc.
	Hair Type	Synthetic, natural etc.
Colour pigments	Blacks, Blues, Browns, Greens, Oranges, Reds, Violets, Whites, Yellows	
Painting Mediums	Linseed oil, walnut oil, poppy oil, Glassing medium, Flemish medium, Black oil etc.	
Paints	Oils, Acrylics, Pastels, Charcoal etc.	
Patrons		
Purpose	Motivated	Entertainment, propaganda, psychological – healing, Communication etc.
	Non-motivated	Human instinct, imagination, ritualistic etc.
Pictorial subjects	Genre, historical, landscape, seascape, portraiture etc.	
Ratio	Four to three, nineteen to nine etc.	
Surfaces	Canvas, panel, paper, sketch book etc.	
Techniques	Impasto, collage, broken colour, glazing, wet on wet, wet on dry etc.	
Time of the day	Morning, noon, evening, night	
Wealth-social status	Very poor, poor, rich, very rich etc.	
Weather	Snow, rain, cloudy, hail, drizzle, tornado etc.	

Table 13. The full set of available annotations

6.4 Knowledge Management

6.4.1 Knowledge in Digital format

This section presents the way that the annotation infrastructure presented in this chapter is employed by interactive applications that allow end users to locate resources, annotate the based on their profile and integrate the resulted knowledge to the model. In this section the life cycle of knowledge within the implementation architecture is presented. More specifically, three main tasks have been identified and are related to (a) retrieval of material from a number of alternative sources, (b) automatic and manual annotation of the retrieved knowledge in order for such knowledge to be imported to the ontology and (c) retrieval of knowledge from the ontology (see Figure 63).

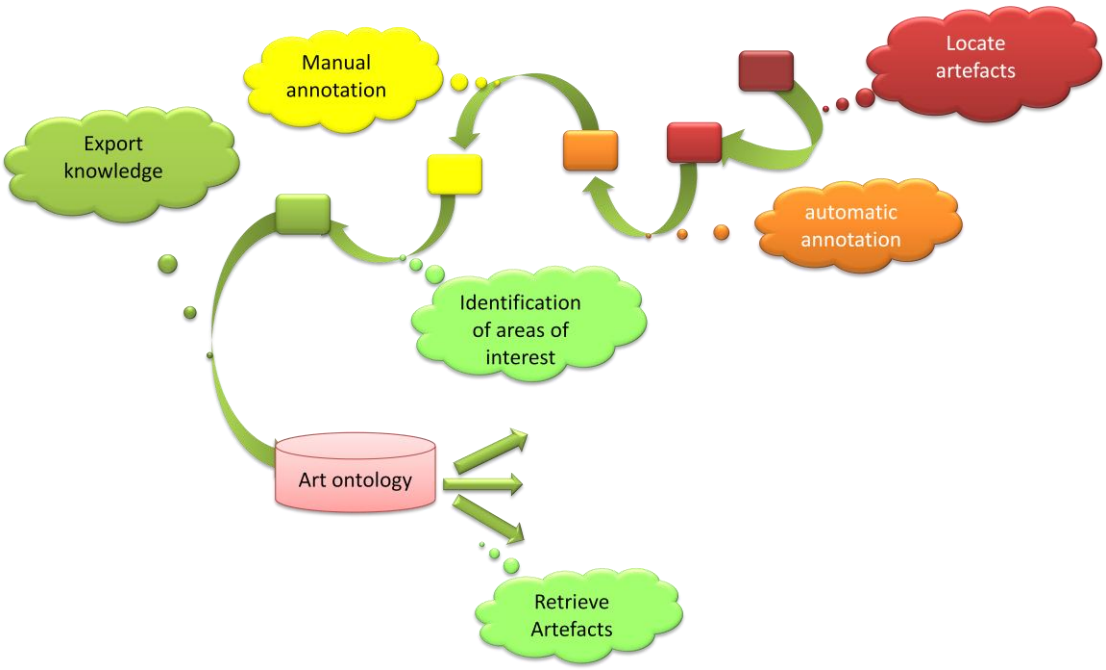


Figure 63: The knowledge life cycle

In the next sections three interactive applications are presented that facilitate the presented life cycle. More specifically the “Artefact Locator” undertakes the task of locating material, the “Artefact Annotator” facilitates the annotation of material and the “ontology Browser” can be used for previewing the inserted information from the ontology.

6.4.1.1 The "Artefact Locator"

Locating Artefacts in a distributed Ami environment can be considered as important as annotating them. In such an environment Artefacts can be located over the internet, on a mobile phone, or in a shared distributed file system (the Ami file system). The "Artefact Locator" is designed to perform searches in these potential sources for retrieving Artefacts and is interconnected to the "Artefact Annotator" for allowing the integration of such knowledge to the ontology (after producing the annotations). Figure 64 presents the "Artefact Locator" after performing a keyword search. The selection of a result provides users with the option to load the recovered artefact to the "Artefact Annotator" preview the artefact on a screen or store the artefact to be used in the future.

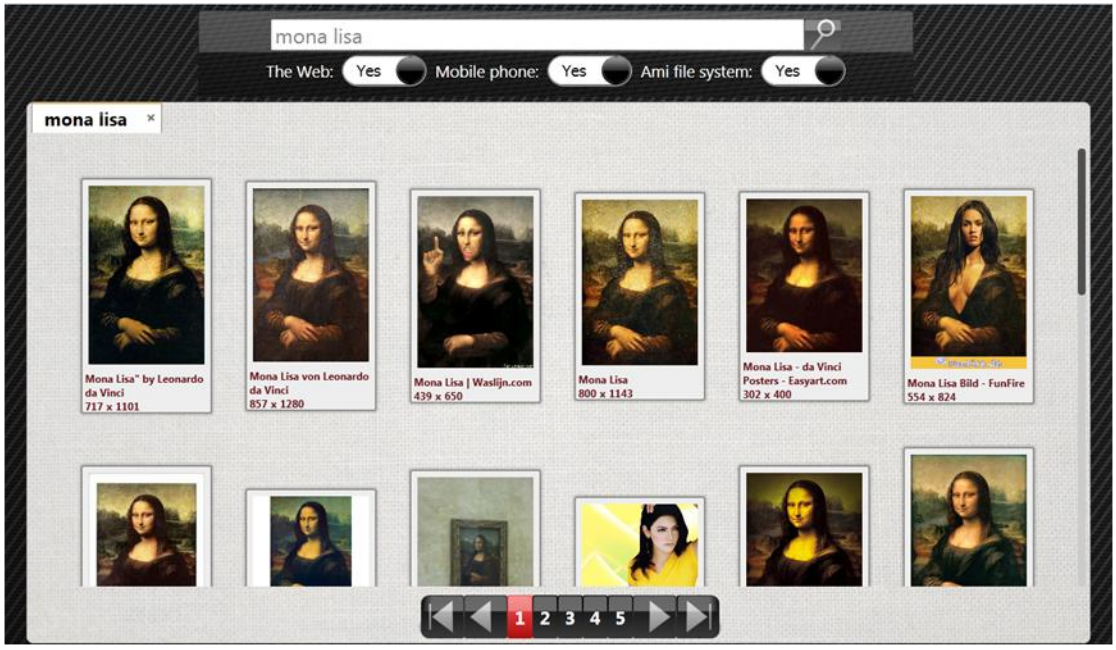


Figure 64: The "Artefact Locator"

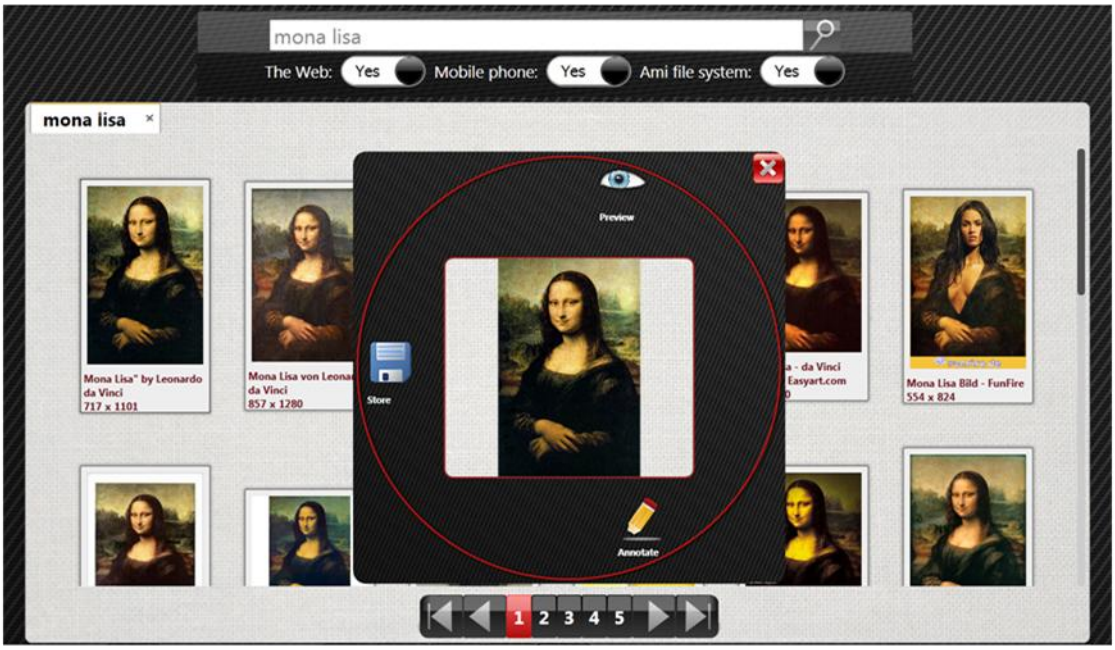


Figure 65: Selecting an image for annotation

Table 14 presents the implementation details of the "Artefact Locator" application.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service • "artServer" service • "webSearch" Service
Ami Services implemented	• "artClient" service
Libraries Used	• "AmiForArtUIToolkit" • "ColorSpaces"
Hardware supported	• Microsoft PixelSense – Samsung SUR-40 • Desktop pc with touch screen
Interaction Schemes	• Multi Touch

Table 14. Implementation details for the "Artefact Locator"

6.4.1.2 The "Artefact Annotator"

The "Artefact Annotator" is designed to facilitate the annotation scheme presented in the previous section, for allowing users to enrich the knowledge contained in the ontology. Interaction with this prototype is initiated by loading an artefact that should

be annotated in order to be integrated to the ontology. This can be achieved either by selecting an item from the local file system or locating an item through a UI search service such as the "artefact Locator". The loading process initiates a number of image processing algorithms in order to infer a number of artistic concepts automatically (such as predominant colour, colour hue etc.) as presented in Figure 66. According to the User Profile users have the option to annotate the loaded artefact according to the annotation strategy presented in the previous section (see Figure 67). Finally, using ink the areas of interest can be identified and a textual description can be attached to each area (see Figure 68). After completion of the annotation the new knowledge can be stored in the ontology and subsequently extracted by all the presented prototypes.

Figure 66: Loaded material to "Artefact Annotator" prototype

Figure 67: Annotation based on User Profile

Figure 68: Identifying areas of interest

Table 15 presents the implementation details of the "Artefact Annotator" application.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service • "predominantColourCalculator"

Ami Services implemented	• "artClient" service
Libraries Used	• "AmiForArtUIToolkit" • "ColorSpaces" • "PigmentColorMixing" • "ColourSpaceOperations"
Hardware supported	• Microsoft PixelSense – Samsung SUR-40 • Desktop pc with touch screen
Interaction Schemes	• Multi Touch & ink

Table 15. Implementation details for the "Artefact Annotator"

6.4.1.3 The "Ontology Browser"

The "Ontology Browser" together with "Artefact Annotator" and "Artefact Locator" form the task force that allows end user's regardless from their user profile to browse the ontology, find artefacts to be added in the ontology and enrich the ontology with artefact upon their annotation. The initial screen of this prototype gives access to a number of collections each of which represents an alternative way of extracting data from the ontology (for example extract data based on their annotations, colour schemes, their creator etc.). The "Ontology Browser" is shown in Figure 69.

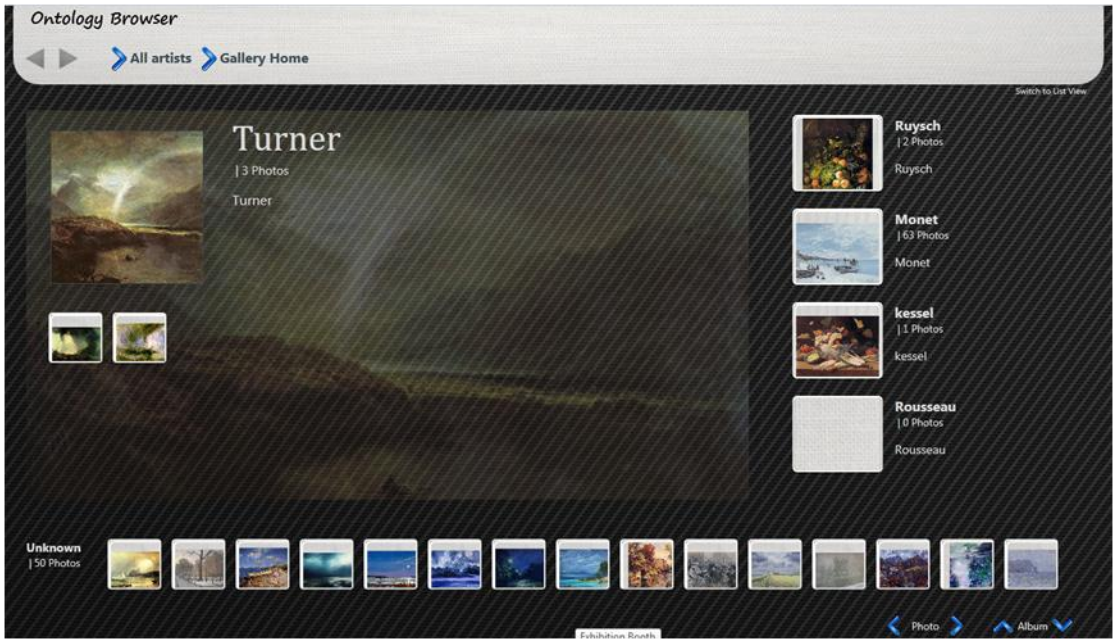


Figure 69: The "Ontology Browser"

Table 16 presents the implementation details of the "Artefact Annotator" application.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231] • PhotoSuru syndication sample [234]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service
Libraries Used	• "AmiForArtUIToolkit"
Hardware supported	• Microsoft PixelSense – Samsung SUR-40 • Desktop pc with touch screen
Interaction Schemes	• Multi Touch

Table 16. Implementation details for the "ontology Browser" Prototype

6.4.2 Knowledge generated through Art Creation

Based on the architecture employed by this research work all the applications participating in the Art Creation activities have the ability to log important for Art Creation information to the ontology. Information that is extracted from monitoring these applications includes: (a) the painting supplies used (paints, canvases, brushes, mediums etc.), (b) the way that the composition was arranged (objects arrangement, lighting and framing details), (c) the actual painting process etc. All these steps are accompanied with additional information such as photos taken by the artist representing important intermediate steps, notes kept by the artist etc. This information is used together with the Artist profile to populate the information about an Artefact. On a second level the process presented in the previous section can be used in order to incorporate user based annotations to the recorded knowledge. The result of this process is the generation of knowledge for using the produced artefacts both within museums but also in the context of application and games for smart living spaces. The interactive application responsible for receiving such and logging such application is the "Diary or a masterpiece" presented in section 8.1.3.1.

7 System architecture

7.1 High Level System Architecture

In the context of a distributed ambient environment, system architectures become fuzzier mainly due to the fact that services distributed in the environment have their internal architecture and structure while the way that services are incorporated and used forms another higher level architecture. A generic abstract view of the architecture employed by this research work is presented in Figure **70**. For the knowledge part of the architecture three ontology meta-models were developed: (a) The Art Ontology that models all the required knowledge for presenting and using visual art, (b) The User Profile ontology that carries out the task of representing users, attributes and preferences and (c) the context ontology undertaking the job of representing the proposed smart environments both in terms of space and available devices. Based on these ontologies specifications class libraries have been generated to support direct integration into various development platforms as long as integration with the middleware and access through web services. This complex knowledge infrastructure is required to address all the potential deployment strategies of the knowledge layer. At the same time IIS-Apache web servers are deployed both to host the generated web services but also for providing seamless access to other critical for the applications data such as multi-scale representations of artefacts. The computer vision and media infrastructure builds on a number of image processing libraries, device drivers and SDKs to provide a number of important features such as a collection of image processing filters, blob detection and tracking using Kinect, raw

image processing, gestures and postures tracking. Both the knowledge and Computer vision infrastructure is used by the service oriented middleware to support the usage of these facilities within a distributed environment. The suite of interactive applications build on top of these layers facilitates a common UI framework created specifically for art creation in order to achieve the maximum reusability of controls and UI components. To this end a number of alternative technologies have been employed for addressing the needs of various application platforms and devices (Windows Presentation Foundation, Silverlight for windows phones, Surface SDK and XNA framework). The developed applications use a common service oriented communication protocol for allowing them to communicate, cooperate and interact in the context of application scenarios. At the same time these applications have access to a number of facilities through the middleware such as knowledge extraction services, interaction metaphors (e.g. Gestures) etc. These applications can request from the content personalisation layer to adapt the provided content based on the profile of the user currently accessing them while the scenario manager is responsible for organising the way that the suite of applications collaborates and adapts to user actions in the context of application scenarios. The UI Adaptation – reasoning engine integrates a decision making component responsible for generating UI and scenario based adaptations. These adaptations occur by running rule sets on a rules engine provided by the Windows Workflow Foundation.

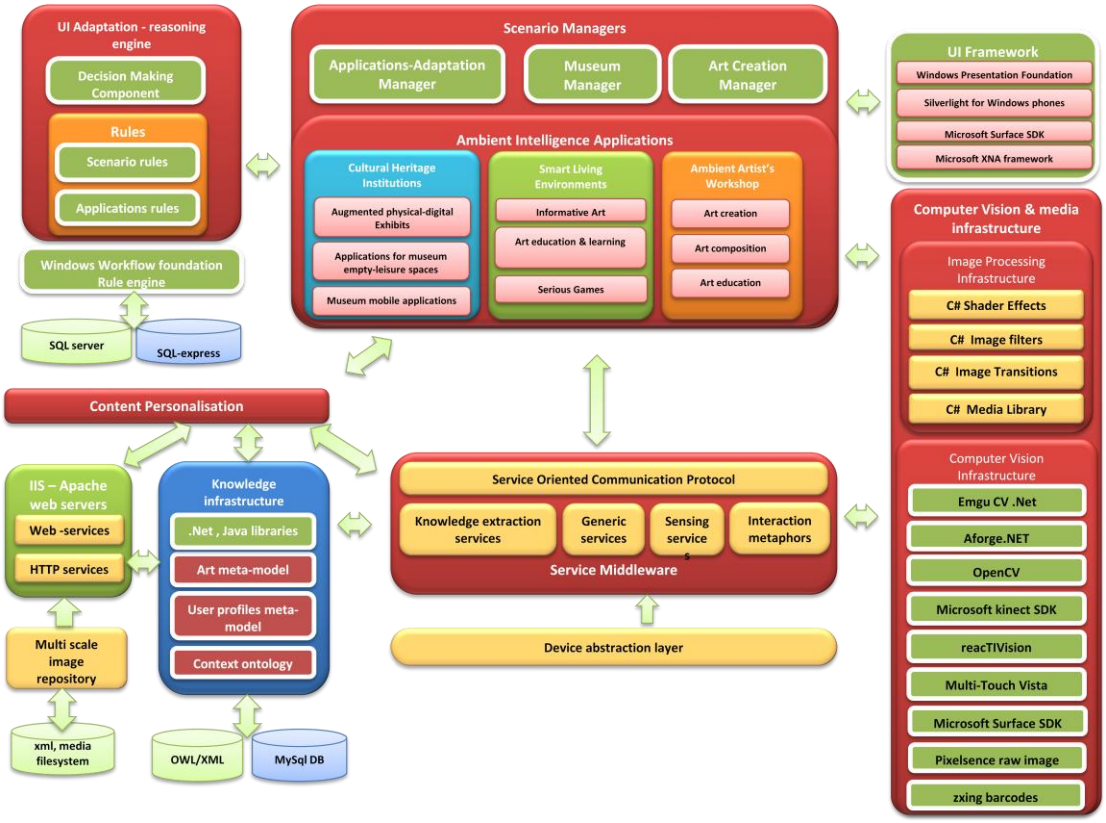


Figure 70: Abstract service oriented architecture

Each of the aforementioned layers of the abstract architecture presented above will be presented in depth in the following sections.

7.2 The Knowledge Layer

An important part of each system is the way that knowledge is handled. To this end, the sub architecture of the system that carries out the task of data handling is presented. As shown in Figure **71**, the lower level of the architecture is the ontology. Although the structure of the ontology is modelled using OWL the actual data are stored either in an XML/OWL format or in a MySQL relational database. Three ontology models have been created to support the representation of artefacts, the modelling of users accessing the environment and the context of use. These models are exported to the higher levels of the architecture through a set of programming language classes developed either manually using c# either automatically exported by the protégé [330] data export facilities. At the same time using the Jess [331] reasoning engine rules have been defined on these knowledge models and applied at runtime by the user and context reasoner. Two sparql query engines have been

defined in top of the knowledge models one that uses the SemWeb.Net library [328] and the other one using Jena [327] and Pellet [326]. These query engines submit SPARQL queries to the ontology while the results of these queries are retrieved in XML and deserialised into meaningful instances of the model. The knowledge infrastructure is exposed to different programming languages and tools in five alternative ways: (a) as a Famine service for allowing access from all deployed services, (b) as an IIS and an Apache Tomcat web service to be used by applications not running on Famine but with support for web services and (c) as a class library both in .Net and Java for direct integration and usage by applications. At the same time the multi scale image repository stores the multi scale representation of artefacts in extremely large size (giga-pixels). These representations (clever partitioning of images for each supported resolution) are stored in the file system together with their xml representations and served to interactive applications through an IIS server. Finally the aforementioned Knowledge Layer architecture provides all the required facilities for plugging-in a ontology reasoning engine in java using the Jess reasoner.

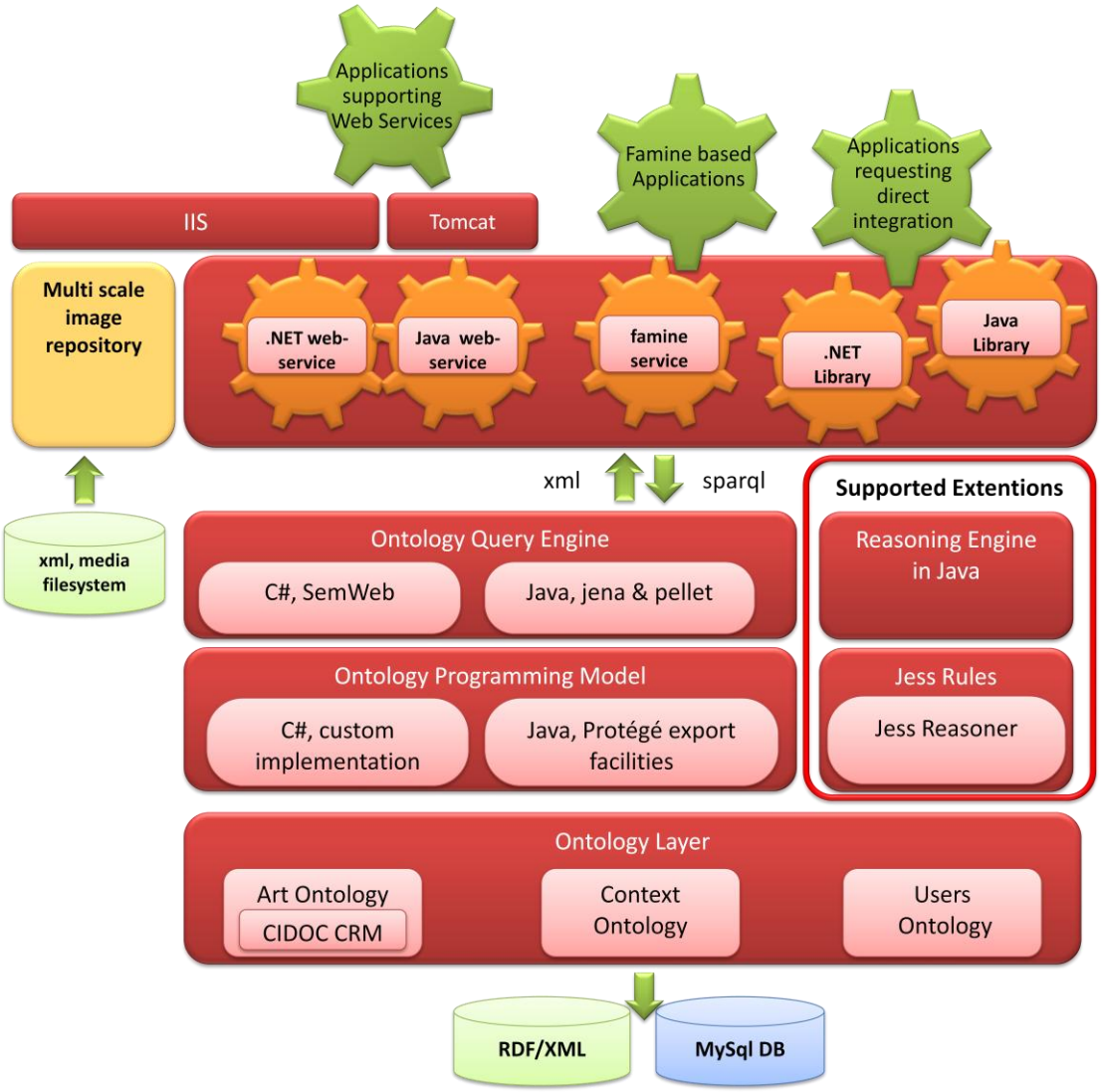


Figure 71: The Knowledge Layer

7.3 The Device Abstraction Layer

The Device Abstraction Layer carries out the integration with a number of devices, such as environmental monitoring sensors, augmented physical objects for user interaction, cameras for object and user tracking, motion tracking sensors, skeleton tracking devices, etc. To accomplish such integration, a number of device drivers are integrated in order to have control over the deployed hardware. For interconnecting such drivers to the overall architecture, services has been created and imported in the service oriented architecture (allowing applications developed into various platforms to access a high level specification of devices in a way that exposes only control functionality and hides the internal aspects of device driver's implementation). Based on the aforementioned device infrastructure, the interaction techniques are being built.

To this end, an Interaction Library of Services has been developed capable of supporting novel forms of interaction including user tracking, hand tracking, gestures, touch-based interaction and shape recognition, input and output through augmented physical objects. Implicit interaction techniques such as localization, gaze tracking and posture recognition are also explored. The majority of the above techniques are built using mainstream devices, keeping the cost as low as possible. As presented in the following figure in the lowest level of the interaction infrastructure reside the Devices and Device Drivers which are exported through low-level services (services that are not related with specific system input or output but provide functionality to other services). These low level services are in turn used to form higher level services responsible for User Interaction and Sensing.

7.4 Computer Vision & Media Infrastructure

The "Computer Vision & Media" is a very important part of the architecture for allowing the interactive applications developed in the context of this research work to produce a number of desired results. At the lower level of this infrastructure the computer vision infrastructure manipulates two main libraries the OpenCV library through its .Net wrapper and the Aforge Image processing library. The computer vision infrastructure is used by the Image processing Infrastructure. In this layer the c# image filters employ the computer vision infrastructure to develop artistic operators while the shader effects library is used for creating artistic operators that are processed by the gpu. The media infrastructure is used for manipulating content through HD web-cams, while the colour manipulation infrastructure carries the tasks of transforming colour spaces and colour mixing. On top of this infrastructure several facilities are built such as physical media digitisation, colour mixing, image filtering, media transition and blob tracking. Especially for the blob detection facilities which are considered important for performing blob recognition to support multi touch on surfaces the contribution to this research work of Mr. Panagiotis Koutlemanis was essential together with the active support of Dr. Xenophon Zaboulis. In the same context Emmanouel Zidianakis was very helpfull into integrating these vision facilities with the reacTIVision [352] tracker and the Multi-Touch Vista library [353] in order for the augmented painting surface to be enriched with multi touch capabilities.

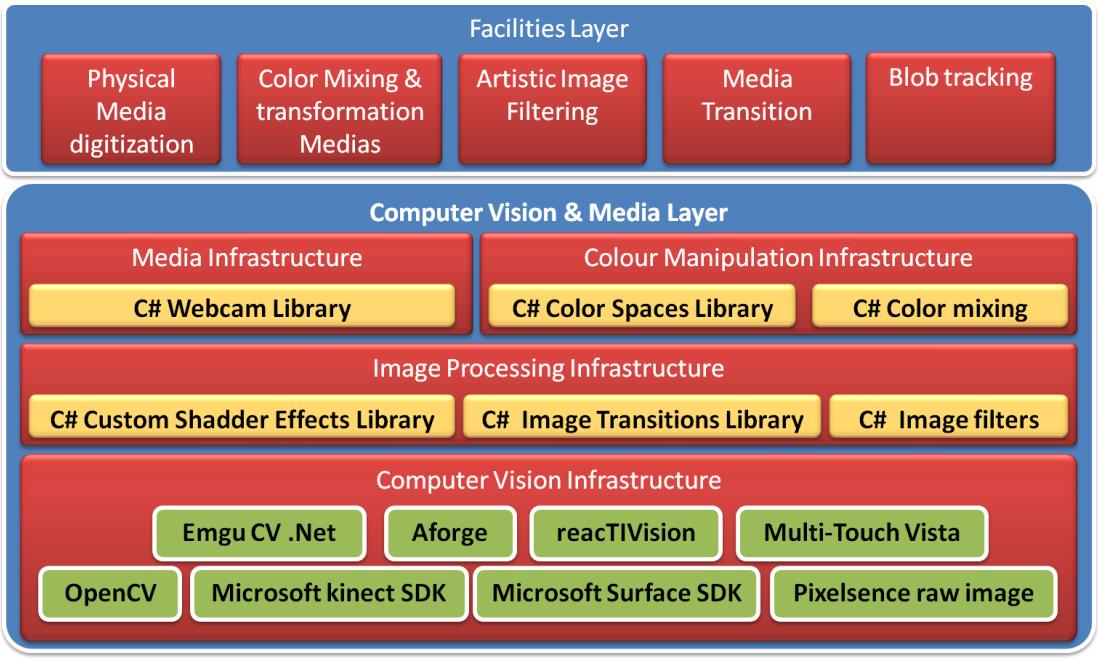


Figure 72. The Computer Vision & Media Infrastructure

7.5 The services middleware

In terms of the service oriented middleware this research work is build using tiered services. As presented in Figure **73**, the lower level of services deployed in the Famine middleware carries out the task of listening to sensors, devices controlling light etc. This layer of services can be considered as a functional layer. The High level services play an important role mainly because they support the main functionalities of the system apart for context monitoring and control.

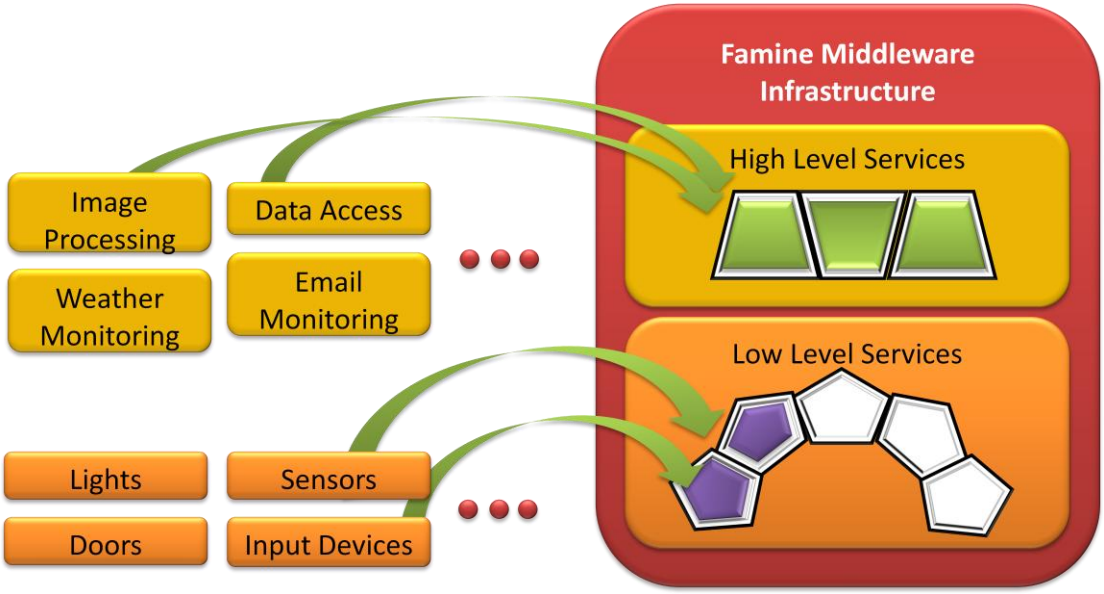


Figure 73: Overview of the service oriented architecture

7.6 The service oriented communication protocol

The service oriented communication protocol provides a common dialect for applications to communicate. In this context the general types of services that have been defined is “artClient”, “artServer”, “artCreationLogger” and “museumLogger”. The “artClient” service is implemented by all the UI applications participating into application scenarios while the “artServer” service is implemented by the scenario – adaptation manager. The UI applications implementing the “artClient” service listen to events produced by the “artServer” service while the scenario – adaptation manager implementing the “artServer” service listens to events coming from all instances of the “artClient” service. The “artCreationLogger” service is implemented by all the applications participating to the art creation process. In this sense all these applications log important states of art creation. This knowledge is used to populate the ontology representation of a painting under development so as to achieve its preservations and its presentation in the context of interactive exhibits. On the other hand the “museumLogger” service is implemented by applications running in the context of Cultural Heritage Institutions in order to log the interaction of users with artefacts.

More specifically the “artClient” service exposes two types of events:

- RequestAction: This event is fired when the application wishes to request something to happen in the context of an application scenario
- StatusNotification: This event is fired when the application wishes to report status changes

The interface implemented by all interactive applications that participate into application scenarios within the various implemented spaces is presented in the following code block.

```
interface artClient {
//
        // Events
        //
        /* Implemented by:   art Components      */
        /* Used by:          art Reasoner        */

        void Event_RequestAction          (in EventArg arg);
        void Event_StatusNotification     (in EventArg arg);
    };
```

The "artServer" service is implemented by the scenario – adaptation manager and used by all the interactive applications. It supports three types of events:

- DeviceCommand: This event is fired when the "artServer" commands a device driver to perform a specific task
- ApplicationCommand: This event is fired when the "artServer" commands an application to perform a specific task
- LogAction: This event is fired when the "artServer" commands the scenario logger to log specific events

The interface implemented by the scenario – adaptation manager is presented in the following code block.

```
interface artServer {

        //
        // Events
        //
        /* Implemented by:    art Reasoner   */
        /* Used by:           art Components          */
        void Event_DeviceCommand        (in EventArg arg);
        void Event_ApplicationCommand   (in EventArg arg);

        /* Implemented by:    Components   */
        /* Used by:                Logger        */
        void Event_LogAction            (in EventArg arg);
    };
```

Finally the interfaces implemented by logging applications and used by application that wish to log information are presented in the following code block. Both support the same event:

- *LogAction*: This event is fired when applications wish to log information

```
/* Implemented by:    Components          */
/* Used by:           Diary of a masterpiece*/
interface artCreationLogger {

        void Event_LogAction                (in EventArg arg);

};

/* Implemented by:    Exchibits           */
/* Used by:           House logger*/
interface museumLogger {

        void Event_LogAction                (in EventArg arg);

};
```

The arguments of the events exchanged between the applications participating in the context of application scenarios are presented in the following code blocks. These arguments contain information about the context where the event is generated so as to be related with a location modelled in the context ontology, the device and application that generated the event, the inferred state generated by the reasoner as a result of running logic based on event values. Finally information is contained about the application that the event should be processed and the actual data of the event.

```
struct EventValue{
        //The type of the value
        EventValueType          type;
        //Storage for boolean
        boolean                 bool;
        //Storage for number
        long                    number;
        //Storage for string
        string                  str;
        //Storage for string params
        string                  str_parms;
};

struct EventArg
{
    //The area where the event took place
    smartArea           area;
    //The device where the event took place
    DEVICE_ID           device;
    //Infered state as a result of reasoning
    INFERED_STATES      state;
    //Application event source
    APPLICATION_ID      application;
    //Application event destination
    APPLICATION_ID      application_dest;
    //Event value
    EventValue          value;
};

//Contextual representation of the event source
struct smartArea
{
    string              smartEnvironment;
    string              smartEnvironmentLevel;
string              smartEnvironmentRoom;
string              smartEnvironmentRoomLocation;
string              smartAreaLocationContext;
};

//Event value types
enum EventValueType
{
    BOOL,
    NUMBER,
    TEXT,
    LIST
};
```

```
enum DEVICE_ID{
                    ART_CREATION_SPACE_VISUAL,
                    ART_CREATION_SPACE_RIGHT_VISUAL,
                    …
                    WORKSHOP_TABLET,
                    SURFACE_UNIT
          };
enum INFERED_STATES{
                    ///DESIGN
                    WS_ARTIST_IN_DESIGN_SPACE,
                    WS_ARTIST_IS_CREATING_A_COMPOSITION,
                    ///ART CREATION
                    WS_ARTIST_IN_ART_CREATION_SPACE,
                    WS_ARTIST_IS_PAINTING,
                    …
                    //AUGMENTED PAINTING
                    EX_AUGMENTED_PAINTING_FULL,
                    EX_AUGMENTED_PAINTING_EMPTY,
                    NONE
          };
enum APPLICATION_ID
          {
                    APP_Reasoner,
                    APP_MeetingSpace,
                    …
                    APP_LifeOfAMasterpiece,
                    APP_cameraComposition,
          }:
```

The communication is facilitated through the provision of definitions such as: **Application contexts:** the context used by services for registering themselves with the middleware. This is used for allowing the routing of events to the appropriate application within the scenario as shown in the following code block.

Device contexts: the context used for determining contextual information regarding the deployment of applications

Message header: pre-defined message header for allowing quick and error free parsing of application requests and commands

Inferred states: for allowing applications to easily identify an inferred state as produced through user and context reasoning

Data structures: for simplifying the definition and propagation of event data between applications

Figure 74 presents the role of the service oriented communication protocol in the context of application scenarios. As shown in this figure all the interactive

applications implementing the ArtClient services use the functionality of this service to submit their requests in the application-adaptation manager. These requests, together with the status notifications are used by the reasoned for evaluating the rule set of the scenario. The results of this evaluation are decisions regarding adaptations that should occur. These adaptations are submitted per application with the help of the artServer service as device and application commands. At the same time important events that should be stored to the ontology are propagated to the appropriate applications through the usage of the logging interfaces.

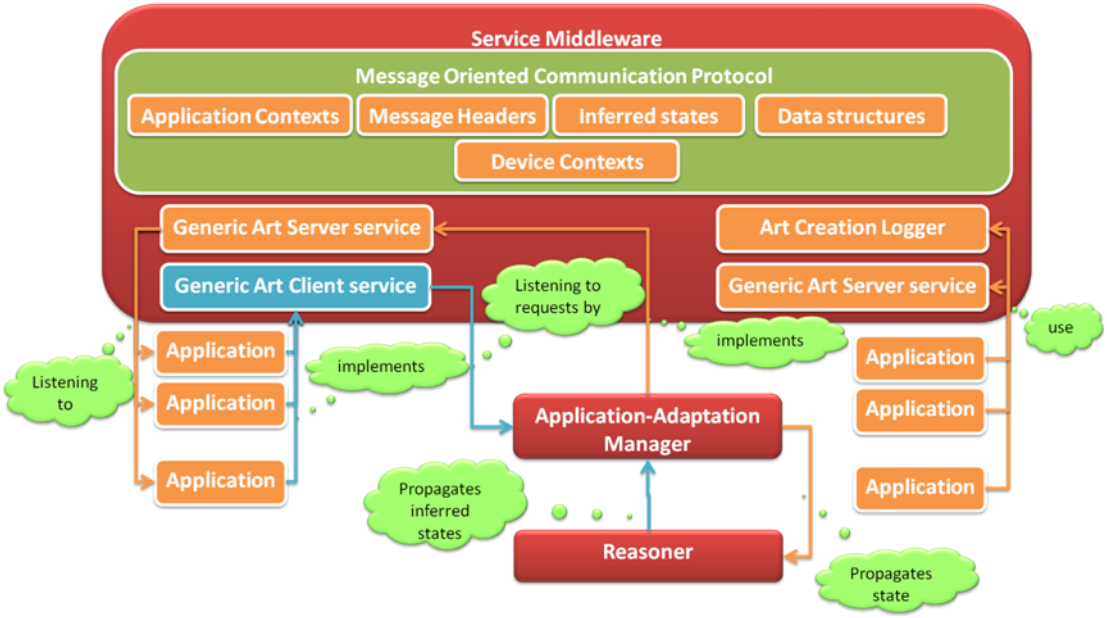


Figure 74: The service oriented communication protocol

7.7 Interaction and content adaptation and personalisation

The applications developed in the context of this research work are built to provide an adaptive and personalisable the user experience (including both interaction and content). The parameters used for adaptation and personalisation are user and context characteristics represented in the respective profiles, artefact characteristics represented in the Art Ontology, as well as monitoring data captured at run-time during the system use. To this end the necessary reasoning infrastructure to take adaptation and personalisation decisions have been developed. The Context Reasoner takes decisions regarding the selection of the devices to be used (from the collection of the available deployed devices), the sensors to be polled, and the applications to be deployed based on contextual information. The User Reasoner, on the other, hand is responsible for deriving contextual knowledge about the user (i.e, determining which

tasks are currently being carried out by the users, which position the user currently occupies, and so on), based on the parameters obtained from the sensors.

The outcome of this process is facts about the state of users and the context that will lead applications to adapt their behaviour. The Adaptation Manager is responsible for taking the final adaptation decisions. The Adaptation Manager gets informed about the facts produced by the User & Context Reasoners (for example the users is in front of a physical painting, within the area where localised information can be presented and has aligned his cardboard with the floor therefore more information should be presented). Based on this information, the Adaptation Manager takes adaptation decisions and issues commands to the applications to perform specific actions (for example the Augmented Physical Painting Application is commanded by the Adaptation Manager to stop tracking gestures from the user and initiate the personalised presentation of information within the cardboard). The overall decision-making life cycle is summarized in the following figure.

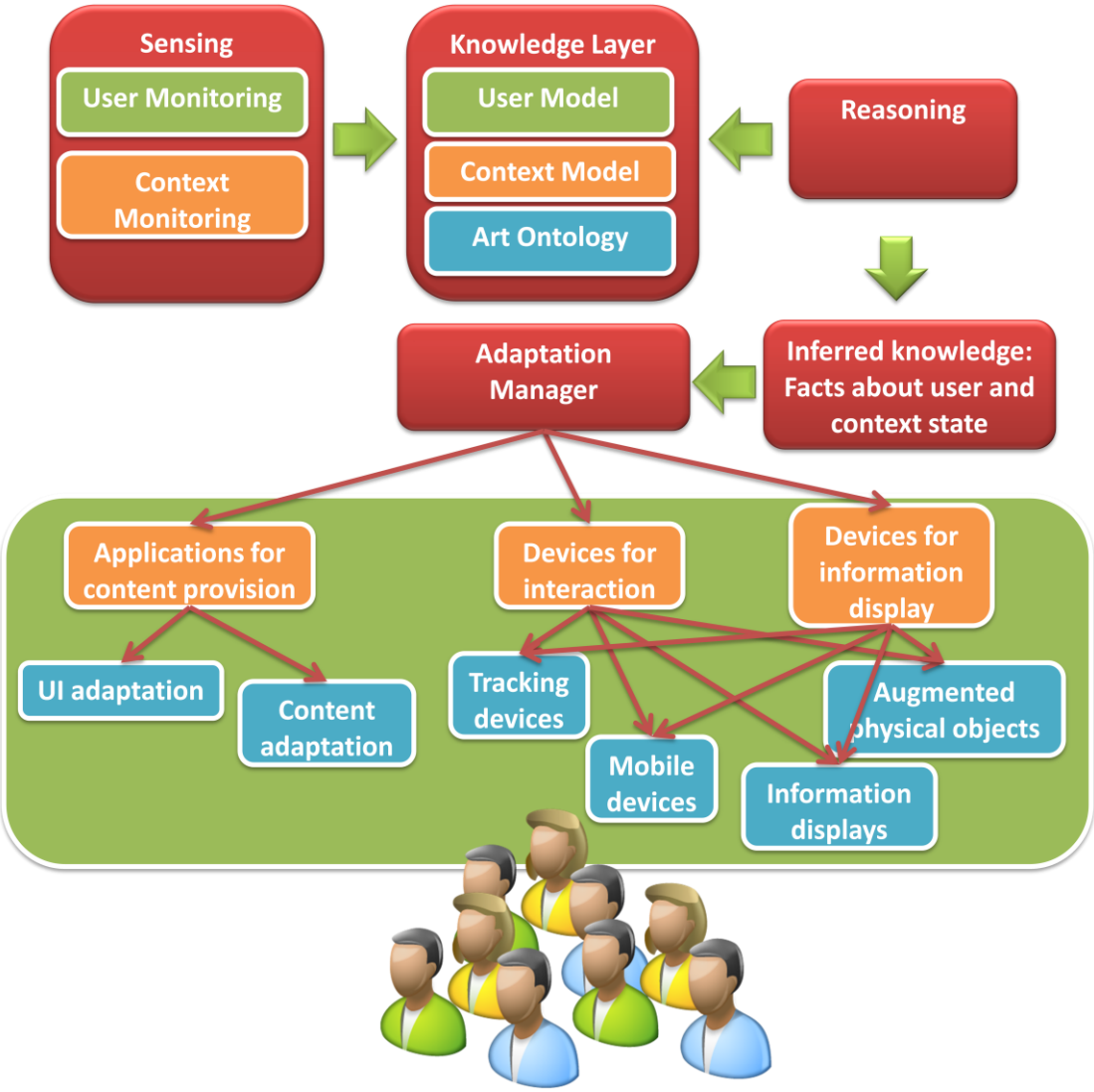


Figure 75. The adaptation decision-making process

The Adaptation Manager performs the following types of adaptations:

- devices to be used for interaction (from a pool of available selections including tracking devices, mobile devices, embedded information displays and augmented objects)
- devices used for information display (from a pool of available selections including mobile devices, embedded information displays, and augmented physical objects)
- applications to be launched on the selected devices
- internal behaviour of the selected applications in terms of
    - UI (select the most appropriate UI setting for the user currently accessing the application)

- Presentation of content to users (decide how to adapt the content representing an artefact from the ontology to the requirements stemming from user models such as user familiarity with art, language etc.).

7.8 The UI Toolkit

Traditional user interface toolkits were set of interactive objects used for the creation of a user interface. These elements typically employed metaphors for bringing elements existing in the physical space to its virtual computer orchestrated alternative (e.g., Desktop, radio button, shopping cart). In the context of Ambient User Interfaces physical objects regain their meaning and coexist with virtual objects for facilitating a novel mixed interaction.

The term interacting with art has been used across the ages to imply a number of different issues. Interaction with art has been sensed as the exchange that takes place between the viewer and art itself. The transmission of drama, passion, meaning are the concepts that make art evolving together with human existence. In the context of this research work, interaction with art is not altered but enriched, aiming at offering new dimensions to this everlasting relation. Ambient interaction elements in this context are all the alternative ways that art can be manipulated, used and access via an Ambient Intelligence Environment. Presenting art for various purposes (information, education, mood setting etc.), with various ways (enriched with information, interactive etc.) and on various devices (projection screen, informative screen, i-table, design space etc.) is by itself demanding in terms of the interaction elements used for facilitating it presentation. Furthermore, controlling art as a design material, as a way to get entertained or educated is also demanding. Finally, the ways that all these alternative ways of using and controlling art is propagated to the user is essential for enabling the user to unleash his creativity. In this context, the importance of the interaction elements used for facilitating interaction can be proven significant for achieving the goals set by this work. The existence of users with various abilities, backgrounds, and purposes in the context of the environment together with a variety of contextual issues that can limit or enrich the interaction leads to the need for adaptation. Adaptation as already presented can be perceived as the ability offered to

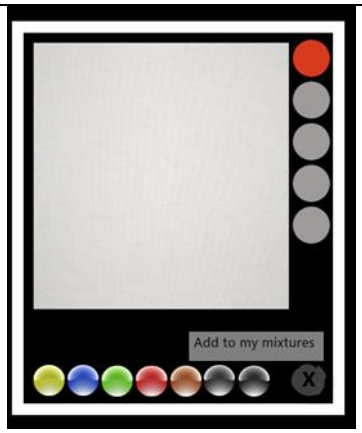
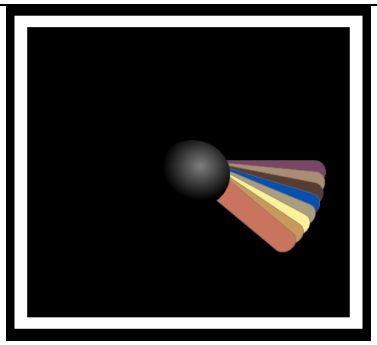
alter interaction by selecting the most appropriate interaction elements according to the available user or contextual information.

7.8.1 Art Creation and Design

This section presents the collection of UI elements generated to support the Art Creation activities within the Ambient Workshop.

7.8.1.1 Colour Manipulation and Mixing

For manipulating and mixing colours a number of UI controls have been developed. These controls provide touch enabled functionality for supporting both standard Microsoft WPF touch events and the variations of these events as required by the Microsoft Surface framework. More specifically the "Colour Swatch" is a control element used for presenting colour that can be used for composing collections of swatches. These collections are in turn used both by the colour mixing controls and the "Colour Wheel" control. The colour mixing controls come into three instantiations a full featured palette for artists, a reduced colour palette for children and a palette specially designed for been used while painting. The potential instantiation of these controls are presented in Figure 76.

	
Standalone colour mixer	Colour pallete for children
	

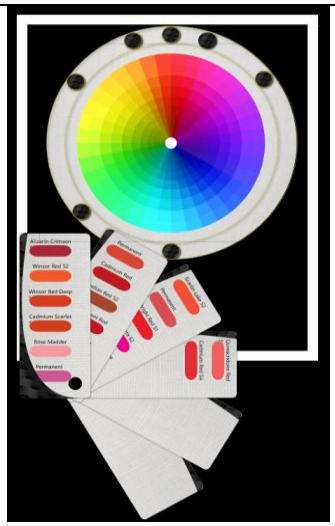
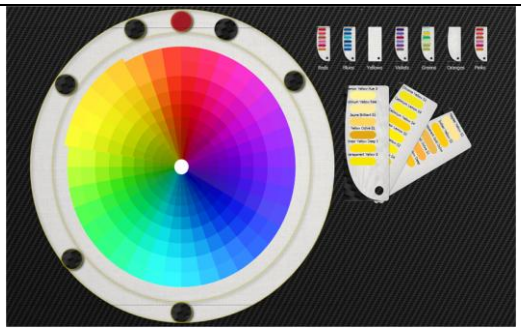
Colour mixer for large screens	Redy to use pallete of colour
	
Colour wheel for augmented surfaces	Stand alone colour wheel

Figure 76. Colour Manipulation and Mixing controls

7.8.1.2 Art Composition and Design

For the purposes of composition a number of controls have been developed. The "Designer Grid" is a control that renders a grid of squares when placed within a container. This control is used to separate a large area into smaller ones and is useful both for painting and composition. The "Designer Canvas" is a touch enabled version of the diagram designer control [332] that has the ability to track designer elements placed within and serialise them to the ontology. At the same time special effort has been put into making the control compatible with touch within application developed for Microsoft surface.

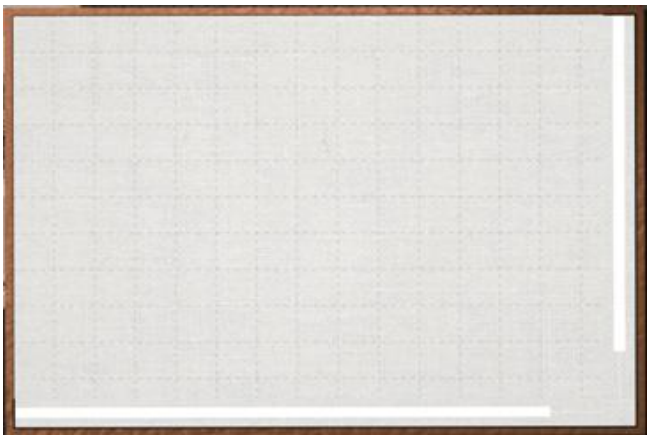
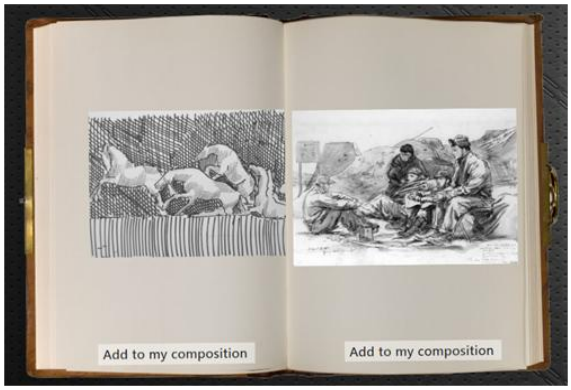


Figure 77. Art Composition and Design controls

7.8.1.3 Sketchbook Control collection

For the needs of creating an augmented artist's sketchbook a collection of controls has been created. The page flip control [347] has been styled to achieve a sketchbook like look and feel and the appropriate adaptations have been made to its event model to support the needs of natural interaction with pages in the context of applications created with the Microsoft surface SDK 2.0 [230]. At the same time this book control is accompanied by a digitiser control that facilitates the process of digitising content using the raw image extracted from the Microsoft Pixelsense device.



7.8.1.4 Image filters control

The "Image filters" control is an image container that integrates functionality for applying a number of image processing filters to the contained image. To do so the services built on top the Computer Vision & media infrastructure are used. The resulting image is generated either by applying pixel perfect algorithms to the source image or by applying shadder effects to the WPF image control. At the same time the control provide the option to render its filtered output in the form of a new image file.

Figure 78. Image filters control

7.8.1.5 Image cropping control

In order for the artist to have the option to manipulate and edit images in order to add sections of images to his created composition an image cropping control has been created. This control facilitates an ink canvas for allowing the artist to naturally select using the lasso metaphor the region of the image to be cropped. The stroked created using the lasso metaphor is used as a clipping path for isolating the part of the picture to be included in the composition.

Figure 79. Image cropping control

7.8.1.6 The design elements toolbox

The design elements toolbox is a control offering access to a collection of draggable design elements. These design elements can be dragged and dropped into compositions for attaching semantic information. These design elements are extracted for a library of design elements created by this research work. These elements are either images or geometric shapes created using the Microsoft Expression Design [348].

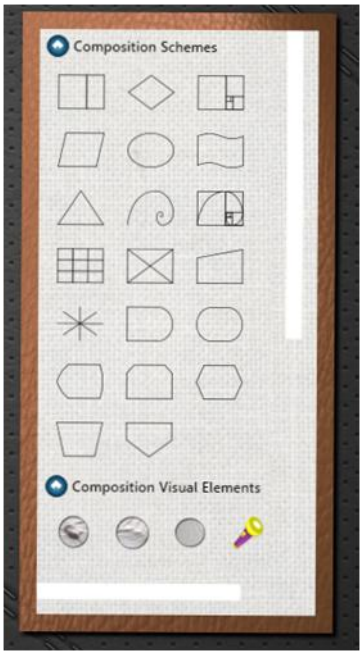


Figure 80. The design elements toolbox

7.8.1.7 The tag comparing control collection

For allowing augmented objects to be compared when placed on the Microsoft Pixelsense table the facilities offered by the item compare sample have been used. The control collection has been enriched to support html text for presenting structured information and at the same time to offer references to external resources. These resources include most of the cases web pages rendered through the usage of the rotatable web browser control described in this chapter. More over special care has been put into allowing the control to be rendered together with other information elements within the same application.

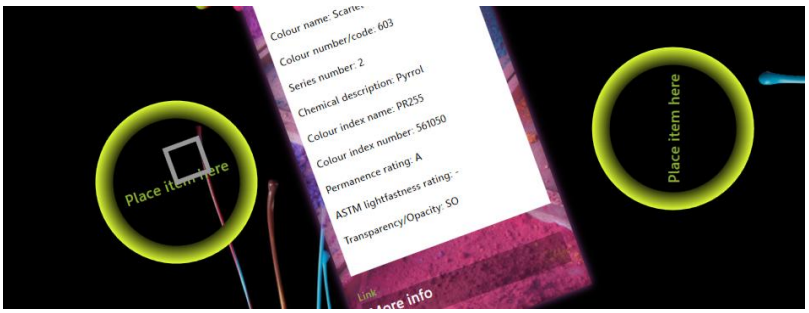


Figure 81. The tag comparing control collection

7.8.1.8 Zoom Canvas

The zoom canvas control allows a vast collection of items to be rendered within a very large canvas. Within this canvas multi touch gestures can be applied to focus

different regions of the canvas or to zoom out for getting access to the "big picture". The implementation of the control used in the context of this research work is derived from the Blake NUI framework [329].

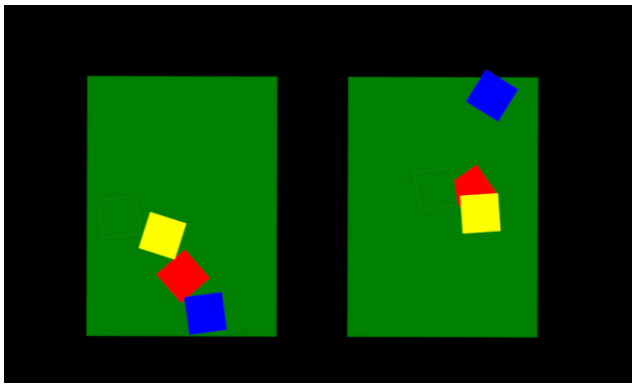


Figure 82. Zoom Canvas

7.8.1.9 Camera manipulation-capturing and framing

For allowing the display of video coming by a high definition camera the WPFMediaKit [349] library has been used. Using the media rendering control provided by this library a capturing-framing control has been creating. When capturing a screen the camera output is hidden and its captured screen is presented in its place. This captured screen can be manipulated through touch for selecting the desired portion of the capture. The capture is in turn replaced with its cropped version.

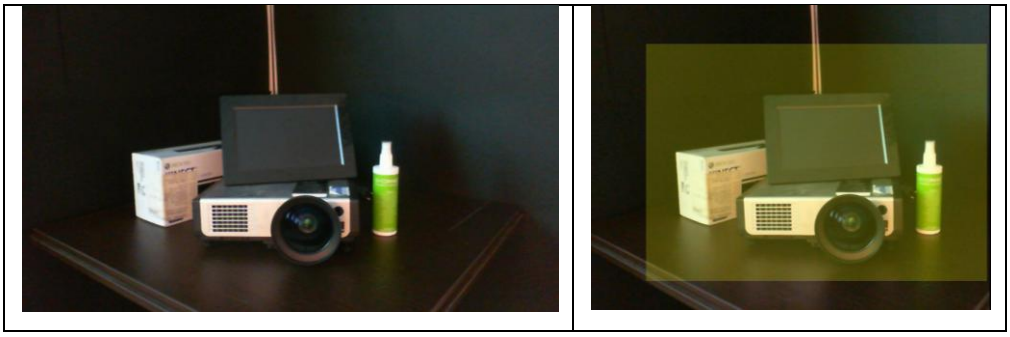


Figure 83. Camera manipulation-capturing and framing

7.8.1.10 Augmented Painting Canvas control

The augmented painting canvas control is a UI elements used to augment the actual painting surface. This control can be adjusted to the dimension of the painting support and offers facilities for the application of digital colour on the canvas the selection of colour from a region of the canvas as long as the option to compare a colour on the canvas with one digitally mixed using the augmented painting palette.

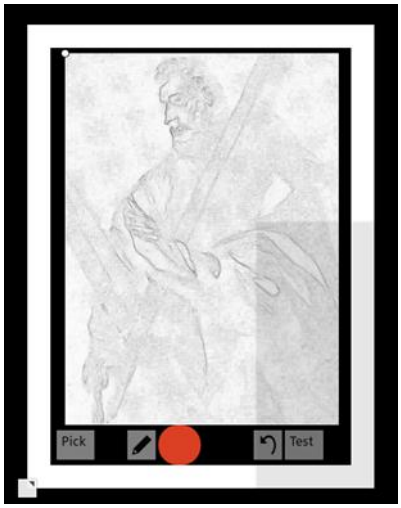


Figure 80. Augmented Painting Canvas control

7.8.1.11 Painting frame control

The painting frame control is created for allowing a frame to be projected and resized within the augmented painting surface. To this end the frame can be bound to a colour and be rendered using this colour and use alternative styles to generate various kinds of frames.

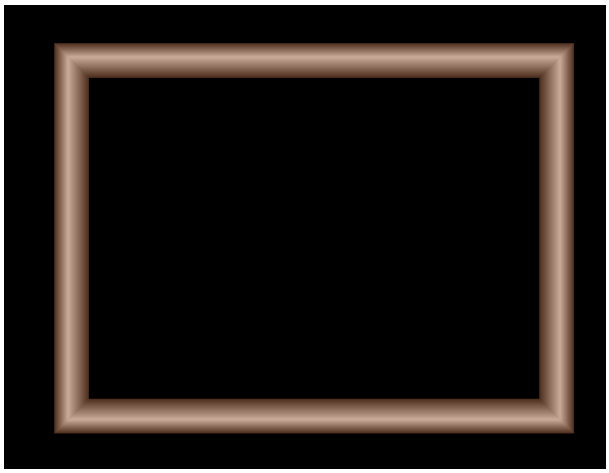


Figure 84. Painting frame control

7.8.1.12 Physical Media Digitizer control

The physical media digitiser control (see Figure 85) is a UI element created to collaborate with the Microsoft Surface SDK 2.0 raw image extraction facilities. This control when operated by the user projects a container where physical sketches can be placed. When such sketches are placed on the surface the control extracts the raw

image and renders it within the container. The user can in turn use the image cropping control within the container to select the section of the sketch to be saved.

Figure 85. Physical Media Digitizer control

7.8.1.13 Social Search control

The social search control is a UI element presenting a search bar for allowing users to enter search string using a virtual keyboard. The control when the search function is selected is using the flickr search api to download publicly available material from flickr and render them as Image filters controls.

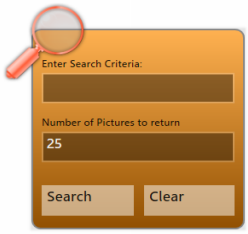


Figure 86. Social Search control

7.8.1.14 Local colour isolator control

The local colour isolator control renders a provided image and listens to touch and mouse events. When the user touches in a region of the picture the colour of the selected region is extracted so as to be used in conjunction with colour mixing controls.

Figure 87. Local colour isolator

7.8.1.14 The tracing grid control

The tracing grid control is a UI element that can be dynamically imported within WPF UI containers (e.g. Grid). When placed within the container the control renders a grid of lines (see Figure 88). Developers have control over the number of lines presented horizontally and vertically and on the colour brush used for rendering lines. In this sense when this control is placed on two different containers with the same parameters it separates them into equal proportions thus allowing the transferring of a sketch from the one container to the other.

Figure 88. The control paced within a Grid container

7.8.2 Art Education

7.8.2.1 Brush Canvas

The brush canvas is an extension to the ink canvas control provided by WPF framework that supports the creation of strokes based on the application of a collection of brush stencils. These stencils have been created in the form of 2d shapes using Microsoft Expression Design. The application of a stencil to the canvas results to the rendering of strokes were the point within the strokes are replaced with the provided stencils. At the same time the stencils are rotated to follow the direction of the stroke for creating a more lifelike effect.

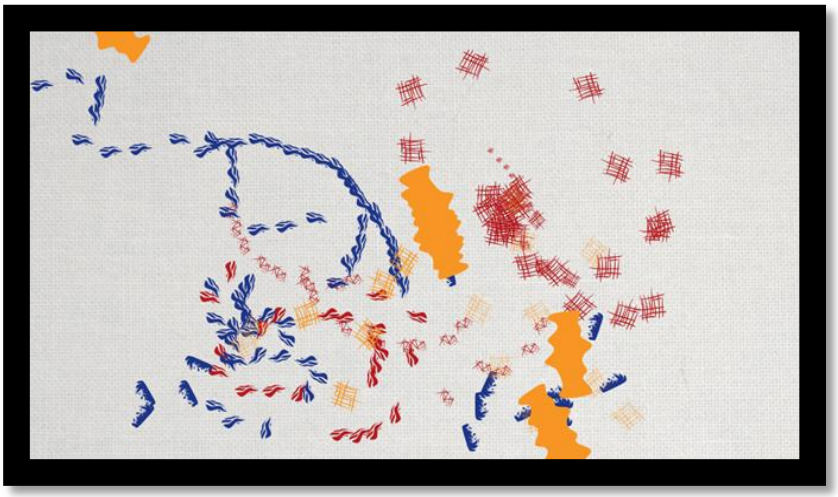


Figure 89. Brush Canvas

7.8.2.2 Rotatable Web Browser

For the needs of presenting web pages within applications developed for Microsoft PixelSense a Web Browser control that could be rotated within a container was required. To this end the WebBrowser control included in the WPF framework was not sufficient. To overcome this difficulty the Chromium Web Browser control was integrated into the UI Toolkit. The Chromium Web Browser control [335] mixes Google's Chromium project [336], a great wrapper called Awesomium [337] and WPF to produce a fully capable and rotatable web browser control for WPF.

Figure 90. Rotatable Web Browser within a Microsoft PixelSense application

7.8.2.3 Transparency Wheel

The transparency wheel is an augmented UI control operating together with an augmented phydget. The wheel follows the rotation of the phydget and adjusts the transparency value between zero and one. Controls interesting into adjusting their behaviour to the control can bind themselves to the transparency property exported by the control.

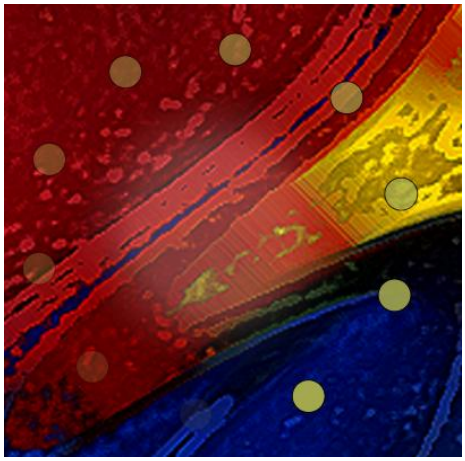


Figure 91. Transparency Wheel

7.8.2.4 3D models

For allowing the creation of three dimensional compositions from the design space a collection of 3D models were defined based on the HelixToolkit [350] wpf 3D library. These models are either rendered using the build in facilities provided by wpf 3D or imported using HelixToolkit from models in other 3D formats.

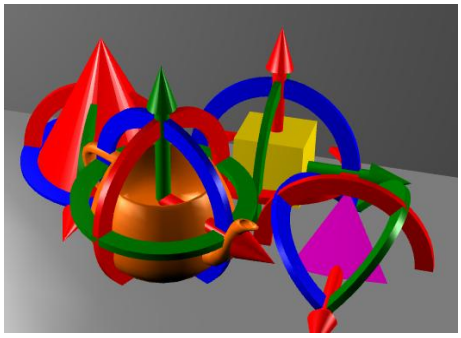


Figure 92. 3D models

7.8.2.5 The painting canvas

The painting canvas is a control capable of rendering a sketch that is either extracted using the image processing infrastructure by a painting or generated from a sketch. This control integrated facilities for rendering brush strokes into various colour and allows the developer to set whether the sketch itself can be overwritten by the artist or not. In this sense the control can operate both in a more forgiving mode for children or using a stricter form. The control can also be integrated with the transparency wheel presented above in order to render brush-strokes using different transparency values.

Figure 93. The painting canvas

7.8.3 Art within Cultural Heritage Institutions

7.8.3.1 Multi-scale image control

The luck of support for rendering multi-scale images by the WPF framework is covered through the integration in the UI toolkit of the Deep Zoom for WPF control [334]. This control offers support for rendering images created by the Microsoft Deep Zoom Composer allowing this research work to generate and use images with size of several gig pixels. At the same time the control has also been integrated with the

kinect gestures based interaction facilities and has been updated to support multi-touch gestures within applications developed for Microsoft PixelSense.

Figure 94. Multi-scale image control

7.8.3.2 Regions of interests presenter

This UI control augments a digital representation of an Artefact through the integration of areas or interests were information is attached. To this end the control receives a digital representation of the artefact together with the annotated areas. These areas are formed using a collection of point within the painting. This collection of points is normalised and used for creating a path within the painting that represents the region interest. Finally the controls offer the ability to focus on specific areas of interest by highlighting the path and presenting a popup container with its attached information. The alternative modalities supported by this control include touch, hand and body location tracking through kinect.

Figure 95. Regions of interests' presenter control

7.8.3.3 Hand mapping control

The hand mapping control uses the data extracted from a kinect sensor to present a hand within an application that follows the trajectory of the hand of the user currently

using the application. At the same time focussing and selection of interactive elements is also supported. This control was based on the Basic Interaction sample provided by the kinect for windows SDK and has been extended to support the concurrent interaction of more than one user.

Figure 96. Hand mapping control

7.8.3.4 User mapping control

The user mapping control uses the data extracted from a kinect sensor to present a pointer within an application that follows the spine of the user currently using the application. This control is used by applications relying on user location in front of an artefact for presenting information. The control supports multiple users and is useful for providing feedback to users regarding their position in front of the painting.

Figure 97. User mapping control

7.8.3.5 Timeline Control

For creating interactive timelines the Silverlight & WPF Timeline Control [225] was used. This control was extended to support a number of features required by this research work. Initially the control was extended to support its integration with the art ontology. At the same time regarding functionality it was altered to support interaction within applications developed for Microsoft PixelSense and its event mechanism was extended to generate timeline focus events (interactive popup when user focuses on an event).

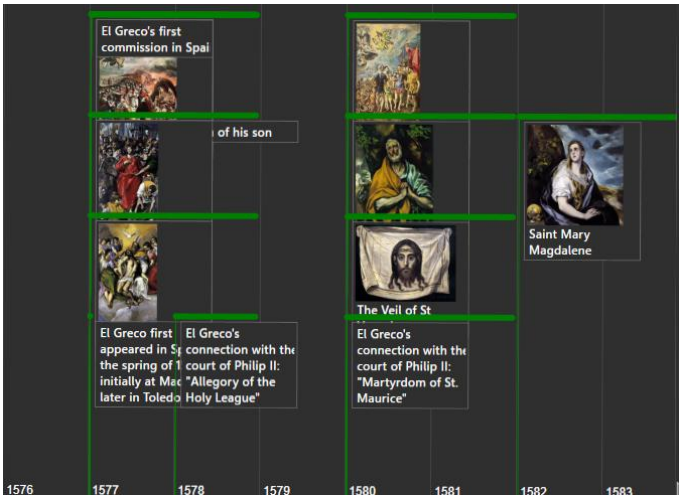


Figure 98. Timeline Control

7.8.3.6 Magnifying Glass

The magnifying glass as a UI element used as alternative the multi-scale image control in cases were not such information (multi-scale representation) is available for an artefact. The control renders a magnifying glass which movement is bound to a source (the mouse, hand tracking data, touches etc.) and magnifies the region of an image that is currently focused by the control.

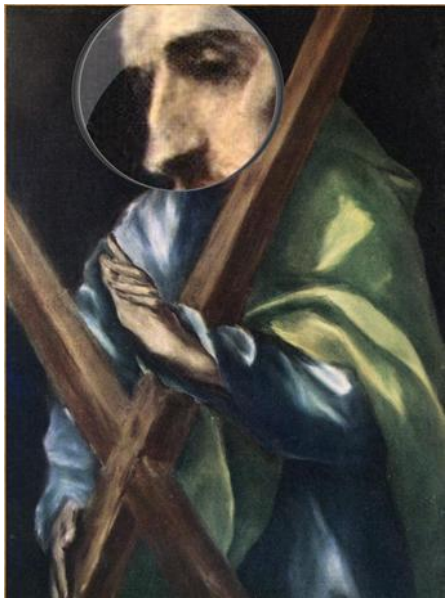


Figure 99. Magnifying Glass Control

7.8.3.7 Painting details control collection

This collection of controls fosters the need to extract and present a multitude of information from the ontology. To this end each painting is rendered as an image with an attached element menu. From this element menu several categories of information

can be browsed such as the painting implementation details, its composition, information about the artist etc.

7.8.3.8 Video player control

The video player control integrates a medial element WPF control and supports typical video manipulation facilities and dynamic video source binding based on an ontology based representation of an artefact (see Figure 100).

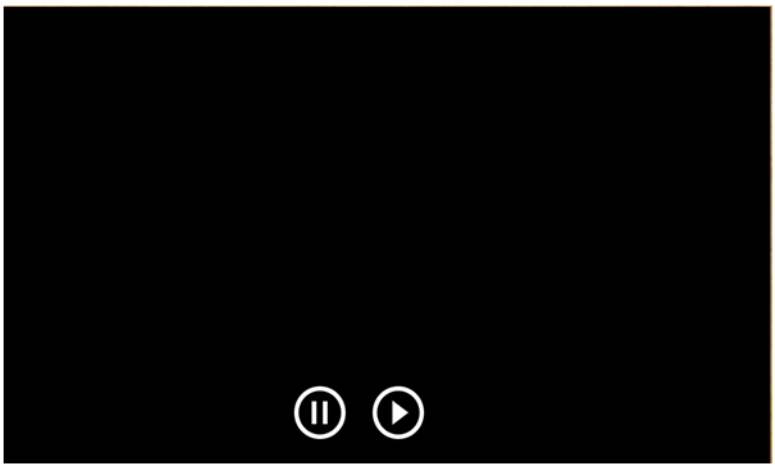


Figure 100. Video Player control

7.8.3.9 Mobile image gallery

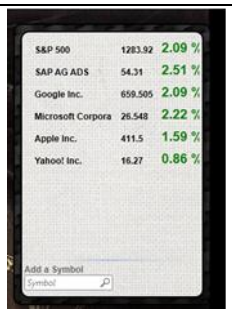
The mobile image gallery is a UI control getting a collection of painting representations from the ontology and rendering them in the form of a standard touch enabled image gallery.

7.8.4 Art within Smart Living Spaces

7.8.4.1 Information Widgets

When information is encoded using painting information widgets are used to allow users to access more information than the one encoded within art. To do so several information display widgets are employed such as: (a) clock control used for rendering an analogue clock within an application, (b) a weather widget used for rendering information regarding the current weather in a specific location as long as

the weather forecast of the week and (c) a widget used to present information regarding the stock market .



7.8.4.2 Art Transition control

The art Transition control takes as input a collection of artefacts from the ontology (e.g. the artefacts browsed by the user during a museum visit) and generates a time controlled slideshow with various transition effects for presenting these artefacts.

7.8.4.3 XNA control collection

The xna control collection is a set of UI elements (drawables in XNA) to support the needs of the Art Collector game. These controls include:

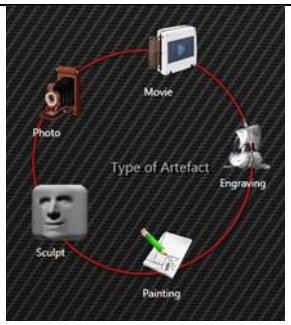
- Dices: a set of Dices that can be either passive (display the results of rolling physical dices) or active (the user touches and roles the dices)
- Player controllers: a collection of four buttons used for replying to questions
- Question prompt window: a control taking input a question from the ontology and rendering it to the current player

7.8.5 General purpose UI elements

7.8.5.1 Menus

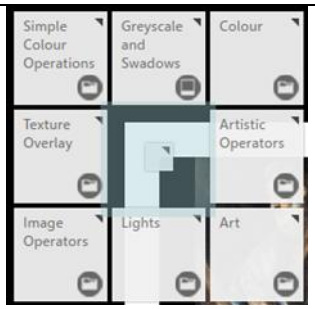
In the context of this research work several menu elements were employed for allowing the natural selection of functionality through gestures and touch. In this context the menu components employed include: (a) fish eye menu were selection appear in a list and are scales when focused, (b) circular selection menu were selection are rendered in the periphery of a circle, (c) panorama metro style menu were users can browse a collection of functions through swipe left and swipe right gestures and select through touch, (d) a carousel menu control were menu elements are rendered in locations defined by a path within the screen and finally various

variation of the Surface SDK element menu where the user touch and holds on elements to reveal submenus and releases touch to select.

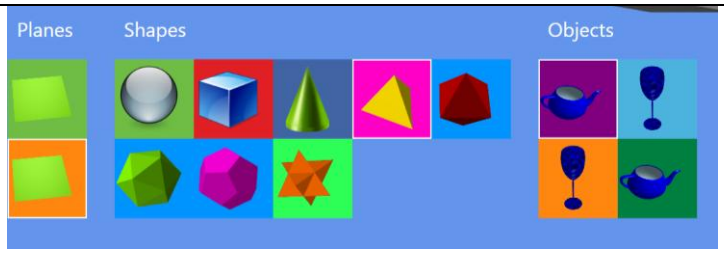


Circular menu

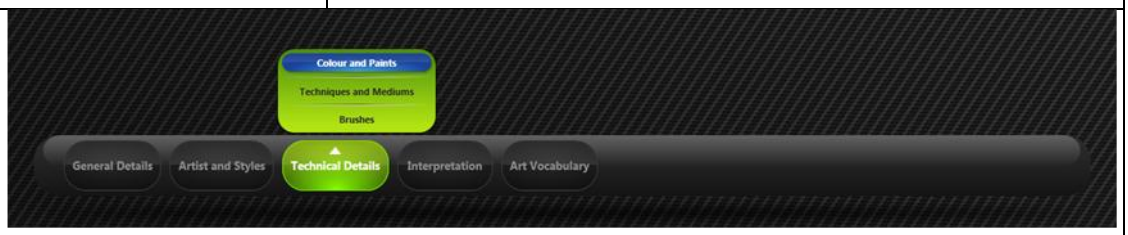
Fish-eye panel menu



Surface SDK menu



Panorama metro-style menu



Categorised menu

Carusel menu

Figure 101. Various menus employed by this research work

7.8.5.2 Image library containers

Image library container present categorised collections of paintings as retrieved for the ontology. These containers facilitate the provided by the Microsoft Surface SDK library bar and library stack controls for creating ready to use containers represented either in the form of tag visualisations or scatterview items.

7.8.5.3 Html Rich Textbox

The integration of an Html enabled textbox was required for allowing the applications developed in the context of this research work to provide html content that was extracted from the web and stored in the ontology.

Figure 102. Html RichTextBox

7.8.5.4 Touch Screen keyboard

In most of the cases no textual input is required by the applications created in the context of this research work. In the cases were such input is required and no traditional input devices are present (e.g. when annotating artefacts using a touch screen display) a touch enabled keyboard is used that is either imported by the UI toolkit or in the case of the Pixelsense device automatically provided by the system.

7.9 Interaction Metaphors

The term interaction techniques refer to the way human activities are translated to computer oriented actions. In the context of mainstream computing, the prevalent interaction technique is point and click. This technique allows the translation of hand movements to location variables on a computer screen or the movement of a finger to selection of item. Ambient Intelligent Environments have made possible the creation

of more complex “alphabets” of interaction allowing the translation of various human activities. In this context, research aims at communicating with the environment in a way similar to communicating with humans. A movement of hands, a placement of an object, even a spoken word can be part of this new convention.

7.9.1 Explicit interaction techniques

Explicit interactions include interaction models, where the user initiates a discrete action and expects a timely discrete response.

7.9.1.1 Gestures

The facilitation of gestures in the context of various applications is essential for providing a modern and intuitive way of interacting with the environment. In this context, the existence of a small set of gestures is essential for maintaining the intuitiveness of the approach and for ensuring memorability and usability. One of the main barriers arising is the need to map specific gestures to specific functions in specific context. For example, moving the hand in front of a display presenting informative material means accessing the next item from the list of sources, but in front of an informative art display means the request of a switch between informative sources. To this end, it is essential to provide an abstract set of gestures to be recognised by the system and use contextual information to drive gesture mapping. This mapping can then be used to map gestures to application specific events to be propagated to the application currently having user focus.

Wpf Multi-touch

The application created using the Windows Presentation Foundation framework rely on the integrated touch events to produce touch based interaction. This low level set of events is specialised by each application for producing the desired behaviour.

Microsoft Surface SDK 2.0

A number of gestures supported by Microsoft Surface SDK 2.0 and Microsoft PixelSense Samsung SUR-40 device are employed as described by the Microsoft® Surface® 2 Design and Interaction Guide [323]. Some examples of these gestures as presented in the Design and Interaction Guide are presented in Table 17.

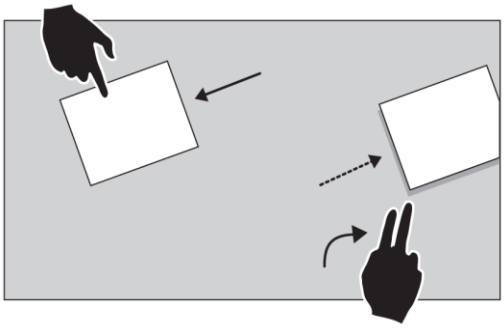
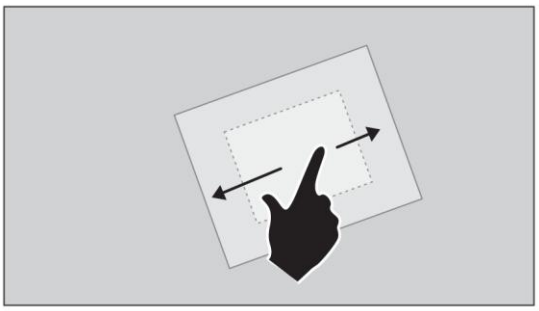
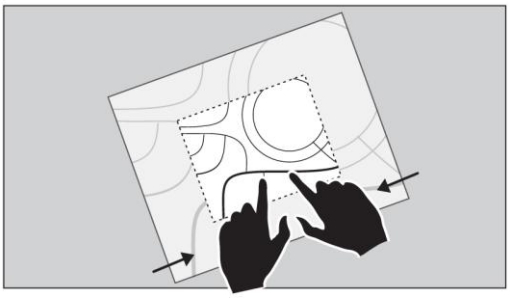
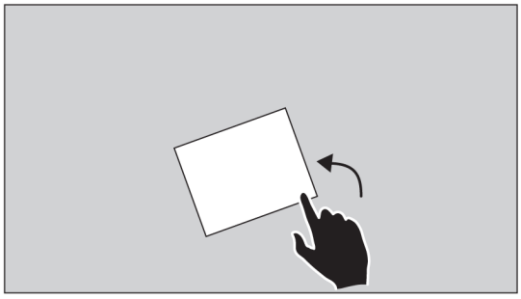
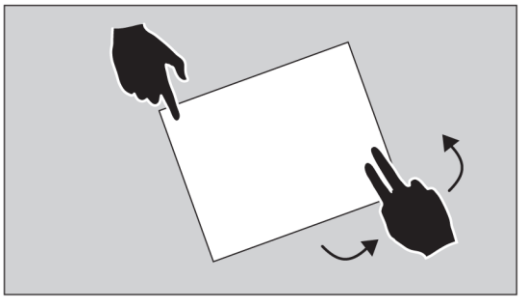
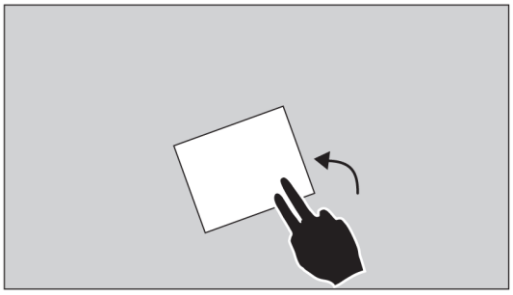
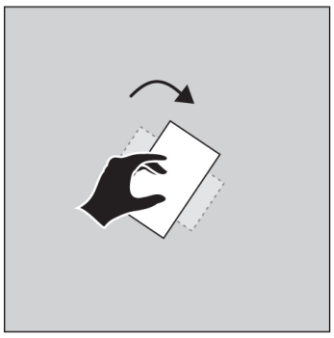
 **Move item**	 **Scale item**
 **Shrink item**	 **Single finger rotate**
 **Pin turn: One finger remains stationary acting as a pivot**	 **Dual finger rotate**
 **Twist to spin**	

Table 17: Single and multi-touch Gestures supported by Microsoft Surface SDK 2.0

Kinect based Gestures

For making the application presented in research work the nibbler gestures manager is used (created in the context of AmI research activities at FORTH by Emmanouel Zidianakis). The nibbler gestures manager is a suite capable of recording user gestures using a Microsoft kinect sensor. These recorded gestures can be in turned recognised

by the manager and propagated to application through its implementation as a famine service (see Figure **103**).

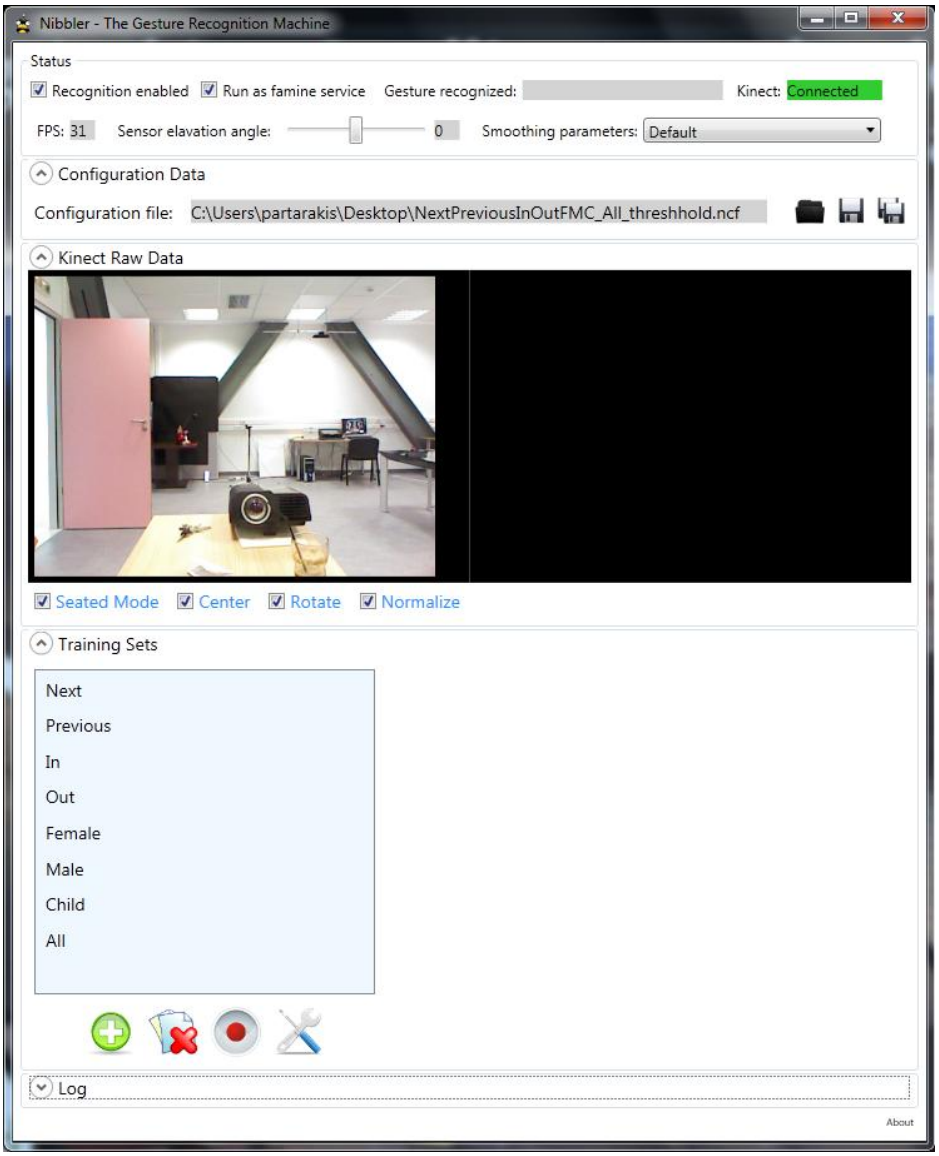


Figure 103. Nibbler Gestures tracker

7.9.1.2 Voice commands

Voice input is the most prominent way of interaction between people and it has been an important research topic in computing. Full automatic recognition and understanding of human languages has not yet been achieved, but modern speech recognition systems are capable of understanding voice commands using a specific grammar syntax and interaction scenarios. This interaction technique can be employed in the context of environment interaction taking into account a number of considerations. Speech input, although intuitive and desirable from the user side, needs to be supported through reliable recognition system. Recognition errors and

misinterpretations of user command tend to frustrate users and making them less comfortable using these facilities. To this end, the usage of a limited set of voice commands is used, together with contextual mapping of these commands to application events. In this context, the same scenario used for gestures can be employed in order to limit the command set and ensure memorability and cross application usage. In the context of this research work both the Microsoft speech SDK and the Microsoft Kinect SDK capabilities for speech recognition are employed.

7.9.1.3 Physical Augmented Objects

The existence of smart or augmented objects (objects that can have both physical and virtual presence and meaning) is essential for enabling everyday objects to become part of interaction with the environment. The existence of a contextual binding of the virtual existence of these objects is also important for enabling each user to facilitate a small number of these objects for a wide range of interaction needs. The types of objects employed by this research work use the Microsoft PixelSense object recognition mechanism. A set of tagged objects has been implemented. These objects can be identified when placed on the Samsung SUR-40 device. En exemplary collection of such tagged objects as employed by the developed applications is presented in Figure 104.

Figure 104. Tagged objects for Samsung SUR-40

7.9.2 Implicit interaction

The term implicit interaction is used here to define the concept of user interaction that is not based on direct user input (manipulating a touch screen, input via hand gestures

etc.). Such implicit input sources include input that is produced by body posture, body localisation and gaze orientation.

7.9.2.1 Body posture - Body Localisation - Gaze orientation using kinect

Body posture was not traditionally considered an interaction technique, but in the context of ambient intelligence can be also employed for allowing the creation of a number of interactive applications. Computer vision can be employed to gather and analyse data allowing applications to mimic and understand user posture.

Interaction based on Body Localisation is carried out by tracking the user's position in the ambient facility and informing applications interested about the user current location. For example, an application presenting informative art may be dependent to the proximity of the user in relation with the ambient art display. This dependency may result in specific decisions regarding the specialisation of the displayed information in the case, for example, of interactive exhibits.

Gaze orientation is a form of interaction used by head tracking systems in Virtual Reality applications in order to simulate user and eye movement in a Virtual World. This was traditional carried out by introducing head tracking sensors on an HMD (head mounted display). In the context of Ambient Intelligence this can be achieved using tracking with cameras installed in an ambient facility. This information can be used for implicit interaction (zooming the specific part of a painting you are currently looking, send visual output to the screen currently receiving user focus etc.).

7.10 Distributed deployment of Services using famine

This section presents Services that are deployed on the Famine middleware, but unlike the applications presented in the previous sections; do not expose any kind of interface. On the contrary these deployed services are used a building blocks from UI enabled services.

7.10.1 The "AmiForArtDataAccess" service

This service exports the functionality provided by the "AmiForArtDataAccess" Data Provider layer to the famine middleware for allowing applications to access the ontology. Therefore this service separated the application UI from the ontology allowing the integration of the ontology to a number of interactive applications regardless of the application platform used for the development.

7.10.2 The "predominantColourCalculator" service

Little work has been directed towards setting the mood of people and thus transforming the leaving environment to a pleasant environment. In this context, art can be employed to transform space to achieve the creation of a unique visual and sensory environment. Different colours can produce different emotions and can be used for different purposes [35]. The "predominantColourCalculator" service is designed to run in stealth in the environment and when requested to calculate the predominant colour from a selected source (for example a screen presenting information). This colour information can in turn be used to adjust the room's lighting using the calculated colour.

7.10.3 The "ColourSpaceOperations" service

This service provides functionality for performing colour operations based on a collection of supported colour spaces (rgb, cmyk, lab etc.). More specifically all the colour operations required for performing colour mixes in term of pigments is realised through this service (the colours are extracted from the ontology, the rgb representation is transformed to a linear colour space and in turn the representation of colours into this linear colour space is used to perform colour mixing).

7.10.4 The "webSearch" service

This service wraps the functionality provided by Microsoft Bing search API [220] for allowing such a service to be integrated and dynamically used by services running on famine.

7.10.5 The "emailer" service

The "emailer" Service wraps up the functionality provided by an open source imap library [215] for providing access to user's mailbox. Its implementation as a famine service exports a number of typical operations in a simple and straightforward way hiding all the library specific information from its potential users.

7.10.6 The "stockMarket" service

The "stockMarket" service uses the Yahoo stock engine [222] for collecting information regarding stock market prices for a specific portfolio. At the same time as a famine service it can be used by all the deployed applications.

7.10.7 The "localWeather" service

The "localWeather" service uses the MSN local weather service [221] to retrieve information regarding the weather conditions in a specific region. This information is wrapped up as a famine service for allowing all the deployed application to gain access to weather reports.

7.10 Generic UI services

7.10.1 The "quickLaunchPad" Service

This service is an interactive application that handles the interconnections between all the available UI services running on each of the proposed smart environments. This service keeps track of all the services running and can be used by each of these services for allowing the users to launch one of the available services on the appropriate infrastructure (for example an Artist creating a composition can request from its colour wheel, running on the touch screen display on the left side of his painting support, to start a colour mixer on the screen on the right side of his painting support). A collection of the alternative application launching views provided by the "quickLaunchPad" prototype is presented in Figure 171.

Figure 105: Accessing all deployed applications through "quickLaunchPad"

7.11 Adaptation-Personalization

In this section the applications created for supporting the concepts of Adaptation, Personalisation and Reasoning are presented. To this end contextual awareness is important for the system to be aware of the context where interactive applications are deployed (the physical space and the devices, deployed within this space). This is achieved through the "Context Explorer" application that employees information stemming from the context ontology and by the runtime instantiation of services. In the same context it is important to have control and coordination of the scenario

currently happening within a smart environment and adapt the scenario to users accessing interactive applications. This is achieved through the scenario manager application. At the same time interactive application should produce intelligent behaviour based on user actions. In this sense the concept of adaptation and personalisation comes into place. To achieve these qualities the adaptation manager employs the results produced by the reasoner to generate decisions that should be followed by applications. Such decisions affect either the functionality of applications (adapting functionality to users and context) or the way that information is presented by applications (adapting content to users). The aforementioned qualities are ensured through the existence of a reasoner and an adaptation manager.

7.11.1 The "Context Explorer"

The context explorer is an interactive application used to present contextual information of space and devices. It used the Context ontology to extract the representation of the smart environments and formulates an interactive graph. This graph can be used in conjunction with the "quickLaunchPad" prototype and the context reasoner for allowing users to manual launch applications within context (e.g. in the room they reside, or in the desk they seat etc.) an on the desired device. An example of the "Context Explorer" application for the three main smart environments defined in this work is presented in Figure 106 while Figure 107 present the presentation of information regarding the lights that are available to control in the main room of Ambient Workshop.

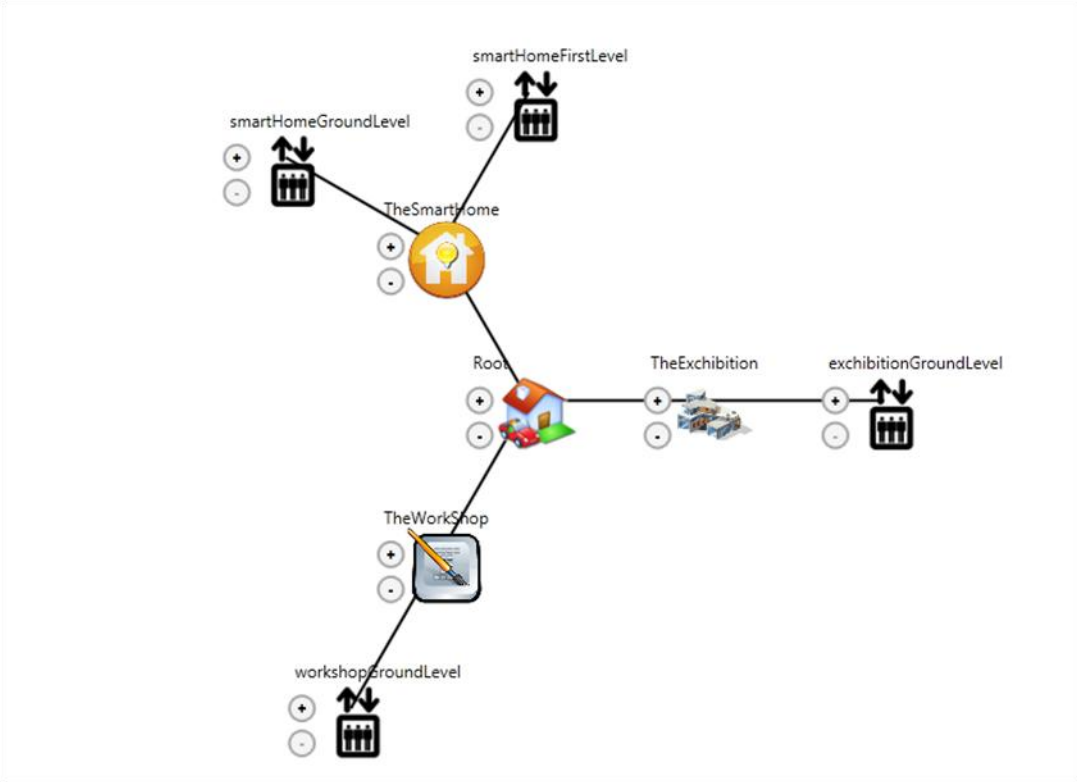


Figure 106: Three smart environments instances

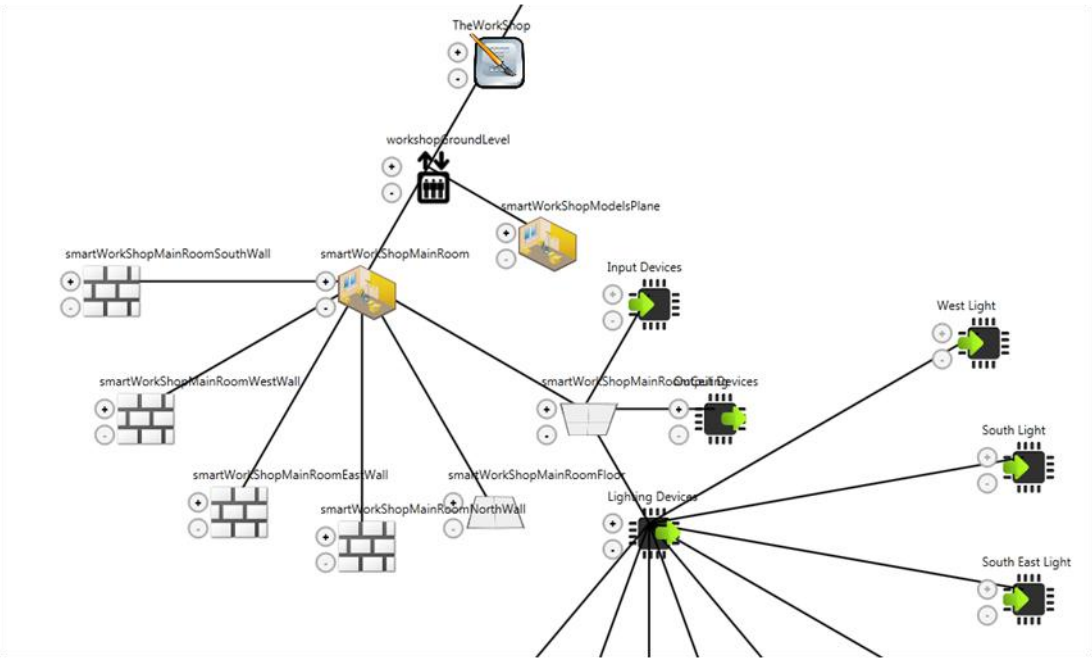


Figure 107: Exploring the lights available in the ceiling of the workshop's main room

7.11.1 Scenario Manager

The scenario manager collects all the events produced by the deployed application within space. When these events represent status notification the data are imported to the Reasoner (in order to have status information about the running scenario). On the other hand when these events are requests for actions to happen the reasoned is used

to determine if the requested action can be performed based on system's state. When a result is returned from the reasoned the scenario manager informs the adaptation manager for the new state of the system.

7.11.2 Adaptation Manager

The adaptation manager is responsible for getting the outcomes produced by the scenario manager and producing commands targeted to applications. These comments affect the behaviour, functionality and interface of the deployed applications. Each of these applications upon receive of the command should produce the appropriate adaptation behaviour.

8 From vision to reality

Ambient Intelligence has been proposed as a concept for enabling people to live, work, learn and have fun in smart environments in which technology is sensitive to people's needs, personalized to their requirements, anticipatory of their behaviour and responsive to their presence [81]. To this end, several applications have already been proposed for domains such as ambient assistive living, entertainment, collaboration, etc. Although much work has been done in various domains, there is a substantial gap in using this technology for supporting the creation and dissemination of art. Research in this field has mainly focussed on informative art (e.g. using art for implicitly presenting information by ambient art displays). This research aims at using such technologies together with traditional techniques and knowledge for facilitating the creation of art (through an Ambient Workshop), the fruition of art for education, training and entertainment (through a Smart Home) and finally for enriching the ways that art is traditional accessed (through an Ambient Art Gallery). This chapter presents the way that this vision is realised through the development of a multitude of applications. In this analysis the state of the art within each of the aforementioned domains is highlighting following by the way that these activities are exploited through the implemented applications.

8.1 The Art Creation Process

Before moving to the presentation of the main concept of this research work which can be summarised by the term “Ami Augmented Creativity” it is essential to identify some aspects of the processes traditionally followed for creating art.

8.1.1 Traditional approaches

The history of painting has proven that there is no one single recipe that presents the process of creating a painting. From the academic art to the impressionists and the modern art numerous theories and approach have been proposed. It most of the cases regardless of their education and background artists tend to develop a personal style both in terms of expression and process. In this sense it is not possible to cover every aspect of artistic creation. This section does not present any kind of recipe for painting but tries to identify alternative scenarios followed by artists for creating their work. In this sense the process followed by an artist can be a mix of the following procedures and can change not only from artist to artist but also each artist may use a different approach based on the result that wishes to achieve.

8.1.1.1 Transferring a composition

The process of painting through a composition implies a substantial effort from the artist to create a visually pleasing composition, study the qualities of light colour value etc. within his composition and determine the visual arrangement of elements. For this point on preparatory sketches can be created in any media prior to moving to the artistic creation. These sketches are in turn used as reference material during painting. In this section this process of creating a transferring a composition will be explained following with the description of techniques and tools used by artists to accomplish their goals.

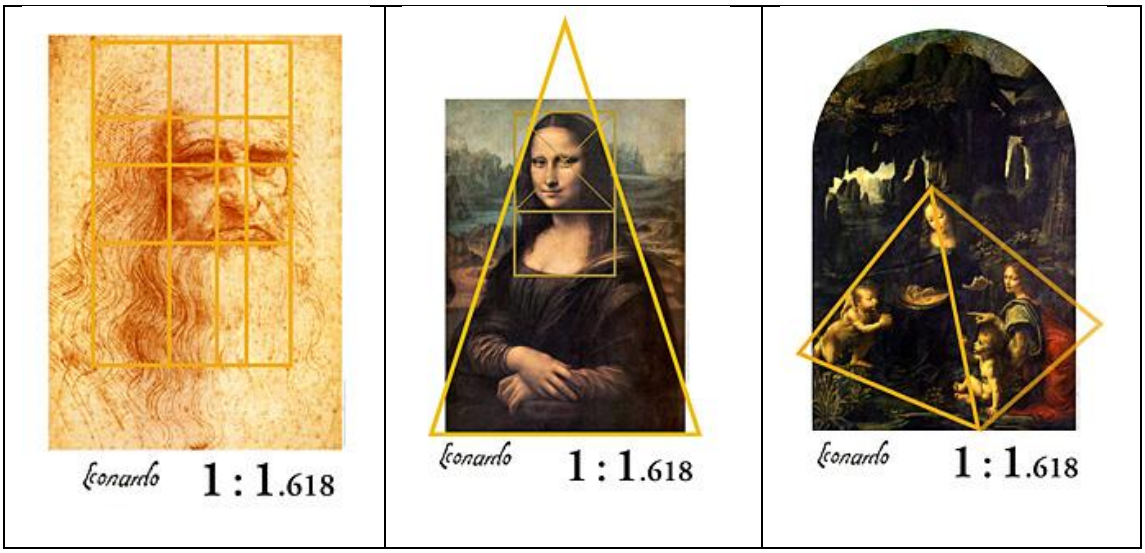
8.1.1.1.1 Creating a composition

In the visual arts and in particular painting, graphic design, photography and sculpture composition is the placement or arrangement of visual elements or ingredients in a work of art or a photograph, as distinct from the subject of a work. It can also be thought of as the organization of the elements of art according to the principles of art. The term composition means 'putting together,' and can apply to any work of art, from music to writing to photography, that is arranged or put together using conscious thought. In the visual arts, composition is often used interchangeably with various

terms such as design, form, visual ordering, or formal structure, depending on the context. For example, the three quarter view approach when used for a portrait can introduce a wonderful almost decorative pose. Figure 108 presents the Ginevra di Benci's portrait by Leonardo Da Vinci. This was the first portrait in the history of painting where this posture where introduced.

Figure 108: Ginevra di Benci, Leonardo Da Vinci 1474-1478

There are unlimited alternative composition variations, each of which produces a distinctive result. Some indicative composition schemes as implied to be used by Leonardo Da Vinci are presented in Figure 109.



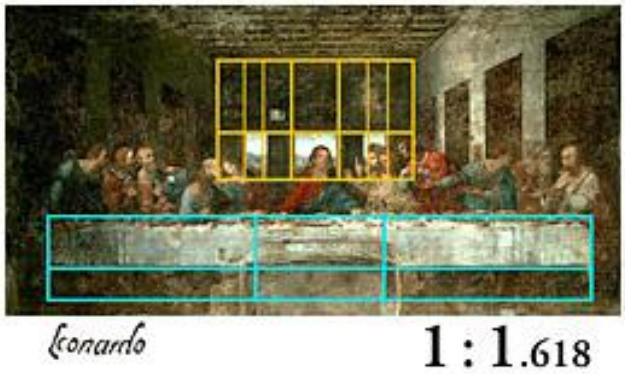
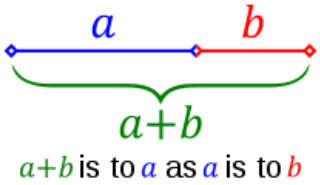


Figure 109: Composition schemes employed by Leonardo Da Vinci

In these compositions the way that Da Vinci was using geometry and mathematics to achieve the desired results is shown. The ration used by Da Vinci in these compositions is known as the golden ratio. In mathematics and the arts, two quantities are in the golden ratio if their ratio is the same as the ratio of their sum to the larger of the two quantities, i.e. their maximum. The following figure illustrates the geometric relationship[10]. Expressed algebraically, for quantities a and b with a > b.



$$\frac{a+b}{a} = \frac{a}{b} \stackrel{\text{def}}{=} \varphi,$$

the geometric relationship the algebraic relationship

Principles of organization

For organizing elements within a composition the artist determines what the centre of interest of the art work will be, and composes the elements accordingly. The gaze of the viewer will then tend to linger over these points of interest. Elements are arranged with consideration of several factors (known variously as the principles of organization, principles of art, or principles of design) into a harmonious whole which works together to produce the desired statement. This phenomenon is commonly referred to as unity. Such factors in composition should not be confused with the Vocabulary of Design Elements themselves. For example, shape is a design element;

[10] http://en.wikipedia.org/wiki/Golden_ratio

the usage of shape is characterized by various principles. Some principles of organization affecting the composition of a picture are:

- Shape and proportion of the elements used (e.g. a large shape looks closer that a smaller one)
- Positioning, Orientation, Balance and Harmony among the elements of a composition
- The area within the field of view used for the picture (the cropping of the scene as made by the artist)
- The path or direction followed by the viewer's eye when they observe the image (orchestrated by the artist through the creation of visual paths)
- Negative space: Negative space, in art, is the space around and between the subject(s) of an image. Negative space may be most evident when the space around a subject, and not the subject itself, forms an interesting or artistically relevant shape, and such space is occasionally used to artistic effect as the "real" subject of an image. The use of negative space is a key element of artistic composition [294].
- Colour
- Contrast: the value, or degree of lightness and darkness, used within the picture.
- Geometry: for example the use of the golden mean, or golden rectangles for placing the centre of interest
- Lines: the visual path that enables the eye to move within the painting
- Rhythm: helps to lead the viewer's eye across a painting
- Illumination or lighting: used to determine the points of interest and their spatial arrangement
- Repetition: when building into pattern rhythm also comes into play, as does geometry
- Perspective: help the spatial arrangement of elements

Artists accessories

Except for following or not specific rules and vocabularies artists also use a number of accessories for supporting them in a number of directions. In this section the most important of these accessories are presented and include material used for capturing compositions for future reference such as sketchbooks but also tools that assist artist

into producing their compositions from actual scenes having embedded into their form some of the basic composition and arrangement principles presented.

Sketch-books

A sketchbook is a book or pad with blank pages for sketching and is frequently used by artists for drawing or painting as a part of their creative process (Figure 110). The exhibition of sketchbooks at the Fogg Art Museum at Harvard University in 2006 suggested that there were two broad categories for classifying sketches: (a) observation sketches focusing on the documentation of the external world and includes many such travel and nature studies and sketches recording an artist's travels and (b) invention sketches following the artists' digressions and internal journeys as developing compositional ideas.

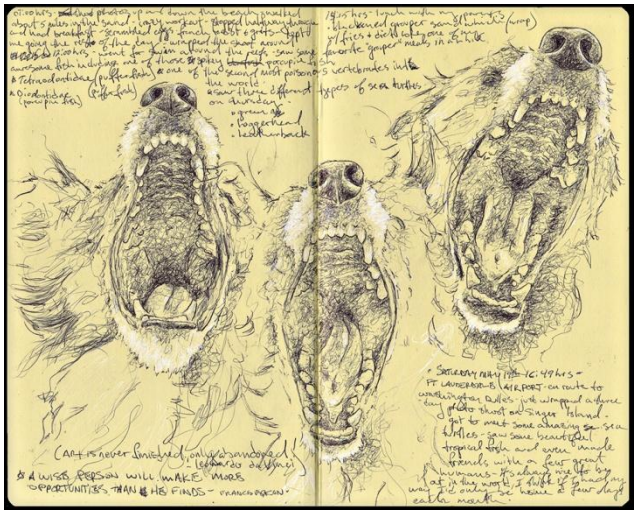


Figure 110. An example of an artist's sketchbook

Sight-Grids

Sight grids are viewable grid systems that help the artist to observe the interplay of visual elements in terms of scale, direction and location. An innovative yet simple tool for artists, sight grid simplifies scale and proportion by making it easier to locate the subjects' centre. The grid system breaks down sizes and distances into easy-to-calibrate sections. The clear viewing grid provides a reference for the closer observation of lines and shapes in drawing or painting. An example of such a tool together with an example of its usage is presented in Figure 111.

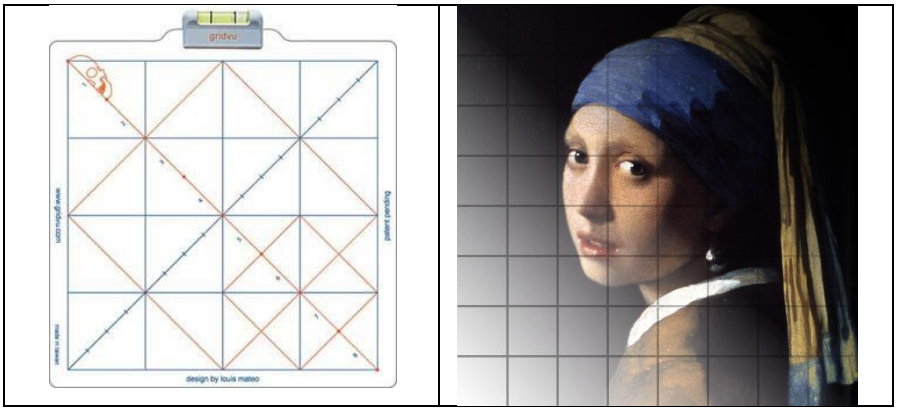


Figure 111. A sight grid together with an example of its usage for recreating Vermeer's “girl with the pearl”

View finders

View finders are used as a means of producing a pleasing arrangement of abstract shapes. A viewfinder is a simple device that allows artists to isolate or “crop” a scene within a rectangular area. The viewfinder can be adjusted back and forth, left and right, and up and down, for determining the most dramatic and engaging composition. Artists use it to find big, simple shapes against small ones and light ones against dark ones. As they locate these shapes and value masses, they start the process of translating the three-dimensional world into two dimensions. View finders also allow the adjustment of proportions of height to width in order for the artist to have the versatility to decide whether his composition will be better in a square, a horizontal or a vertical format.

Some viewfinders divide the area of the rectangle into thirds. You can place major masses along those lines. They create pleasing visual divisions and can help immeasurably in drawing accurately. Without the thirds-indicators artists inevitably tend to let things drift toward the middle into very static and conventional placement.

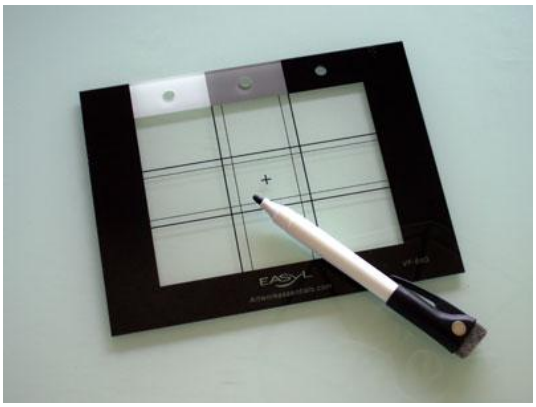


Figure 112. A View finder

Local colour isolators

Local colour isolators are used by artists to isolate the colour for its surrounding in order to reproduce it without the effects produced by the simultaneous colour contrast phenomenon. Such tools are valuable both for accomplished artists and those that don't yet have a "trained eye" capable of identifying colour values and hues. An example of such a tools and its usage is presented in Figure 113.

Figure 113. A local colour isolator

Perspective Grids

Perspective grids are traced by artists into the painting surface in order to provide define the space where elements of composition will be placed. Figure 114 presents an example of a perspective grid with two vanishing points.

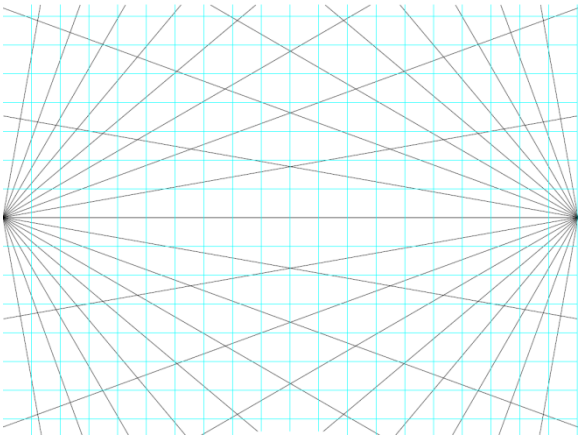


Figure 114. A perspective grid with two vanishing points

8.1.1.1.2 Producing Preliminary sketches

A preliminary sketch (ultimately from Greek σχέδιος – schedios]) is a rapidly executed freehand drawing that is not usually intended as a finished work. A sketch may serve a number of purposes: it might record something that the artist sees, it might record or develop an idea for later use or it might be used as a quick way of graphically demonstrating an image, idea or principle. Sketching is generally a

prescribed part of the studies of art students. The term "sketch" has most often been applied to graphic work executed in a dry media such as graphite pencil, charcoal or pastel. It may also apply to drawings executed in pen and ink, ballpoint pen, water colour and oil paint. The latter two are generally referred to as "water colour sketches" and "oil sketches". An example of invention sketches as produced by Pablo Picasso during the creation of Guernica is presented in Figure 115.

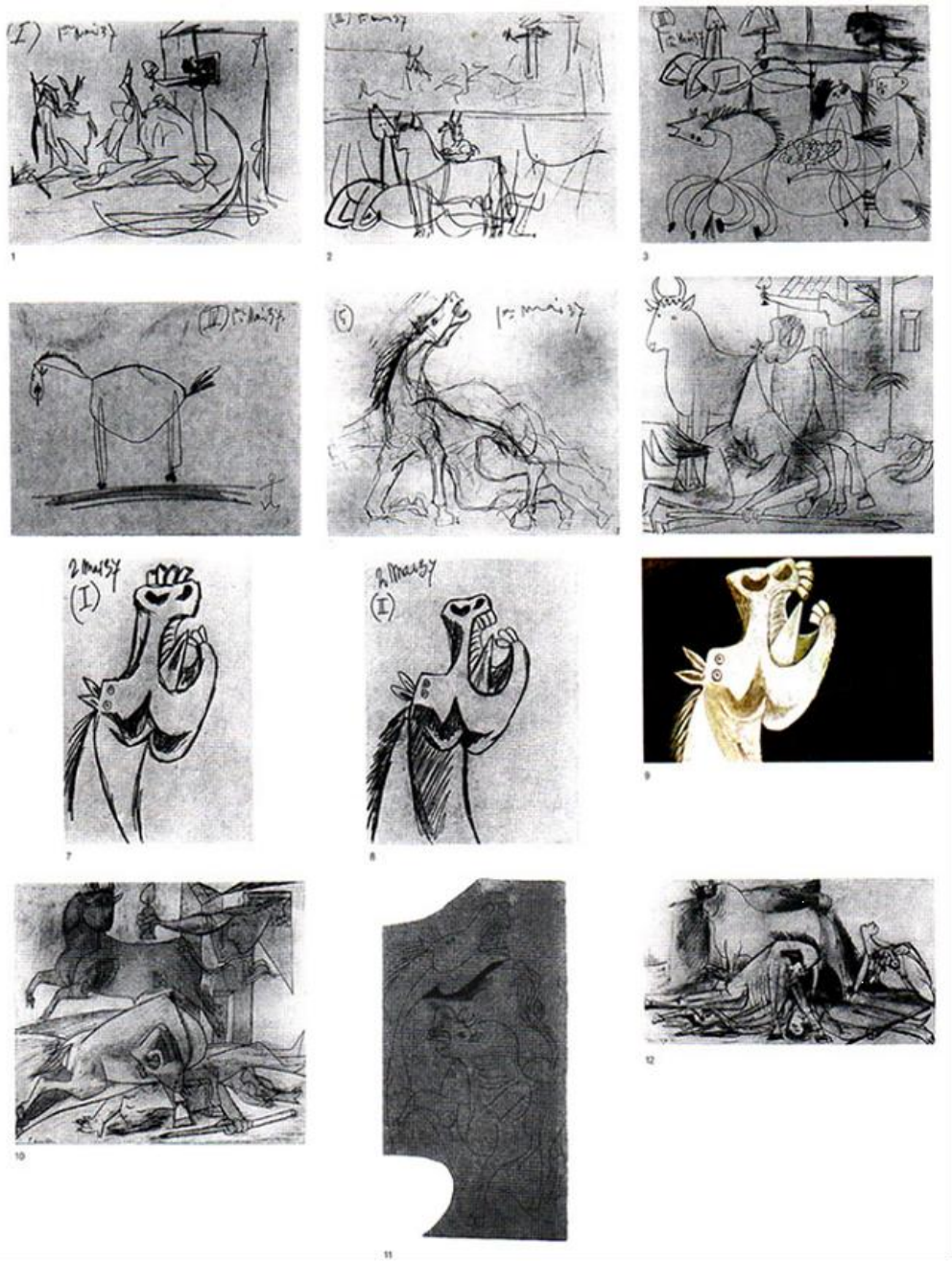


Figure 115. Preliminary Sketches created by Picasso during the creation of Guernica

Those that are aware of the finished painting can identify the transfer of several concepts from these sketches to the final painting.

8.1.1.1.3 Art creation

After having produced the composition and several sketches of the final painting or parts of it the artists typically move to the creation of the final painting. This process is not always happening immediately after the processes described above but whenever the artists fills ready to complete the painting. The existence both of the composition and of the preparatory sketches are the only reference material needed by the artist to create. In the creative process several accessories are used. Some of these are more suitable for young and inexperienced artists but there are always clues that accomplished artists use them for quick reference.

Colour Wheel

Colour wheels are systems designed to explain the behaviour and properties of colour. Figure 116 presents an example of a colour wheel system created by the Swiss artist and designer Johannes Itten (1888 – 1967). Colour wheels provide a way to compare and contrast colour appearance and to observe the effect of a given colour on adjacent colours [18]. At the same time the colour wheels can be considered a great tool for the artists while painting for getting informed about the way colour are mixed and furthermore for quickly identifying complementary colours for producing dynamic contrasts.

Figure 116: An example of a colour wheel

Chromatic chart

Novice artists tend to think that you can light up a colour using white and darken it up using black. In practice when trying to create a still life of an apple using black and white for dulling or lighting colour the result is a chalky and dull painting. On the contrary when using greys that contain colour we can achieve astonishing results. These chromatic greys are created by mixing together the complements (the colours directly opposite to each other on the colour wheel. In this context the chromatic chart

is a series of greys created with colour from the colour wheel. A chromatic chart is useful both for novice and accomplished artists for quickly identifying the appropriate chromatic grey and at the same time determining the appropriate colour mixing recipe.

Textures

Textures are essential when working with mediums that their consistency allows the rendering of textures. This three dimensional arrangement of paint can produce remarkable effects due to the fact that light plays on the uneven surface. Textures together with techniques such as glazing and scrambling can produce effects that can live up a whole painting (see Figure 117).

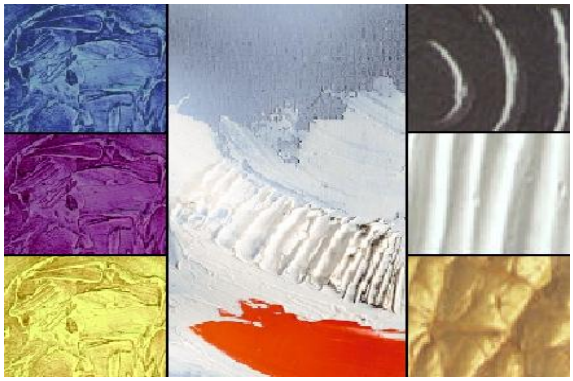


Figure 117: Different results from the application of alternative texture styles

8.1.1.2 Painting from life (using a model)

Another popular approach to painting is through a model or using a physical composition of items as a model. The task of arranging a model or a still life when painting from life is a very important task for the success of a painting. The position and posture of the figure, lighting and framing are considered vital for enabling the artist to transfer to the viewer his personal subjective approach on his subject matter.

8.1.1.2.1 Visual arrangement

Creating a composition when working with physically present models (for example human models or objects for setting up a still life) entails the need of an enclosed space where the artist has absolute control over several things such as lighting, subject matter positioning, posture, etc. In this area, the artist can set-up his subject matter, preview his composition and make the appropriate arrangement for producing the desired results.

8.1.1.2.2 Lights

Controlling light has been one of the major success elements of many famous paintings. Many artists have become famous over the ages based on their ability to control light, visualise and present lighting such as Michelangelo Merisi da Caravaggio who has mastered the chiaroscuro effect, or Leonardo da Vinci inventor of the foggy "sfumato" effect. To understand this concept, a number of alternative lighting schemes should be considered:

- **Still life (front lighting):** Figure 118 presents an example of how front lighting is employed for setting up a still life.

Figure 118: Setting up a still life

- **Chiaroscuro lighting:** Figure 119 presents "The Calling of St. Matthew" by Michelangelo Merisi da Caravaggio. In this painting, Christ stretches out his hand in a stylized limp gesture. This limp gesture forms a synaptic junction that allows for a maieutic flow of dialogue between God and man, transcendence and history [37]. The intense use of chiaroscuro lighting forms a diagonal thrust of light directed to Matthew in one of the most striking religious subjects ever created.

Figure 119: The Calling of St. Matthew, Michelangelo Merisi da Caravaggio 1599-1600

8.1.1.2.3 Framing

Framing a composition is considered very important for achieving specific results. For example, the concatenation of a painting creates a feeling of drama emphasizing the main elements of the composition. Furthermore, a feeling of continuance is propagated to the viewer allowing his mind to travel over the edge of the canvas. Another example relates with the term of negative space, namely the space remaining when the basic elements are subtracted. It is important for a portrait for example to leave more negative space in front of the figure allowing the existence of enough space for the figure. The opposite could result to a feeling that the model is squished to the edge of the canvas.

8.1.1.2.4 Art creation

When painting using a model the completion of composition, lighting and framing is what needed to continue. The artist can either paint from life, while having the composition in front of him, take a number of pictures of the composition and use these pictures as reference material or use a device for tracing the composition such as the camera obscura. In this section we are not going to focus only on presenting tracing devices while the other two methods rely on the personal style of the artist.

Camera Obscura

The camera obscura is an optical device that projects an image of its surroundings on a screen. It is used in drawing and was one of the inventions that led to photography and the camera. The device consists of a box or room with a hole in one side. Light from an external scene passes through the hole and strikes a surface inside where it is reproduced, upside-down, but with colour and perspective preserved. The image can be projected onto paper, and can then be traced to produce a highly accurate representation (see Figure 120) [303].

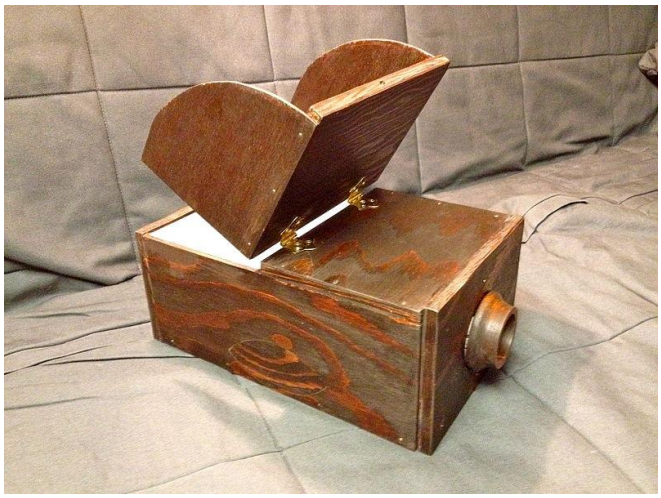


Figure 120: Camera Obscura

Using mirrors, as in the 18th century overhead version it is possible to project a right-side-up image. Another more portable type is a box with an angled mirror projecting onto tracing paper placed on the glass top, the image being upright as viewed from the back.

8.1.1.3 Painting from pictures

Taking photographs is the easiest way for artists to get references of subjects they wish to paint. They're also essential if it's a subject they are not going to encounter again easily, such as a landscape in an area or an exotic bird.

8.1.1.3.1 Reviewing material

The process of painting from photos includes the reviewing of reference material by the artist without having a specific subject in mind. This process may result to the selection of a single picture or a combination of pictures that could be used for the creation of a composition. The artist can use these pictures to create a college of elements until finding a pleasant arrangement. From this stage on the artist could

prepare a number of preparatory sketches of the composition prior moving to painting.

8.1.2 Art Creation within the Ami Environment

The previous section provided a description of some of the processes followed by artist while painting. These processes are not always followed as is because each artist tends to produce a personal style and process. In this section the way that these processes can be facilitating though the usage of an Ami environment is presented providing an initial set of clues for proving the success of this research work.

8.1.2.1 Meeting Art Patrons: The Artist's Portfolio

The "Artist's Portfolio" is an interactive application that allows Artists to advertise their works to their clients. More specifically a shared interactive space is available to both the artist and its clients visiting the workshop. Via this shared workspace the artist can display previous works based on a number of criteria such as the pictorial subject, the medium used etc. (see Figure 121). At the same time this application can provide useful information to the artist regarding the piece of art such as the composition scheme used, the colour palette, the mediums used etc. This information is valuable for allowing the Master not to reinvent the wheel but build on the knowledge collected by the system. The "Artist's Portfolio" is using the "universe of things" metaphor for presenting collections of Artefacts. In this interaction style the users have a vast zoom-enabled surface on their disposal. This surface can be scaled and shrink using multi-touch gestures in order for the users to locate a region of interest within the "universe" or on the other hand isolate and focus on an area. In this sense a vast amount of information is available concurrently allowing the users to focus on the part that gain their interest.

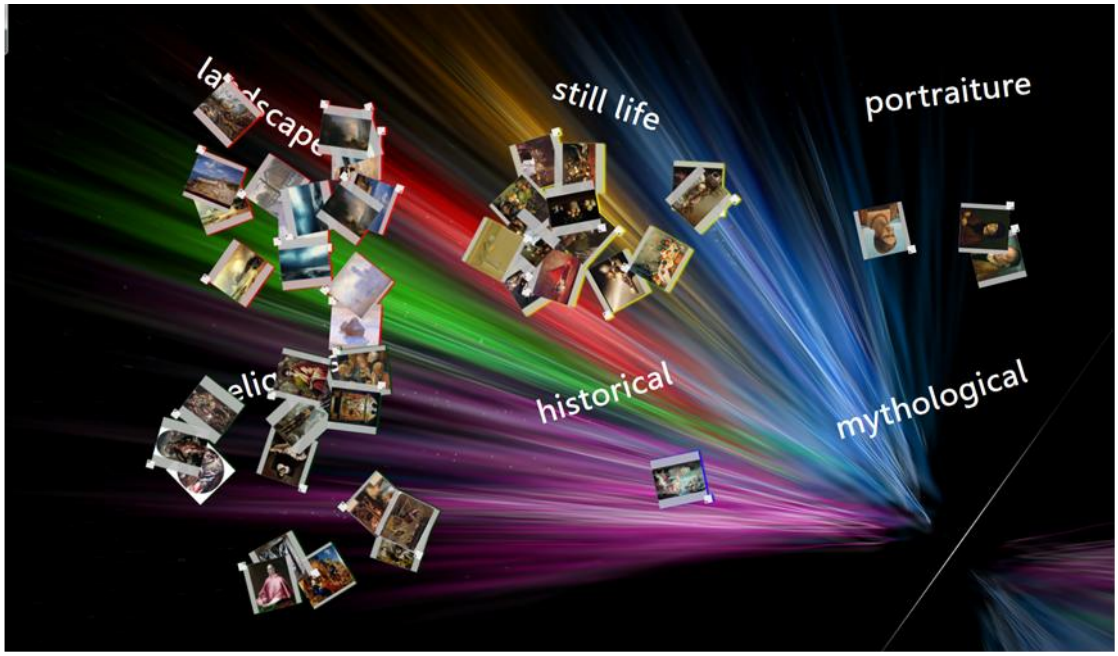


Figure 121: A "universe" of artefacts in the "Artist's Portfolio"

Figure 122: Isolating a part of the "universe" in the "Artist's Portfolio"

Table 18 presents the implementation details of the "Artist's Portfolio" application.

Implementation Framework	• Microsoft surface SDK 2.0 [230] • Windows Presentation Foundation (WPF) [231] • Microsoft Visual C# [232] • Blake NUI framework [329]

Ami Services Used	• "AmiForArtModel" service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service
Libraries Used	• "AmiForArtUIToolkit" ○ Zoom Canvas
Hardware Used	• Microsoft PixelSense – Samsung SUR-40
Interaction Schemes	• Multi Touch and gestures • Augmented physical objects

Table 18. Implementation details for the "Artist's Portfolio"

8.1.2.2 Transferring a composition

This section presents the process of artistic creation that involves a systematic effort from the artist to create a composition and possibly preliminary sketches prior to the creation. Composition depicts the visual arrangement of elements within the painting together with additional information regarding textures, colours, contrasting elements etc.

8.1.2.2.1 The Artist's Composition Suite

The "Artist's Composition Suite" presented in Figure 123 can be thought of as an augmented design surface where artists use modern technology such as multi-touch interaction, object recognition, augmented physical artefacts as a means of enhancing their artistic creation. At the same time the suite offers a standard desktop based instantiation for usage with traditional interaction means (mouse, single touch) as shown in Figure 124. This composition suite offers a wide range of facilities to artists including:

- **Digital augmented sketchbook:** allows artists to synchronise physical sketches created during their outdoor inspiration activities to their digital sketchbook.
- **Composition surface:** A surface where new compositions can be created using existing elements for various collections. This surface has built in facilities for artists such as build-in grid viewer, perspective grids cropping and framing functionality.

- **Toolbox of elements of design and organisation:** A toolbox with ready to use artistic terms derived for the vocabulary of art and from the principles of organisation.
- **Toolbox of composition schemes:** collected through an extensive overview of the schemes traditionally used by art Masters for achieving an optimal visual arrangement of composition elements. These schemes have been created using a design tool applying their mathematical description.These schemes include golden rectangles (single, encapsulated, encapsulated with spiral), spiral, triangle, trapezoid, circle, ellipsis etc.
- **Collection of sketches:** An online collection of sketches from other artists that can be used either as reference material or for selecting material to be integrated into new compositions.
- **Colour mixer for artists:** Used for producing colour mixes that will be considered the colour scheme to be used when producing the work of art from its composition
- **Cropping and integration facilities:** Used by artists for importing elements to their compositions.

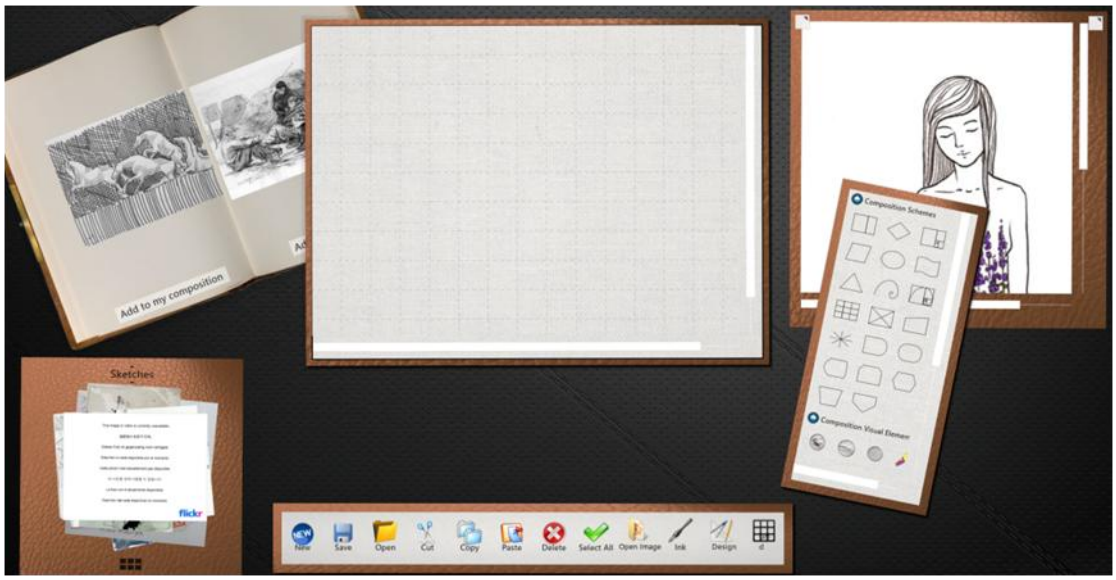


Figure 123. The “Artist’s Composition Suite” for Microsoft PixelSense

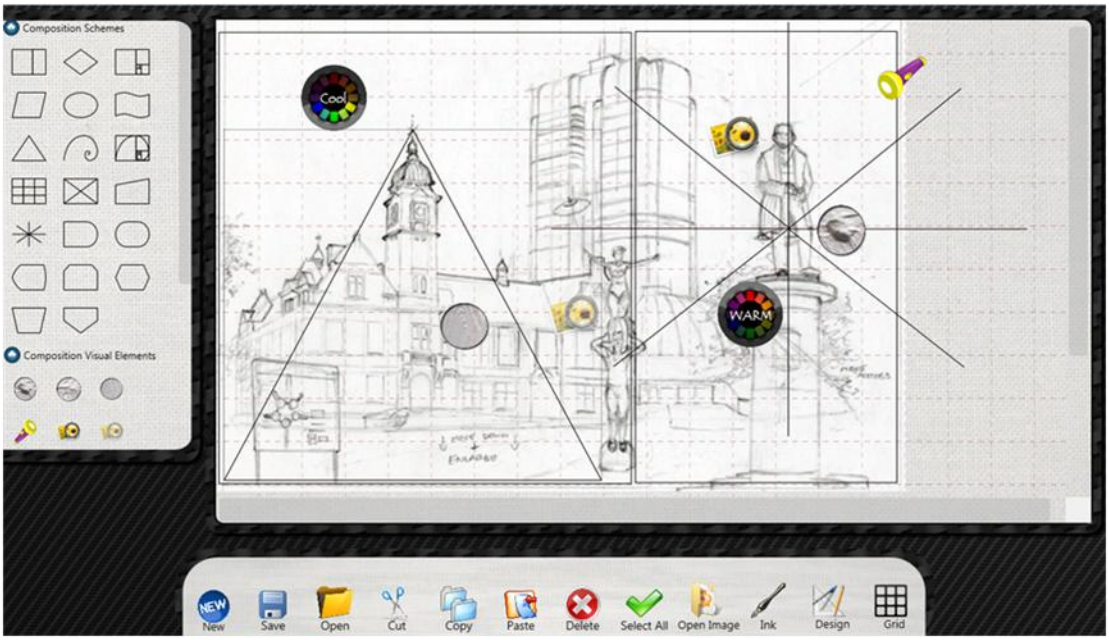


Figure 124. The "Artist's Composition Suite" for desktop use

A Digital augmented sketchbook

Many artists prefer to make preparatory sketches of their subject matter in order to test their composition ideas, or when the creation of a complete painting is not feasible (when painting on the open space, or when someone wants to quickly capture the essence of his subject matter). A sketchbook is a book or pad with blank pages for sketching and is frequently used by artists for drawing or painting as a part of their creative process. A digital augmented sketchbook (see Figure 125) can be though both as a way of preserving handmade outdoor sketches by synchronising such sketches with the augmented composition surface and as a digitised collection of reference material that can be edited or included as are in artistic compositions. In this sense artists are not discouraged for using their traditional sketchbooks as they should but having these sketchbooks synchronised to their suite. At the same time such synchronisation radically increases the potential of actual using old sketches to their work making them easier to locate and protects them from damaging through time.

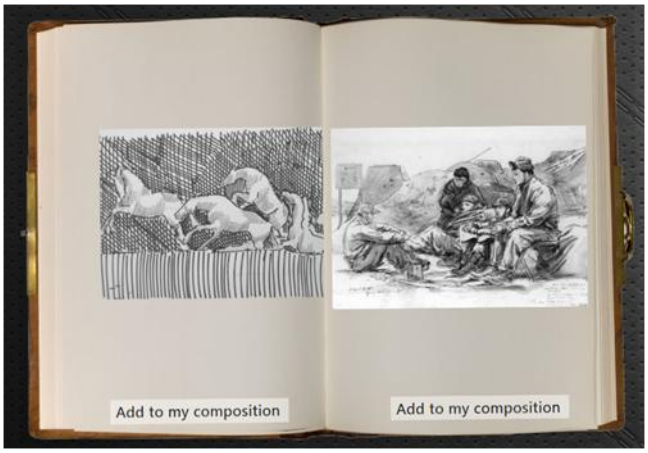


Figure 125. The Artist's Digital Sketchbook

Digitization of sketches

The digitisation of sketches happens by employing the raw image extraction facilities offered through the Microsoft Surface SDK. As shown in Figure 126 the user simply inserts the black and white sketch to be digitised on the control presented on the surface. The application digitises the sketch by capturing the raw image allowing the user to further edit the sketch prior to its insertion to the artist's sketch book.

Figure 126. Physical Media Digitizer

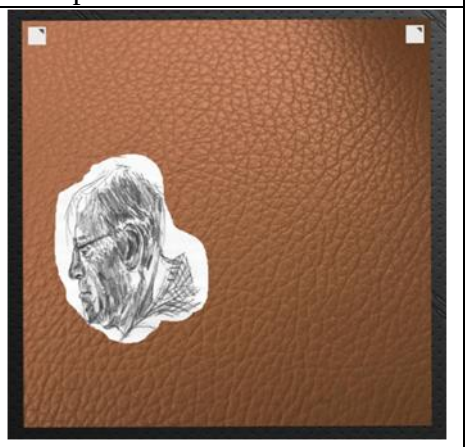
Integration of cloud based collections of artistic material

Flickr is almost certainly the best online photo management and sharing application in the world. This globalised collection of material is a valuable source of artistic inspiration for artists. At the same time collections of sketches and drawings with appropriate licence can be reused as elements of new compositions. In the Online

Gallery provided by the Artist's Composition Suite can be though as an online collection of material. Items dropped to the composition surface can be edited to be imported to new compositions.

A globalised collection of composition elements

Manipulation of online material



Editing and importing material to composition

Figure 127. The Artist's Online Gallery

Elements of Design and Organisation

One of the most important factors in creating successful artistic compositions is having awareness of the tools that could be facilitated in this process as these were defined in the vocabulary of visual arts and in the principles of organisation. Based on this knowledge the practical exploitation and usage of such knowledge in the created compositions can enhance the artistic quality of artist's work. The artists toolbox presented in Figure 128 contains composition schemes derived from geometry such as the golden rectangles and their derived spiral, the rule of thirds etc. At the same time visual elements are present such as light, texture, primary and secondary point of interest etc. Colour concepts are also integrated to the toolbox for allowing the definition by artists of areas where primary, secondary, warm etc. colours should be used in their composition. Finally values can be used by artists to define the value of

colour used for each region while ready to used perspective grids can be used for representing the space where elements of composition will be placed.

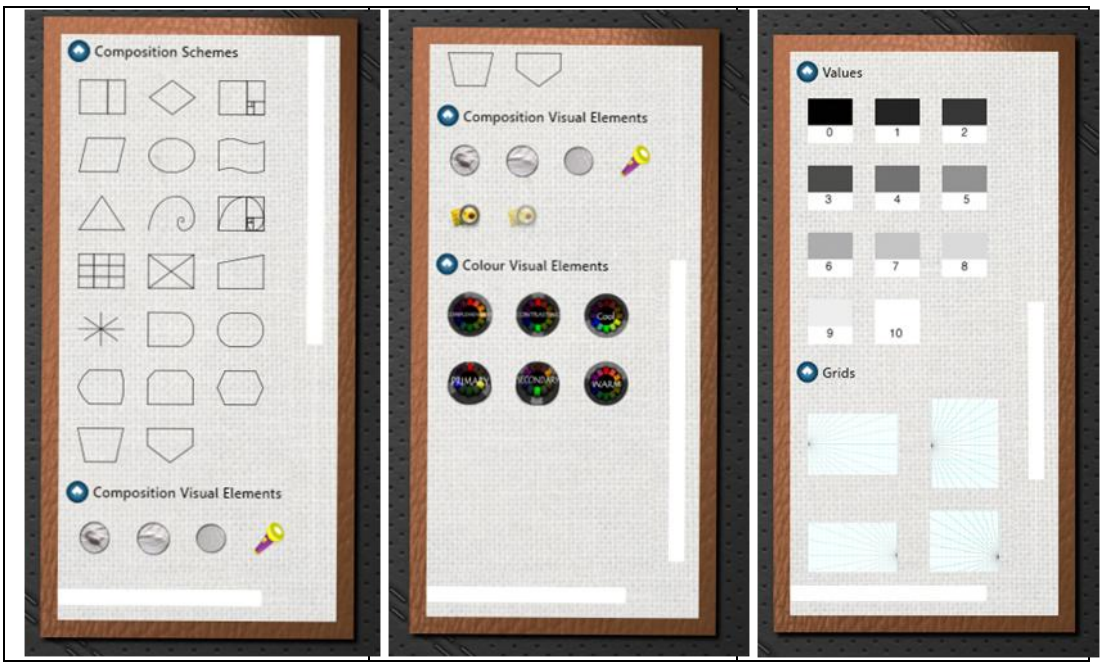


Figure 128. The Artist's Toolbox

Colour schema

Except from the usage of basic colour concepts such as primary, secondary, complementary colour etc. many artists prefer to have a well-defined palette of colours prior to the initiation of their artistic creation. This colour indication is sometimes incorporated into the sketches (for example some artists make preliminary colour sketches in oil or in watercolour outdoors and then use them as a reference for the actual painting). The Artist's Colour Mixer allows artist to digitally mix actual artist's colours from the Winsor & Newton Artists collection [307] and test or integrate these mixtures into their composition.

Figure 129. The Artist's Colour Mixer

Table 19 presents the implementation details of the "Artist's Composition Suite" application.

Implementation Framework	• Microsoft surface SDK 2.0 [230] • Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service

Libraries Used	• "AmiForArtUIToolkit"
	  ○ Colour Manipulation and Mixing
	  ○ Art Composition and Design
	  ○ Sketchbook Control collection
	  ○ Image cropping control
	  ○ The design elements toolbox
	  ○ Physical media digitizer control
	  ○ Menus
	• "CompositionDesignElements"
	• "ColorSpaces"
	• "PigmentColorMixing"

Hardware supported	• Microsoft PixelSense – Samsung SUR-40 • Desktop pc with touch screen
Interaction Schemes	• Multi Touch & gestures • Augmented physical objects ○ Sketches

Table 19. Implementation details for the "Artist's Composition Suite"

Putting it all together

Using the aforementioned facilities artists can create ready to use compositions through the facilitation of well-defined artistic concepts. The elements used or assigned to a composition get integrated to the final outcome which allows all the process to be maintained for future use. In the same manner the facilities provided by the Artist's Composition Suite can be used to extract composition by existing works

of Art and therefore be used for understanding and teaching art in the context of educational activities.

Using Artist's Composition Suite to highlight the composition of "The Calling of Saint Matthew"

The Calling of Saint Matthew is one of the most beautiful paintings, painted between 1599 and 1600 by the painter Michelangelo Merisi da Caravaggio, better known under the name of Caravaggio. The painting is now exposed to its original location, in the chapel of the church Contarelli Saint-Louis-des-French of Rome and is part of the monumental paintings artist by its dimensions (322 x 340 cm). This demonstration is based on an analysis of the painting to reconstruct its composition [295]. The result of using the elements provided by this Suite to reconstruct the composition as assumed to be used by Caravaggio is presented in Figure 130.

Figure 130. The composition reconstructed by "Artist's Composition Suite" in conjunction with the analysis of the painting [295]

8.1.2.2.2 The Augmented Painting Surface

The "Augmented Painting Surface" is the application that provides real time support of the Artist during the art creation process. This is achieved through the augmentation of the artist's creative process. In this sense the surface is a cavalette or a wall where a virtual painting frame is projected. The artist can align his canvas with the painting frame allowing interaction to happen within the canvas. In this sense the canvas of the artist becomes not only the area where the creativity is unfold but at the

same time a fully capable multi touch surface. Therefore information can be projected at real time within the painting surface allowing the artist to test inline artistic concept project compositions and paintings. In the same context the areas on either side of the canvas get enriched with assistive facilities. An example of the "Augmented Painting Surface" is presented in Figure 131.

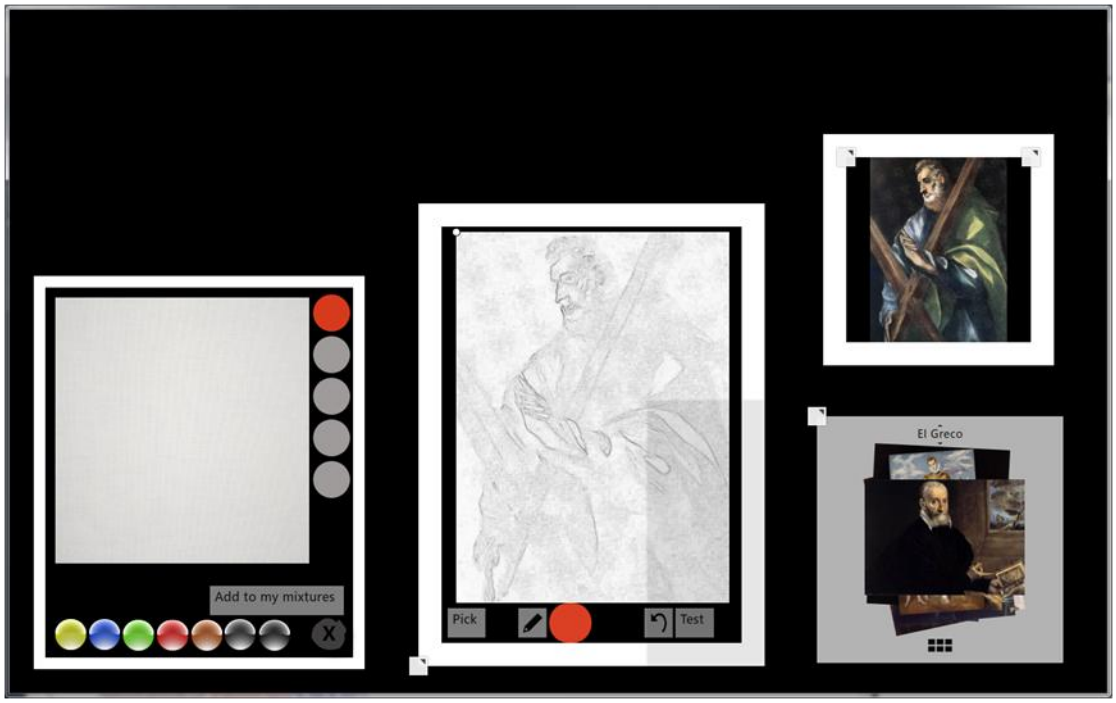


Figure 131. The "Augmented Painting Surface"

The augmented "Augmented Painting Surface" offers a number of accessories to the artist each of them assisting to the creation of a unique artistic experience. Through the canvas menu the artist can select the preferred assistants to be displayed while the rearrangement and manipulation of elements happens through touch on the wall itself.

The Collections Browser

The collections browser is a gallery providing access to collections of reference material to the artist. This reference material can consist of famous paintings by other artists, photos, sketches etc. The material can be dragged and dropped within the augmented surface allowing the artist to post process the selected artefacts. A dropped material offers a multitude of artistic operators that can be applied. At the same time the artefact itself after the appropriate post processing can be projected within the canvas for tracing or reference. An example of such a reference material and its accompanying post processing facilities is presented in Figure 132.

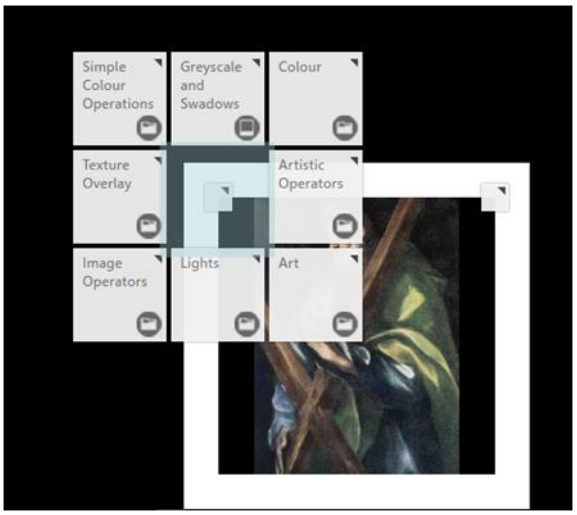


Figure 132. The Artistic Concept menu of the "Augmented Painting Surface"

The Artist's Colour Mixer

The Artist's colour mixer provides facilities for simulated mixing of colours prior to the creation of real colour mixtures and their application on the surface (see Figure 133). To this end through this assistant the artist can mix colours using the colour mixer apply them virtually on his painting surface and then add these mixtures to the collection of mixtures for the specific painting.

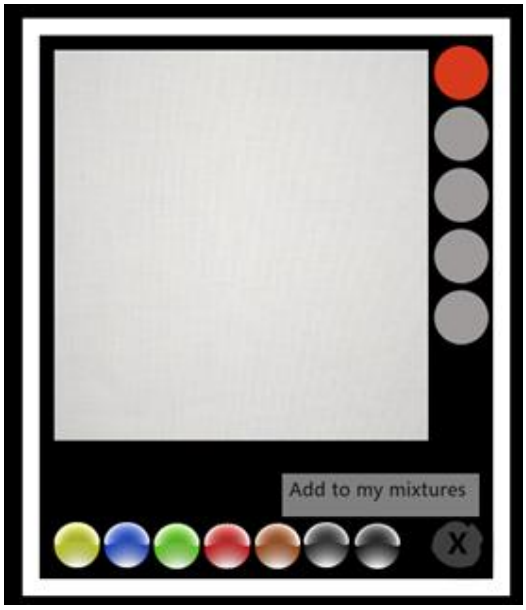


Figure 133. The Artist's "Colour Mixer"

The collection of colour mixtures created by the artist is presented in Figure 134. After the completion of the virtual mixing process the artist can select the mixtures

one by one by his mixed palette and produced the actual colour mixtures to be used during the painting process.

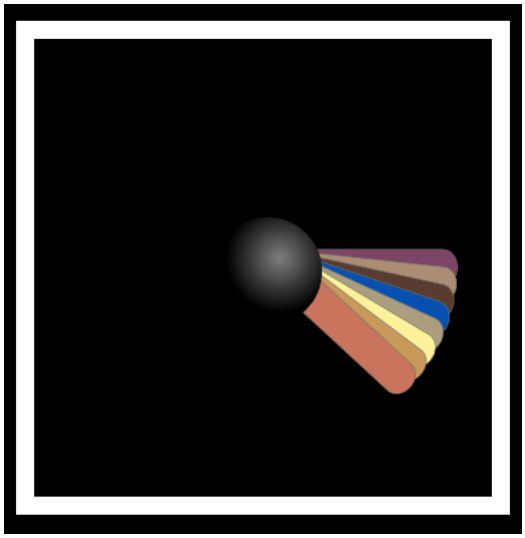


Figure 134. The Artist's mixtures

The Artist's Colour Wheel

The "Artist's Colour Wheel" shows primary, secondary, tertiary, warm, cool and complimentary colours as used in colour theory when painting (see Figure 135). Having a colour wheel instantly available while painting is essential, for assisting artists to mix, determine the appropriateness of and select colours.

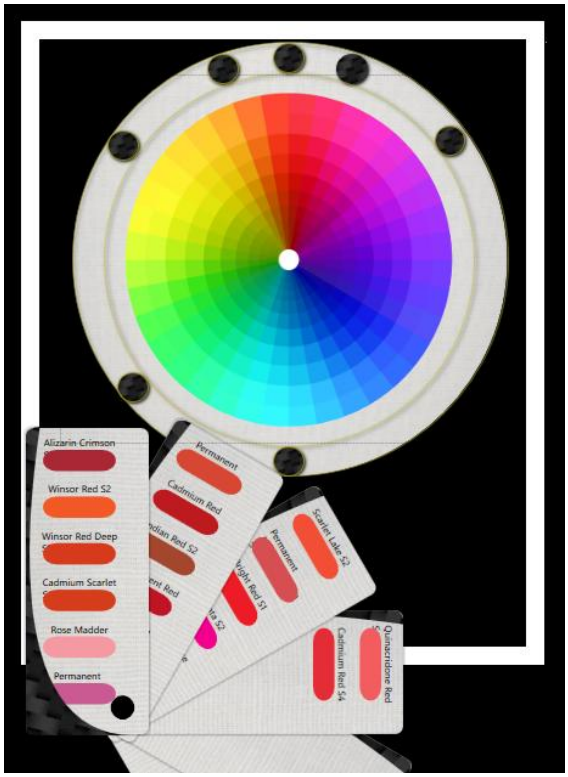


Figure 135. The embedded Colour Wheel

The Artist's Composition Views

The "Augmented Painting Surface" has the ability to present compositions created for painting using either the "Artist's Composition Suite" or the "3D Composition suite" presented later. Examples of created compositions as transferred for painting are presented in Figure 136. Transferred compositions can be used as reference material for sketching or projected after the application of artistic concepts to the painting surface.

Figure 136. View of the Created Composition

Table 20 presents the implementation details of the "Augmented Painting Surface" application.

Implementation Framework	• Microsoft surface SDK 2.0 [230] • Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "KinectMultiTouch" service • "artServer" service
Ami Services implemented	• "artClient" service • "artLogger" service
Libraries Used	• "AmiForArtUIToolkit"

	○ Colour Manipulation and Mixing ○ Image filters control ○ Augmented Painting Canvas control • "ArtFilters" • "ArtShaders" • "ColorSpaces" • "PigmentColorMixing"
Hardware supported	• Microsoft Kinect • Desktop pc • Short throw projector
Interaction Schemes	• Multi Touch & gestures

Table 20. Implementation details for the "Augmented Painting Surface"

8.1.2.2.3 Design time assistants

In this section a number of support applications that aim at facilitating the artist while being on the creative process are presented. To this end the presented application are intended to assist in quickly carrying out peripheral tasks allowing the minimum loss of artist focus from his actual subject matter. Many of these applications affect the way that artist controls colour which is considered to be of fundamental importance. It is proven from theoretical studies that painting consists a more difficult task for the human brain because the focus must be put both in selecting the appropriate colours (mixing paints checking values and hues against the painting) and on applying these colours to form the subject matter. The limitation of the time between these transitions is critical for maintaining the artists focus on what's important in art. The assistants presented in this section can be used as autonomous services or be used by their integrated into the "Augmented Painting Surface" forms.

Artist's Colour Mixer

Colour mixing can be fascinating, fun or frustrating, depending on the knowledge and experience of each artist. To find out which paint represents the various colours artists tend to read the manufactures information, books on colour, other people's advice or some detective work themselves. Accomplished artists frequently advice apprentices that learning comes from experimentation rather than referring to instructional material (although they do not misjudge the value of such material). The Artist's Colour Mixer is a valuable tool for Artists during the art creation process but also an

educational tool for art students and young artist to practice and exercise their skills on colour mixing. In this sense it can be used for: The "Artist's Colour Mixer" does exactly that by allowing artists to experiment on colour mixes through an interactive application without having to "get their hands dirty". The application extracts the colour and pigment information from the ontology while using specific colour space transformations to accomplish colour mixes that can resemble the qualities of actual pigments. Acting as a deployed Famine service "Artist's Colour Mixer" can be used to test colour schemes for an artefact under development and use this information for making the appropriate mixtures when moving from designing to art creation. A snapshot of the "Artist's Colour Mixer" is presented in Figure 137. As shown in this figure on the left side of the application gesture are supported (by dragging up on the left side adds the mixture to the painting's colour mixtures).

Figure 137: Screenshot of the "Artist's Colour Mixer"

Table 21 presents the implementation details of the "Artist's Colour Mixer" application.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service

	• "UserAwareness" service • "ContextAwareness" service • "KinectMultiTouch" • "artServer" service
Ami Services implemented	• "artClient" service • "artLogger" service
Libraries Used	• "AmiForArtUIToolkit" ○ Colour Manipulation and Mixing • "ColorSpaces" • "PigmentColorMixing"
Hardware supported	• Touch panel pc • Microsoft PixelSense – Samsung SUR-40

Interaction Schemes	• Multi Touch & Gestures
	• Augmented objects
	  ○ Brushes
	  ○ Paint tubes

Table 21. Implementation details for the "Artist's Colour Mixer"

Artist's Colour Wheel

The "colour wheel" application incorporated on the artist's creative space offers real time support when creating art. The Colour Wheel can help artists understand the use of colour in art, illustration and design. The Colour wheel shows primary, secondary, tertiary, warm, cool and complimentary colours as used in colour theory when painting:

- **Complementary Colours:** These are the hues which sit directly opposite each other in the colour wheel. For example purple and yellow, red and green. Colour complements are colour opposites and contrast each other in the most extreme way.
- **Secondary colours** originate from primary colours. They are a result of mixing two primary colours of equal amounts. Secondary colours are therefore dependent on the selected primary colours. If blue and yellow are primary colours and mixed together, then green is a secondary colour.
- **Tertiary colours** are a **result of mixing** one primary and one secondary colour of equal amounts. Tertiary colours therefore are also dependent on the selected primary colours.

In painting these theories apply regardless of the media. The trouble with most 'colour wheels' is that they show the colours but not the name of paint that represents that colour. The “Artist’s Colour Wheel” is an interactive colour wheel that can be used as an assistant by artists that associates actual pigments with regions of the colour wheel. This is achieved through the presentation of a colour wheel as the ones used by artists and the collections of colours per colour wheel area. In this way artist can select an actual pigment colour from their swatch and compare it with the “ideal” colours presented on the wheel. An example of the prototype for allowing the artist to check the relevance of a pigment red with the reds of the wheel is presented in Figure 138.

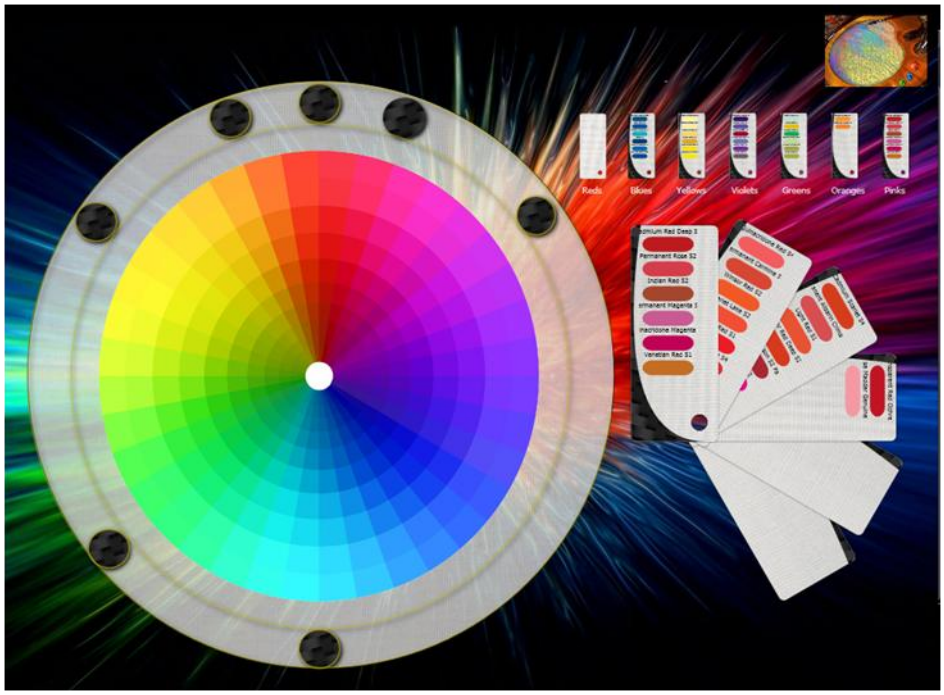


Figure 138: Screenshot of the “Artist’s Colour Wheel”

Table 22 presents the implementation details of the “Artist’s Colour Wheel” application.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• “AmiForArtModel” Service • “UserAwareness” service • “ContextAwareness” service • “artServer” service
Ami Services implemented	• “artClient” service

	• "artLogger" service
Hardware supported	• "AmiForArtUIToolkit" ○ Colour Manipulation and Mixing • "ColorSpaces"
Hardware Used	• Desktop pc with touch screen • Touch panel pc • Microsoft PixelSense – Samsung SUR-40 • Tablet pc
Interaction Schemes	• Multi Touch & Gestures • Augmented objects ○ Paint tubes

Table 22. Implementation details for the "Artist's Colour Wheel"

Art Supply Wizard

Many artists use reference material when painting in order to access information about techniques, colours, composition schemes and ideas, get inspired by a painting or picture etc. To assist in getting the appropriate reference material contextual information is employed such as (a) What kind of art is developed (portraiture, landscape etc.), (b) what medium is used, (c) what support type is used, (d) what is the artist expertise and (e) knowledge from past works of the artist. Using such information knowledge can be extracted from the model (residing on the ambient environment), or generated from searching the web. The "Art Supply Wizard" is an artist assistant that allows artists to get informed about the qualities of their painting material during the art creation process. A typical example of using such an application is when required to use a transparent colour over an opaque layer of paint or when wishing to get informed about the drying time of a specific painting medium. The "Art Supply Wizard" offers an interactive surface where tangible objects such as painting, mediums brushes etc. can be placed to reveal their secrets. An example of using the "Art Supply Wizard" to access information about a paint tube is presented in Figure 139.

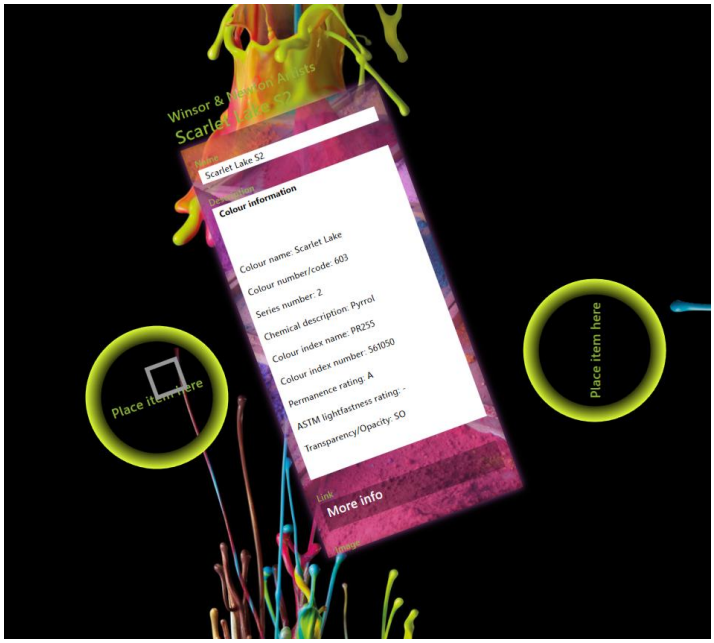


Figure 139: Using "Art Supply Wizard" to identify the properties of a paint tube

Table 23 presents the implementation details of the "Art Supply Wizard" application.

Implementation Framework	• Microsoft Visual C# [232] • Microsoft surface SDK 2.0 [230] • Windows Presentation Foundation (WPF) [231] • "ItemCompare" Surface SDK 2.0 sample [338]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service • "artLogger" service

Libraries Used	• "AmiForArtUIToolkit"
	  ○ tag comparing control collection
	  ○ Html RichTextBox
	  ○ Rotatable Web Browser

Hardware supported	• Microsoft PixelSense – Samsung SUR-40

Interaction Schemes	• Multi Touch & Gestures
	• Augmented objects
	  ○ Painting material (paint tubes, brushes, mediums)
	  ○ Artists tags
	  ○ Art styles tags

Table 23. Implementation details for the "Art Supply Wizard"

8.1.2.3 Painting from life (using a model)

Another popular approach to painting is by using a model or using a physical composition of items as a model. This section presents the usage applications implemented by this research work to support the painting activities involved when painting from life.

8.1.1.3.1 Arrangement of subject matter

Creating a composition when working with physically present models (for example human models or objects for setting up a still life) entails the need of an enclosed space where the artist has absolute control over several things such as lighting, subject matter positioning, posture, etc. In the model's area, the artist can set-up his subject matter, preview his composition and make the appropriate arrangement for producing the desired results.

8.1.1.3.2 The Lights Controller

In the context of the Ambient Art Workshop, the model's plane offers the hardware and software infrastructure for enabling full control over the available lights. To this end, an interactive application running on the artist's plane offers the facilities for controlling direction – intensity and colour of lights. More specifically the artist using this infrastructure can:

- Control lighting through setting lighting colour, intensity and direction (through a hardware interface communicating to the available spot lights and servo mechanisms)
- Control lighting through the usage of pre-sets: using this facility the lighting can be automatically arranged to achieve the desired lighting for several commonly used schemes such as for example the three quarter view portrait.

- Save colour pre-sets: the pre-sets facility can be used for allowing the artist to save a lighting scheme upon the manual configuration of lighting.

The lights Controller is programmed to be implemented in the future extensions of this research work.

8.1.1.3.3 The Composition Framer

As presented in section 7.1.1.1.3 the way that a composition is framed is important for allowing the artist to achieve a number of goals. The "Composition Framer" building on this knowledge allows an artist to take control of the framing and separate the actual subject matter from the space not involved in their creation. This application runs on the augmented painting surface where the contents of the Model's plane are presented (see Figure 140). In this screen a virtual frame is presented allowing the artist to increase or decrease the size of the frame and move it to set up the point of interest of his composition. Therefore using touch artists can limit their visual space to the one that will appear on their composition. This concatenation can be also be related to the actual painting support used for their creation. An example of such a framing process via the "Composition Framer" is presented in Figure 141.

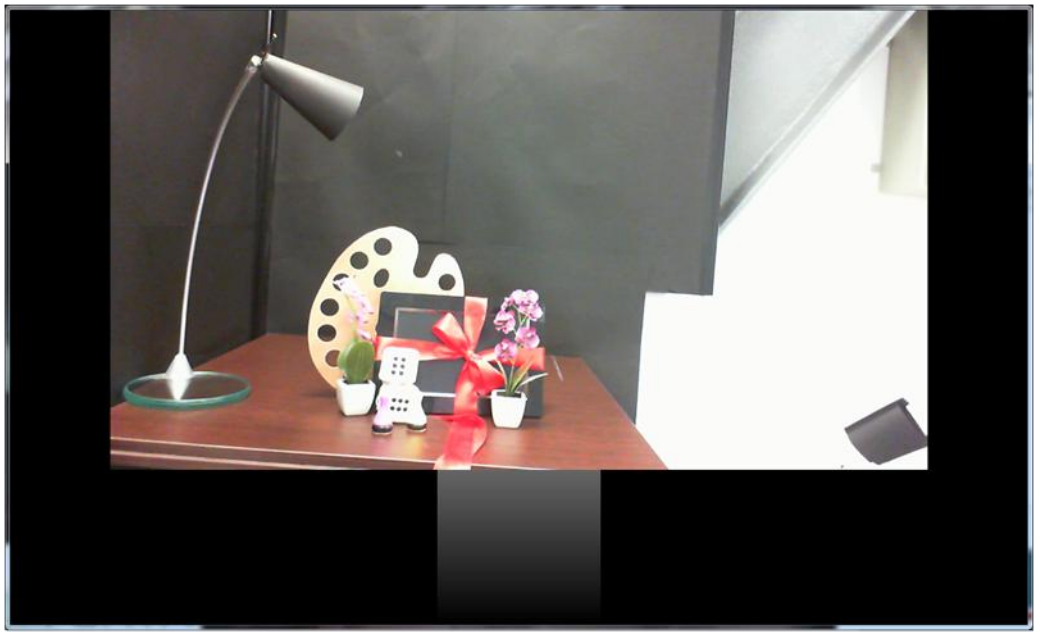


Figure 140: View of a created composition

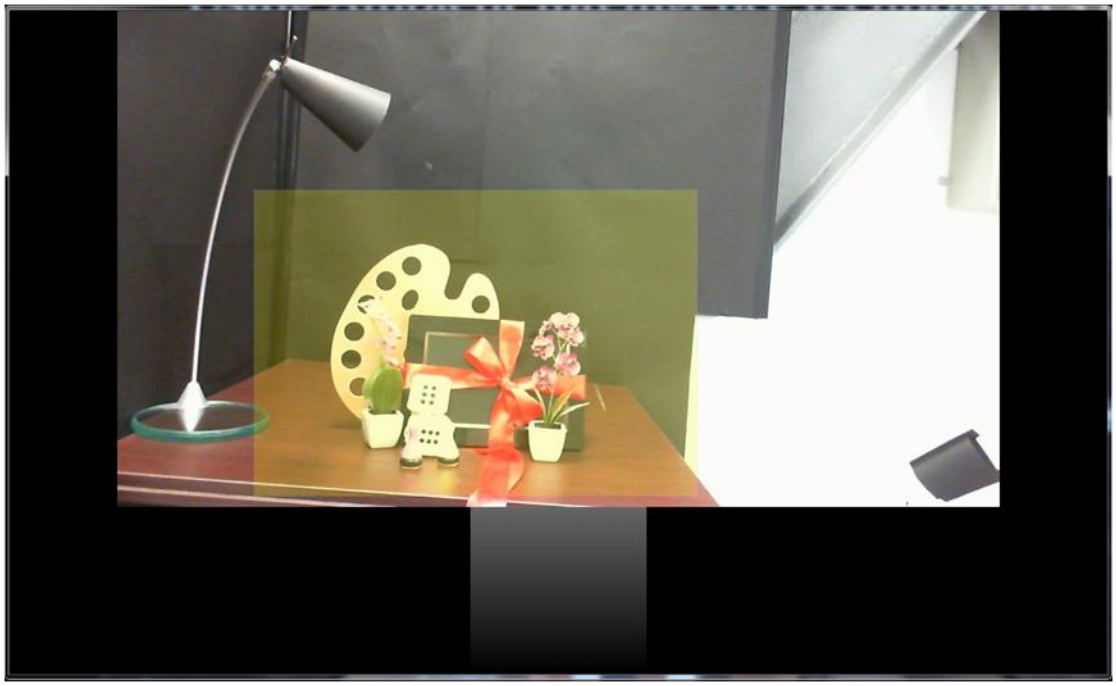


Figure 141: Framing a rectangular composition using the "Composition Framer"

Table 24 presents the complete set of implementation details for the "Composition Framer" application.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" • "UserAwareness" service • "ContextAwareness" service • "KinectMultiTouch" • "artServer" service
Ami Services implemented	• "artClient" service • "artLogger" service

Libraries Used	• "AmiForArtUIToolkit"
	  ○ Camera manipulation-capturing and framing
	  ○ Image cropping control

Hardware supported	• Desktop pc with touch screen • Desktop pc • HD camera • Kinect Sensor • Short throw projector

Interaction Schemes	• Multi Touch & Gestures ○ Pointing: One hand gesture for object selection ○ Drag: One hand gesture for controlling the position of the frame ○ Increase – decrease: Two hand gesture for controlling the size of the frame

Table 24. Implementation details for the "compositionFramer" Prototype

8.1.1.3.4 The Augmented Painting Surface

Having the subject matter arranged and the composition frame adjusted the artist can move to the creation of the final work of art. This process employs the "Augmented Painting Surface" presented previously. The surface in this case employees contextual and task based information to adapt the painting surface. The framed composition becomes available within the surface allowing the artist to use the desired sketching process for creating the initial sketch (project the composition on the surface, use a tracing grid, look at the composition to create a free hand sketch etc.).

8.1.2.3 Painting from pictures

Painting from picture is an area of dispute among Artists. This research work doesn't step into deciding whether it is a good practice or not but provides the means to facilitate such process as an alternative painting scenario.

8.1.2.3.1 The Artist's Concepts Designer

Using image processing software in painting is preferred by some artists for allowing them to quickly evaluate sketches, apply image processing filters into pictures and even creates compositions by combining elements from digital media. Although this process is a source of great dispute many tend to think that image processing software do not restrict but can enhance artist's creativity. Many artists prefer to paint from pictures in various occasions (when the model can't pose or when a composition is created by mixing fragments from other compositions). When this type of painting is selected, then the "Artist's Concepts Designer" can be employed. The "Artist's Concepts Designer" offers an interactive surface for artists where material can be located from known sources or extracted dynamically from the internet. At the same time a suite of artistic concepts has been specially designed for artists through the combination of several image processing techniques. These ready to used concepts can be applied into photographs allowing the artist to easily evaluate several concepts.

The "Artist's Concepts Designer" can be used both in the case of the painting by pictures process or be combined with the "Artists Composition Suite". An example of the "Artist's Concepts Designer" is presented in Figure 142 while Figure 143 presents its desktop based instantiation.

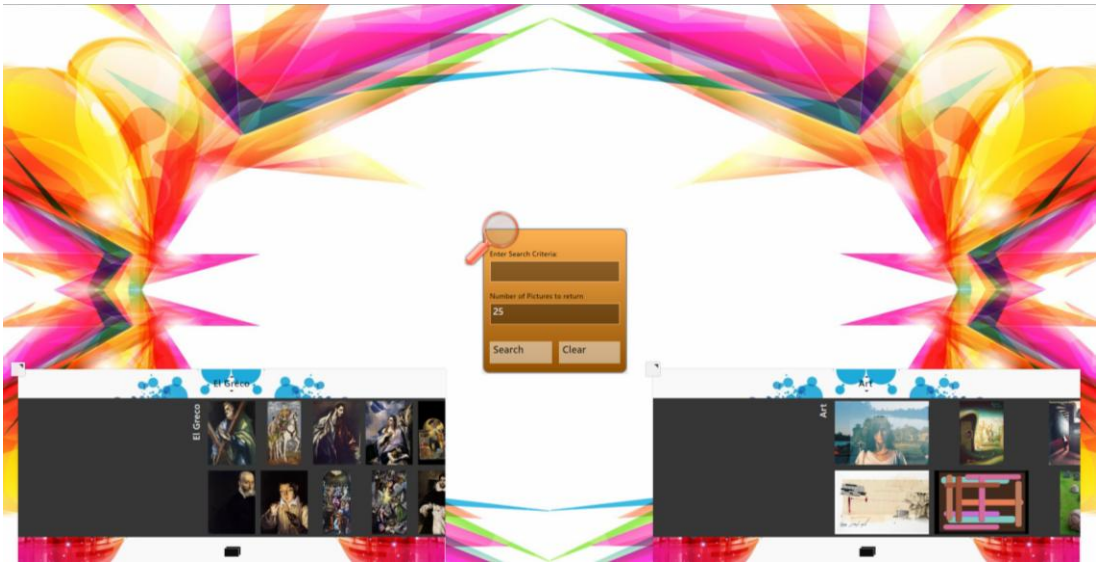
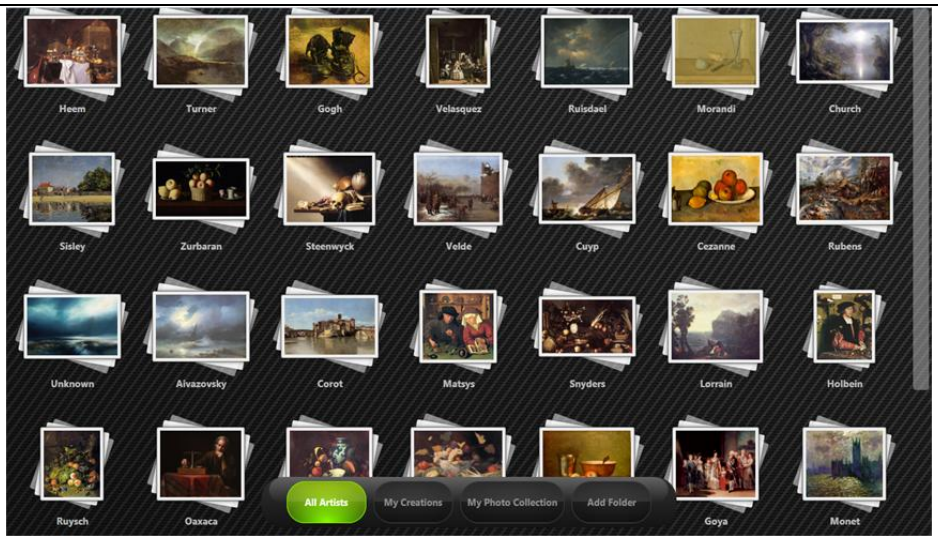


Figure 142. The Artist's Concepts Designer



Collections of Artefacts on the Design Space

Browsing a collection of Artefacts	Concepts Designer

Figure 143: Desktop based (single touch version) of concepts designer

As shown in this figure two are the main start-up components available for picture browsing. The one is the “The Masters Collection” while the other is the “The Social Repository”.

The Masters Collection

With the “Artist’s Concepts Designer” the masters collection is a source of inspiration from the past. This collection contains paintings created by the most prominent artists of the past and can be used both for inspiration but also for educational purposes. One the most important part of succeeding as an artist is being able to copy the masters of the past in a process of learning through re-inventing the solutions followed within famous paintings.

The Social Repository

Flickr is almost certainly the best online photo management and sharing application in the world. This globalised collection of material is a valuable source of artistic inspiration for artists. At the same time collections of sketches and drawings with appropriate licence can be used as a base for new painting projects. The Online Gallery provided by the “Artist’s Concepts Designer” can be though as an online collection of material.

The Social Search Component

Artists are also provided with the ability to bypass the build in collections offered and do their own searching for reference material. In this case search queries are

transmitted to Flickr and the results are dropped to the surface in the form of photos for manipulation. An example of submitting a search for the tern "Modern Art" is presented in Figure 144.

Figure 144: Using the social search component

Manipulating Photos

The artist can drag items from this collection to the surface. These items are in turn enriched with a menu of available artistic concepts that can be applied by the artist. The ones that the artist wishes to keep for considering a number of alternative possibilities can be in turn dropped again in the surface (see Figure 145).

Figure 145: Applying artistic concepts to a picture while preserving a previously applied concept

Using Mobile Devices

Mobile devices can be are considered an important source of material for the "Artist's Concepts Designer". Pictures taken by the artist can be transferred from the device to the designer and in turn post processed by the artist to achieve the desired results.

Implemented Artistic Concepts

The complete list of image processing operations that can be applied via the "Artist's Concepts Designer" prototype is presented in Table 25. This table presents the filter together with their implementation details.

Simple Colour Operations	
Invert	AForge Image Processing Library
Rotate	
Sepia	
Extract Red Channel	
Extract Green Channel	
Extract Blue Channel	
Red	
Green	
Blue	
Cyan	
Magenta	
Yellow	
Texture Overlay	
Clouds	AForge Image Processing Library
Rust	
Dirt	
Labyrinth	
Wood	
Marble	
Textile	
Flip	
Flip Horizontal	Custom Pixel Shader running on the GPU
Flip Vertical	
Flip Both Directions	
Artistic Operators	
Anaglyph	Custom Pixel Shader running on the GPU
Show brush-strokes (Darken)	AForge Image Processing Library
Show brush-strokes (Lighten)	
Highlight texture	
Old photo	Custom Pixel Shader running on the GPU
Triptych	
Glass tiles	
Water	
Water Calm	
Water Wave	
Image Operators	

Blur	AForge Image Processing Library
Sharpen	
Smoothing	
On Canvas	
Canvas	AForge Image Processing Library
Canvas Grayscale	
Canvas Sepia	
Comics	
16 Colours	AForge Image Processing Library
32 Colours	
64 Colours	
Sponge teqniques	
Soft	AForge Image Processing Library
Soft (with colour)	
Medium	
Medium (with colour)	
Thick	
Thick (with colour)	
Oil Painting	
Small strokes	AForge Image Processing Library
Medium strokes	
Large strokes	
Drawing	
Thin lines	AForge Image Processing Library
Medium lines	
Thick lines	
Preserve colour indication	
In colour(Thin Lines)	
In colour(Medium Lines)	
In colour(Thick Lines)	
Old drawing	Custom Pixel Shader running on the GPU
Sketch granite	
Sketch pencil	
Posters	
Small regions	AForge Image Processing Library
Medium regions	
Large regions	
Watercolour Small regions	
Watercolour Medium regions	
Watercolour Large regions	
Watercolour	
Watercolour bright	Custom Pixel Shader running on the GPU
Mosaic	
Small psifida	Custom Pixel Shader running on the GPU
Medium psifida	
Large psifida	
Round psifida	
Pop Art	
Pop Art (Red Gren Blue)	AForge Image Processing Library
Pop Art (Pink Violet Orange)	

Pop Art (Yellow Mauve Orange)	
Pop Art (Pink Blue Orange)	
Pastels	
Pastel Pencil Drawing	Custom Pixel Shader running on the GPU
Pastel Sticks	
Lighting	
Lighting	Custom Pixel Shader running on the GPU

Table 25. Available image processing filters

Table 25 presents the complete set of implementation details for the "Artist's Concepts Designer" application.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231] • NoteTable sample [233]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service • "artLogger" service

Libraries Used	• "AmiForArtUIToolkit"
	  ○ Image filters control
	  ○ Social Search Control
	  ○ Menus
	  ○ Image library containers
	• "ArtFilters"
	• "ArtShaders"
	• "WebSearch"
	• "SocialSearch"
	• "MobileSync"

Hardware supported	• Microsoft PixelSense – Samsung SUR-40 • Desktop pc with touch screen
Interaction Schemes	• Multi Touch & Gestures

Table 26. Implementation details for the "Artist's Concepts Designer"

8.1.3 Art Preservation

Although the process of developing art is fundamental for this research work there is also important to consider the possibilities towards facilitating the preservation and distribution of art. Research has dedicated years for revealing the techniques used for creating the masterpieces of the past and much of this knowledge still remains a mystery because of the lack of proper documentation techniques. By facilitating the information stemming from the art creation process it is possible to automatically generate the documentation to accompany the painting.

8.1.3.1 The diary of a master piece

The diary of a master piece aims at dynamically forming a collection of knowledge that represents the process of creating a masterpiece from the phase of composition to its actual creation and framing. Information that is extracted from the creative process includes: (a) the painting supplies used (paints, canvases, brushes, mediums etc.), (b) the way that the composition was arranged (objects arrangement, lighting and framing details), (c) the actual painting process etc. All these steps are accompanied with additional information such as photos taken by the artist representing important intermediate steps, notes kept by the artist etc. The material collected by this application can be used in a number of directions such as the automatic generation of instructional material or art documentaries. For example using such information the artist could author a tutorial based on a painting he created in some past painting session. Figure 147 shows the painting details of a painting recorder by the “Diary of a master piece”.

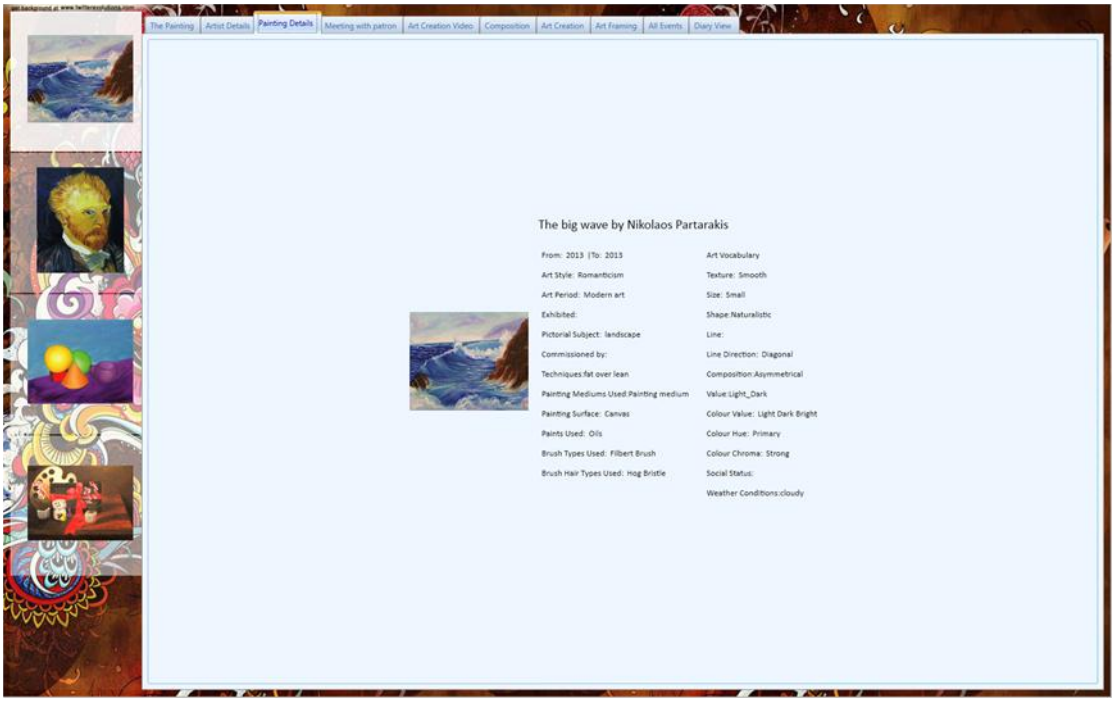


Figure 146: The diary of a master piece – Painting details

At the same time the application can generate the so called diary view of the painting's creation allowing users to view the steps followed by the artist in conjunction to the phases of creation (see Figure 147).

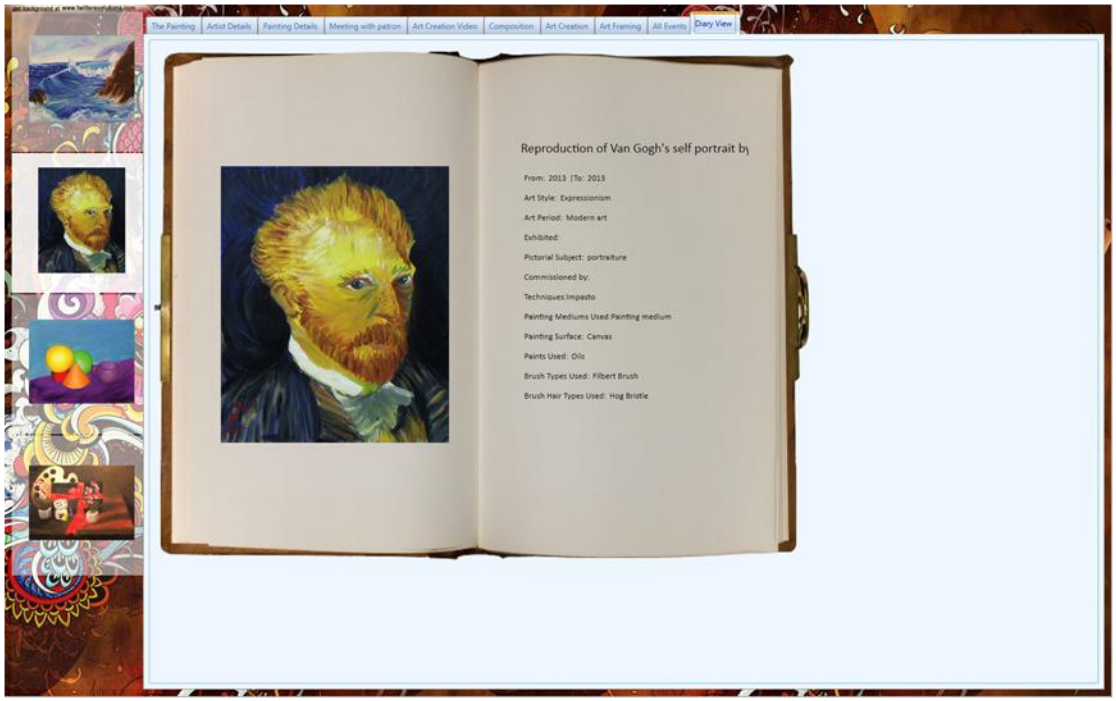


Figure 147: The diary of a master piece – Painting Diary

Table 26 presents the complete set of implementation details for the "Diary of a master piece" application.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service • "artLoggerServer" service
Libraries Used	• "AmiForArtUIToolkit"
Hardware Used	• Desktop pc
Interaction Schemes	• Touch

Table 27. Implementation details for the "Diary of a master piece".

8.1.4 Displaying artwork: The painting frame

The frame is an important element needed to be taken into account when appreciating art. Paintings have been framed ever since the portable image was invented, i.e. since imagery ceased being permanently fixed into the wall and became mobile, hung according to the whim of the owner. It is definitely the frame that gives to painting its known window effect, inviting us to peep into a different reality. In fact it is such a natural accompaniment to painting that the sudden absence of framing gave in itself to modern painting an important and surprising new dimension. The painting is hemmed in by the frame, which consequently has the potential of serving as gradient transition, enclosure or obstacle. Too often the frame leads us astray or calls for the attention itself [39]. The selection of the appropriate frame is a vital part of getting the most from the artefact mainly through the special attributes of frames already presented. To this end the existence of facilities that enable to preview several frame setups is considered essential. The "Painting frame" application is running on the augmented painting surface and presents a virtual adjustable painting frame. The frame itself can be scaled to cover the area covered by the painting while the colour of the frame can be also selected and previewed. In this sense the Artist can preview a work of art hanged and framed therefore in the ideal conditions for selecting the most appropriate painting frame. An example of using the "Painting frame" for rendering a frame around a painting is presented in Figure 148.

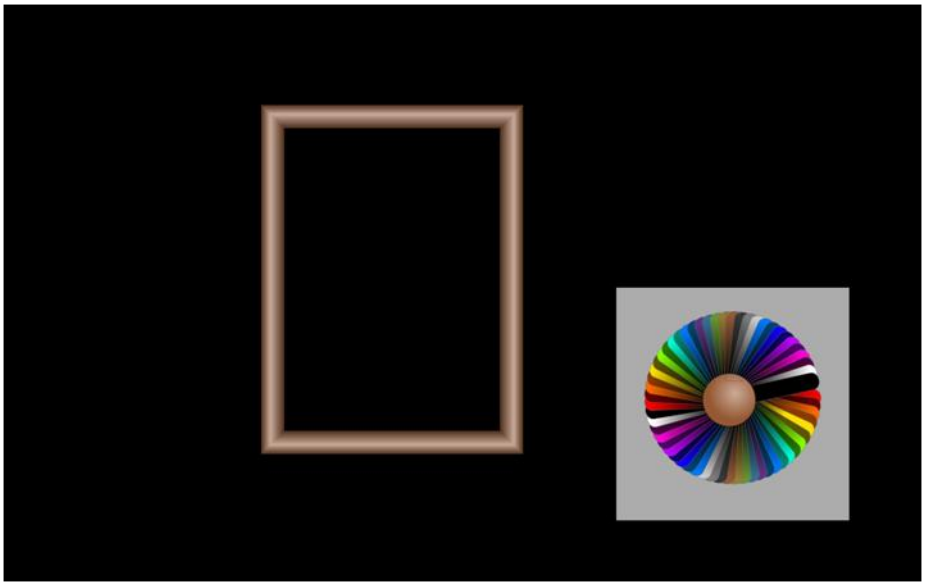


Figure 148: Projecting a virtual frame using the "Painting frame"

The complete set of implementation details for the "Painting frame" application is presented in Table 28.

Implementation Framework	• Microsoft surface SDK 2.0 [230] • Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "UserAwareness" service • "ContextAwareness" service • "KinectMultiTouch" • "artServer" service
Ami Services implemented	• "artClient" service • "artLogger" service

Libraries Used	• "AmiForArtUIToolkit"
	  ○ Painting frame control
	  ○ Colour Manipulation and Mixing
	• "ColorSpaces"
	• "PigmentColorMixing"

Hardware Used	• Microsoft Kinect • Desktop pc • Short throw projector
Interaction Schemes	• Multi Touch & gestures

Table 28: Implementation details for "Displaying Artwork"

8.2 Art & Education

This section introduces academic education in fine arts in order to highlight the essentials that should be taught to young artists in the context of their academic education. Based on this background information the ways that the Ami oriented facilities developed in the context of this research work can be employed to facilitate the educational process is outlined.

8.2.1 Academic Education in Fine Arts

8.2.1.1 Bachelor in Painting

Academic education programs in universities are focusing primarily on drawing and painting as fundamental facets of a visual arts education. These usually make up a major portion of the foundation program. During these programs students study perspective and spatial relationships through geometric forms, including the cube, the cone, the sphere, and the cylinder, and work with more complex variations of these forms as they relate to the human figure, one of the most fascinating and challenging artistic themes, in anatomy and drawing classes.

Though there have been profound changes in the art world, painting programs also promote painting in its varied manifestations as a fundamental form of visual and artistic expression. At the same time studio activity, with students exploring various forms of painting is encouraged in order for students to develop an individual vision.

Students are also encouraged to explore painting's elements of colour, light, space, volume, tone, texture, and composition through still-life, landscape, and invented motifs. In addition, instructors place emphasis on composing from memory and imagination, allowing art students to give personal expression to what they have learned.

8.2.1.1 Master of Fine Arts in Painting

Master of Fine Arts (MFA) in Painting programs are sometimes combined with studies in drawing, but students may concentrate their efforts on painting. Students can learn painting theories and techniques in their classes and experiment with various artistic methods during studio sessions. They are encouraged to develop unique visions and painting styles. Graduates are prepared to enter professional art careers.

Students can study historical and contemporary developments in painting. Techniques for analysis and criticism of artwork can be developed through a specialized art

vocabulary. Enrolees may study visual arts aspects, such as shape, colour, composition, quality and the creation process.

Such programs give students many opportunities to personally grow as artists. They'll have access to a variety of facilities and artistic materials, including oil, acrylic and watercolour paints. Additionally, they can practice printmaking and other art forms. Collaborative projects with faculty, fellow students, visiting artists and other art professionals may be possible.

Individuals may develop ideas through series of paintings. In order to complete a program, students must typically create an original exhibition of their artwork and write a master's thesis.

8.2.2 Ami oriented Art Education

Ami oriented Art Education stands for the effort put by this research work to understand the processes and techniques of academic art education and to provide the means that the unique framework provided by this research work can be employed for facilitating academic training in art.

8.2.2.1 Art History, mediums and supplies

In the context of this research work important aspects of academic education in painting include knowledge regarding:

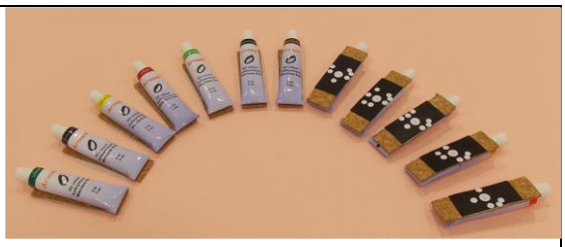
- artists, movements and styles that influenced art
- pigments, paints, mediums and in general material used for art creation
- colour theory and it practice
- colour mixing and pigment qualities
- composition and perspective
- studio practice
- etc.

8.2.2.1.1 Art Compare

The “Art Compare” covers the need of young artists to gain an overall insight of art allowing them to learn through exploration. To this end “Art Compare” offers an interactive surface where tangible objects can be placed to reveal their secrets. Painting supplies such as brushes, paint tubes, mediums etc. can be compared by the application allowing the artist to learn through their atomic qualities but also through the identification of their differences. At the same time several augmented objects

have been created to present artist, art styles and movements. These can be used to get encyclopaedic knowledge of art allowing the also to explore more information through several linked sources of information. The collection of augmented objects created to be facilitated by the "Art Compare" is presented in Figure 149. At the same time an example of using the application to compare Art Supplies is presented in Figure 150.

Brushes



Paint tubes

Artists Tags

Art Movement Tags

Figure 149: The "Art Compare" collection of augmented objects

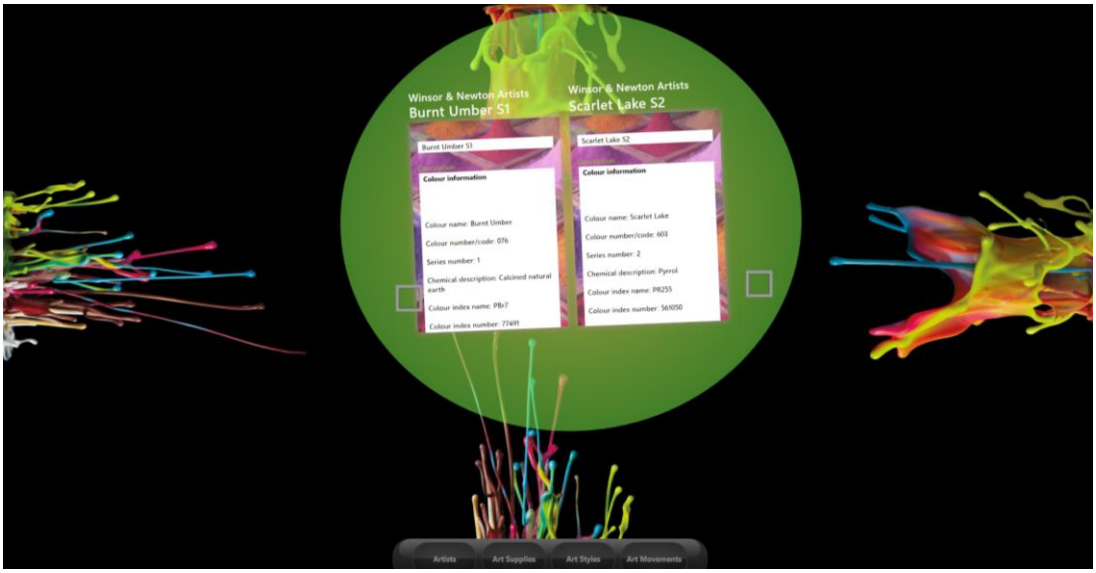


Figure 150: Using "Art Compare" to compare Art Supplies

Figure 151 highlights the usage of "Art Compare" as a valuable knowledge source. By placing augmented tagged objects on the surface the student can not only get information about artistic subjects but also access a variety of alternative sources of information that are interlinked through the knowledge base with the select artistic subject.

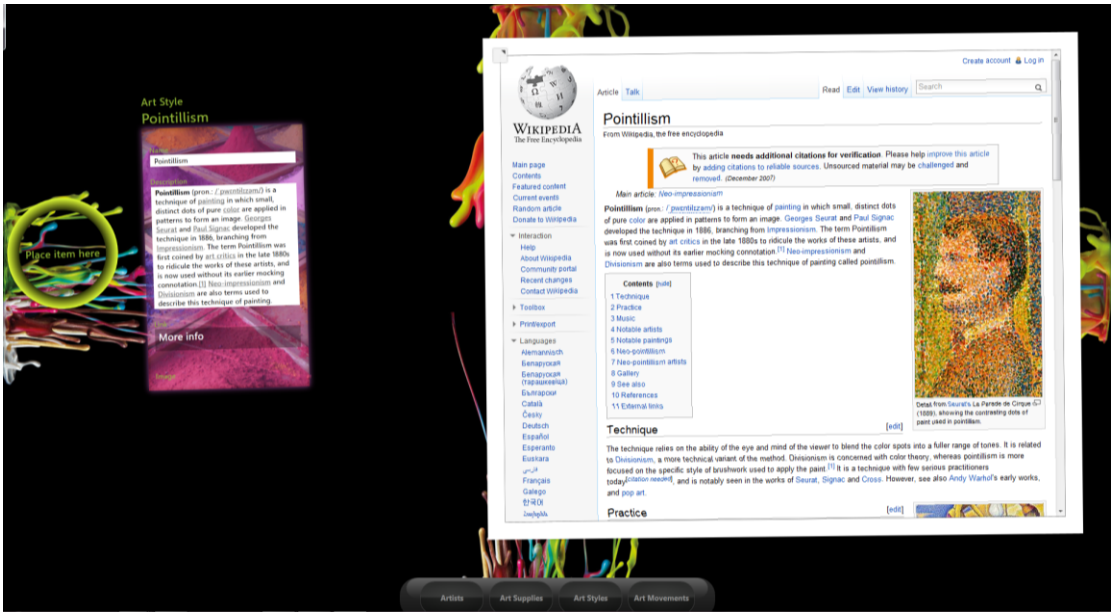


Figure 151: Using "Art Compare" to access reference material regarding pointillism

The complete set of implementation details for the "Art Compare" application is presented in Table 29.

Implementation	• Microsoft Visual C# [232]

Framework	• Microsoft surface SDK 2.0 [230] • Windows Presentation Foundation (WPF) [231] • "ItemCompare" Surface SDK 2.0 sample [338]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service

Libraries Used	• "AmiForArtUIToolkit"
	  ○ Tag comparing control collection
	  ○ Rotatable Web Browser
	  ○ Html RichTextBox

Hardware Used	• Microsoft PixelSense – Samsung SUR-40

Interaction Schemes	• Multi Touch & Gestures
	• Augmented objects
	  ○ Painting material (paint tubes, brushes, mediums)
	  ○ Artists tags
	  ○ Art styles tags

Table 29. Implementation details for the "Art Compare" Prototype

8.2.2.1.2 Master Brushes

Brushes are an important tool for painting. Accomplished artists use different shapes of brushes and different filaments according to the effect they wish to achieve. Typical brush shapes include Filbert, Bright, Flat, Fan, Round, and Rigger while typical filaments include hog bristle (which hold the paint well and has plenty of "spring") sable, sable & synthetic mixed or synthetic (sable and sable/synthetic mix will usually give a softer, smoother look to the applied paint, these are also useful for detail work). The "MastersBrushes" application aims at teaching the attributes of brushes to art students. Mastering Brushes is very important for getting the most from your painting mediums. A number of different brush variations exist each of which produces different textures and is appropriate for achieving specific results as presented in Figure 152. Brushes vary in quality and size. The application is operated using the brushes of the art studio and the interactive surface. The application extracts

information from the ontology regarding brush types and filaments and associates such information with virtual brushes or physical brushes used by artists. In turn Artists can experiment with the effects accomplished by each brush on a virtual canvas using a virtual representation of a specific tube colour (as presented in Figure 153).

Figure 152: Various brush types and the effects produced by their usage

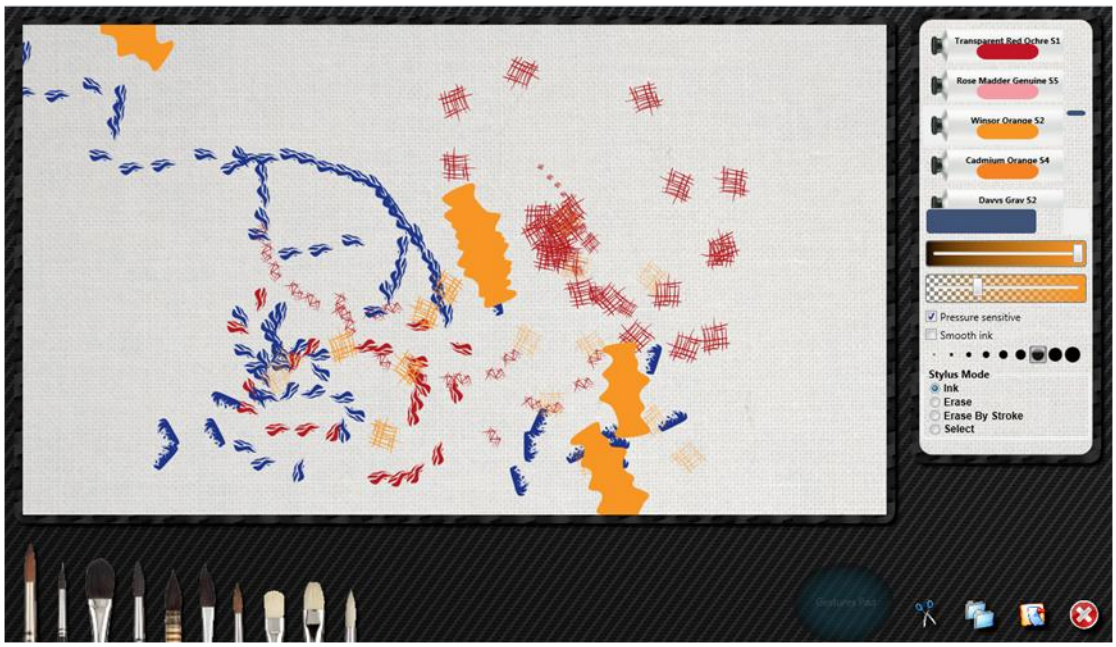


Figure 153: The “Masters Brushes”

The complete set of implementation details for the "Masters Brushes" application is presented in Table 30.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service

Libraries Used	• "AmiForArtUIToolkit"
	  ○ Menus
	  ○ Brush Canvas
	• "BrushStencils"

Hardware Used	• Microsoft PixelSense – Samsung SUR-40 • Desktop pc with touch screen • Touch panel pc • Tablet pc
Interaction Schemes	• Multi Touch & Gestures • Augmented objects ○ Brushes

Table 30. Implementation details for the "Masters Brushes" application

8.2.2.2 Colour Theory

8.2.2.2.1 Paint it for young artists

Paint it for young artists is an interactive application designed not actually for painting but for allowing artists through experimenting on painting to understand and learn colour theory and colour mixing. In this sense young artists can master the qualities of their art supplies and experiment on mixing colours to solve a number of problems such as local colour mixing, shadows, reflected light etc. A typical instantiation of Paint-it for young artists is presented in Figure 154. As shown in this

figure the Van Gogh's Starry Night has been selected from the collection of available painting. On the surface the painting itself is presented together with a canvas containing the extracted from the painting sketch. Young artists can use their colour wheel to relate actual pigment colour with ideal colour of the colour wheel and use the mixing palette to mix the colours of the painting. Using the transparency widget they can control the opacity of their brush strokes prior to the application of paint to the painting surface.

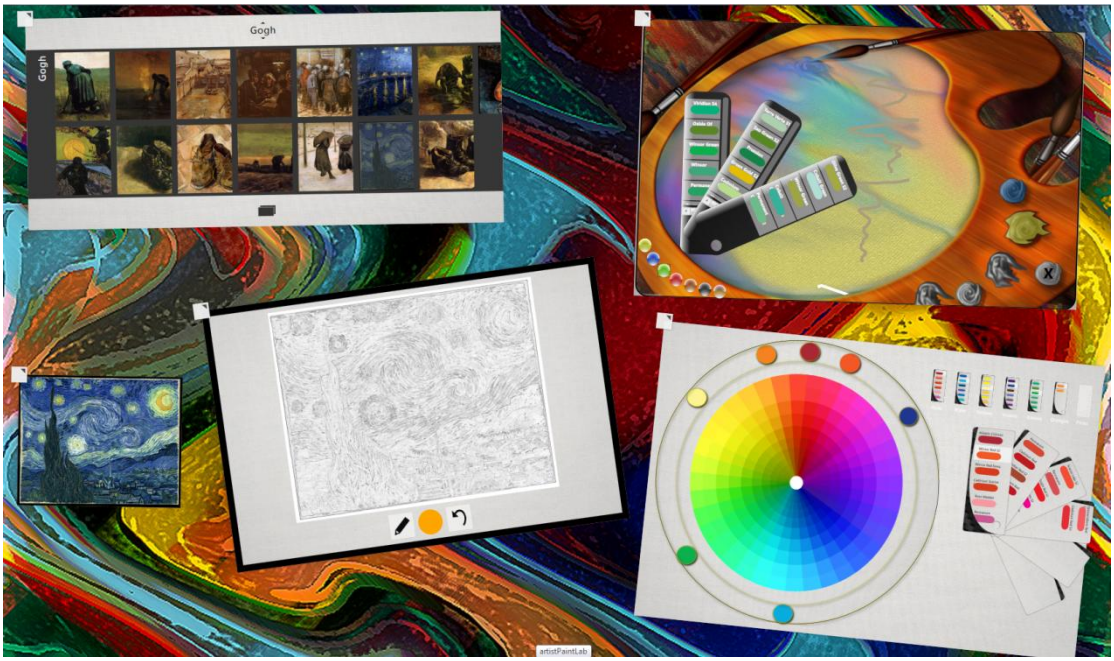


Figure 154: The Paint-it variation for young artists

Overall the facilities offered by Paint-it variation for young artists include:

The Collection: The collection Library contains works of art created by famous artists. When Dragging one of the paintings to the surface the painting itself appears together with a painting canvas where the sketch of the painting has been extracted by the painting itself. In this sense users can see the colours used on the actual painting and mix them on their mixing palette.

Canvas: Using the canvas widget an empty canvas can be presented on the surface for freeform painting.

The colour mixing palette: Colour mixing can be fascinating, fun or frustrating, depending on the knowledge and experience of each artist. To find out which paint represents the various colours artists tend to read the manufactures information, books on colour, other people's advice or some detective work themselves. Accomplished artists frequently advice apprentices that learning comes from experimentation rather

than referring to instructional material (although they do not misjudge the value of such material). The colour mixing palette does exactly that by allowing artists to experiment on colour mixes without having to get their hands dirty. This mixes can be in turn used to tint a canvas appearing on the surface.

Colour Wheel: Colour Wheels can help young artists understand the use of colour in art, illustration and design. The Colour wheel shows primary, secondary, tertiary, warm, cool and complimentary colours as used in colour theory when painting. In painting these theories apply regardless of the media. The trouble with most 'colour wheels' is that they show the colours but not the name of paint that represents that colour. The Paint-it Colour Wheel is an interactive colour wheel that can be used as an assistant by artists that associates actual pigments with regions of the colour wheel. This is achieved through the presentation of a colour wheel and the collection of available colours per colour wheel area. In this way young artists can select an actual pigment colour from their swatch and compare it with the “ideal” colours presented on the wheel.

Transparency Wheel: The transparency wheel is presented when its tagged phydget is laid on the surface. Users can rotate this phydget to change the transparency their brush work by altering the opacity of the currently mixed colour in their mixing palette.

Brush Compare: Comparing brushes allows young artist to learn the attributes of their painting materials and the effect that can be achieved through their usage. The Brush Compare tool is presented when its tagged phydget is laid on the surface. Users can place a brush on the table to access its attributes while when to brushes are laid down simultaneously a comparing facility is presented.

The Paint-it collection of augmented physical objects

A number of augmented physical objects have been created in the context of Paint-it. Such objects can be grouped into two main categories. The first one consists of objects used to emulate the feeling of painting using augmented artists supplies while the second category contains phydgets that act as control elements (provide access to the functionality of the game and thus can be considered as physical game controls).

Brushes

Brushes are an important tool for painting. Accomplished artists use different shapes of brushes and different filaments according to the effect they wish to achieve. Typical brush shapes include Filbert, Bright, Flat, Fan, Round, and Rigger while typical filaments include hog bristle (which hold the paint well and has plenty of "spring") sable, sable & synthetic mixed or synthetic (sable and sable/synthetic mix will usually give a softer, smoother look to the applied paint, these are also useful for detail work). A number of different brushes are used for the Paint-it applications. In most of the cases the actual brush work is carried with blob detection. In the case where information regarding a brush is required, for assisting young artists price tags are integrated for object recognition. The variety of artist's brushes offered by Paint-it is presented in Figure 161.

Figure 155: Artist's brush set with price tags

Augmented physical paint tubes

Paint tubes are the essential source of pigments for artists. Augmenting these object allow young artists to experiment with the results of actual colour mixing without getting their hands dirty. Learning colour mixing is an essential part of painting for avoiding the creation of muddy colours which is considered by artists the most common mistake done by their students.

Figure 156: A set of augmented paint tubes

Augmented phydgets

Paint-it phydgets in are augmented physical objects that act as control elements and therefore provide access to the functionality of the game. Several phydgets are employed by Paint-it such as:

- **Artist Brushes:** Provides access to a brush comparing facility
- **Canvas:** Presents and empty painting canvas
- **Paint Lab:** Gives access to the main menu of the game
- **Palette:** Presents the colour mixing palette of the artist
- **Transparency:** Can be rotated to adjust the transparency of brush strokes
- **Colour wheel:** Presents a colour wheel where artists can relate pigment to ideal colours

Figure 157: Augmented phydgets

Potential uses of "Paint it for young artists" for artist's education

The "Paint it for young artists" can have several interesting usages for education of young artists:

- **Free practice:** In this mode the student applies a number of colours in his virtual palette allowing the student to freely mix colours, or on the other hand the system can automatically produce colours that the student must reproduce using the colours on his palette.
- **Creating a colour wheel:** A colour wheel is very important for understanding, basic and complementary colours and the way these are mixed. Furthermore the colours produced when these colours are mixed with white and black. For the colour wheel game students are introduced with the basic colours, black and white and are asked to mix them appropriately for producing the colour wheel.
- **Creating a colour chart:** For the colour chart game students are introduced with the basic colours, black and white and are asked to mix them appropriately for producing the colour chart.
- **Defining local colour:** One of the most possible causes of error for young artists is their inability to define the local colour of an object. For example novice artists tend to think that apples are red bananas are yellow etc. On the contrary if properly investigated each object contains a number of colours produced by shading, reflections and variations to the local colour. In this game a student is introduced with a picture of a still life and prompted to mix the local colour in various locations of the painting. The student has the option to try mixing the local colour without help or with the usage of a peephole viewer.
- **Mastering shadows:** Shadows are considered the most difficult aspect of painting. Even accomplished artists have problems rendering the perfect shadow. In this context mastering the way that shadows are represented through colour is essential. Novice artists tend to think that shadows are grey but the truth is that shadows include a darker variation of the local colour the complementary of the local colour and blue. In the game of shadows the student is introduced with an object from a still life and has to mix the colour of its shadow.

The complete set of implementation details for the "Paint it for young artists" application is presented in Table 31.

Implementation	• Microsoft Visual C# [232]

Framework	• Microsoft surface SDK 2.0 [230] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service

Libraries Used	• "AmiForArtUIToolkit"
	  ○ Colour Manipulation and Mixing
	  ○ Image filters control
	  ○ Transparency Wheel
	  ○ The painting canvas
	  ○ Menus
	  ○ Image library containers
	• "ColorSpaces"
	• "PigmentColorMixing"

Hardware supported	• Microsoft PixelSense – Samsung SUR-40 • Desktop pc with touch screen • Touch panel pc • Tablet pc

Interaction Schemes	• Multi Touch & Gestures
	• Augmented objects
	  ○ Painting material (paint tubes, brushes, mediums)
	  ○ Augmented phydgets

Table 31. Implementation details for the "Paint it for young artists" for young artists

8.2.2.3 Composition Light & Shadows

8.2.2.3.1 3D Composition – Light & Shadows

In the process of studding art it is essential for the artist to get involved into testing the arrangement of subject matter in several composition schemes. Such exercises are useful both for allowing the artist to get familiar with the visual qualities of compositions but also through painting these simple compositions learning about the

qualities and attributes of lights and shadow. The “3D Composition” applications allows young artist to experiment different composition schemes by importing simple (such as cubes, pyramids, spheres etc.) and complex items (such as vases, fruits etc.) into a 3D scene. Using the “3D Composition” application artists can review, rotate and scale 3d objects while also being able to select the appropriate lighting scheme of his composition (see Figure 158).

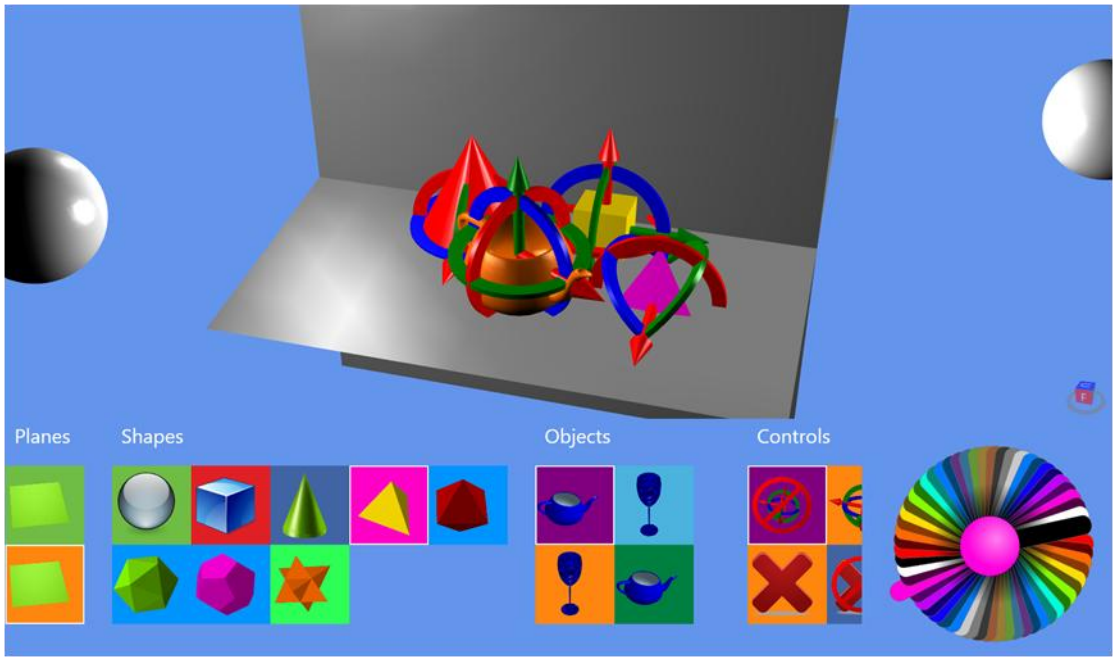


Figure 158: Manipulating 3D elements within a 3D scene

Finished compositions can be transferred to the “Augmented Painting Surface” for exercising the rendering of objects using real art material. An example of a finished composition is show in Figure 159.

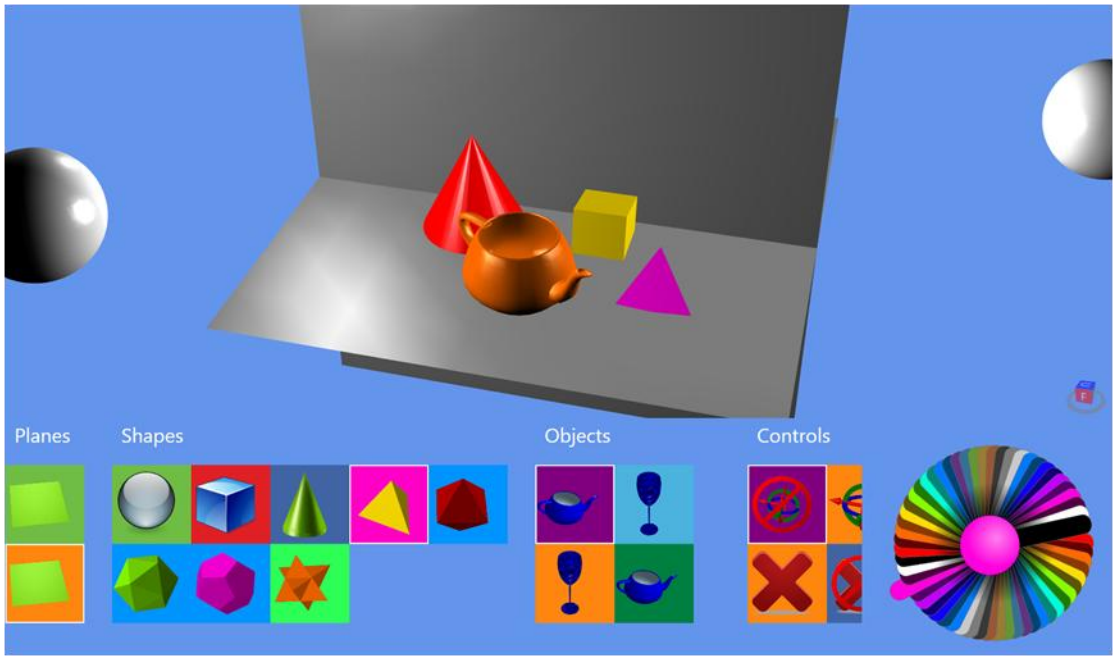


Figure 159: The finished composition ready for painting

The complete set of implementation details for the "3D Composition" application is presented in Table 32.

Implementation Framework	• Microsoft Visual C# [232] • Microsoft surface SDK 2.0 [230] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service • "artLogger" service

Libraries Used	• "AmiForArtUIToolkit"
	  ○ Colour Manipulation and Mixing
	  ○ Menus
	  ○ 3D models
	• "HelixToolkit"

Hardware Used	• Microsoft PixelSense – Samsung SUR-40 • Desktop pc with touch screen • Touch panel pc • Tablet pc

Interaction Schemes	• Multi Touch & Gestures

Table 32. Implementation details for the "3D Composition"

8.2.2.3.2 Artist's Composition Suite

The artist composition suite presented in the context of the Artist workshop can be used in the context of Art education and training activities. Through this suite art students can experiment on creating their compositions allowing them to experiment on a variety of composition schemes and artistic concepts. In this context the personalisation aspects of the proposed research work come to play for producing an environment as powerful as the artist's counterpart but at the same time directed towards educating young artists through the usage of techniques and tools.

8.2.2.3.3 The Artist's Concepts Designer

The artist's concept designer when used by young artists can provide an environment where experimentation, through the application of artistic concepts to image, can assist young artist into gaining experience regarding the usage of photography for art creation at the same time experiment on several subject matters and styles.

8.2.2.4 Studio practice

For practicing young artists have a multitude of tools as provide by the Artist's workshop. These tools can be used as is in their painting sessions offering them a unified environment for composing using the aforementioned facilities or using the model framing facilities, transferring their composition to canvas and framing their finished works of Art.

8.3 Art for children's education and entertainment

This section presents the usage of interactive games for educative purposes. Educational games (sometimes called edugames, a portmanteau of the two words) are games that have been specifically designed to teach people about a certain subject, expand concepts, reinforce development, understand an historical event or culture, or assist them in learning a skill as they play. They include board and card games, and video games [131].

8.3.1 Paint-it for children

8.3.1.1 The Game

The Paint-it variation for young children is partially striped of by the seriousness of its other counterpart. This is for allowing children to access a joyful and playful environment for learning where gaming gets the primary focus while learning happens silently while mixing and pairing colours to achieve the desired by the game results. A typical instantiation of Paint-it for young artists is presented in Figure 154. In this figure a sketch has been selected for painting from the collection of available sketches. The surface presents the painting canvas together with the completed painting sketch for reference. At the same time the physical palette of colours is augmented with colour by the surface. Children should use their painting palette to generate the colours presented on the completed sketch and then use their physical paint brushes to fill the area of their canvas.

Figure 160: The Paint-it variation for children

The colour mixing palette: The colour mixing palette for children comes into two different instantiations. The first on is a digital mixing palette that can be accessed through the game menu while the other one is a mixed physical and digital palette. The second instantiation appears when the physical augmented palette is placed on the surface. Then the colours are projected through the holes of the physical palette.

Sketches: The sketches collection offers a variety of sketches in a number of categories ready to be painted. Dragging a sketch to the surface results to the presentation of a painting canvas with the sketch together with the same sketch

painted in colour. Children should locate the colours from the painted sketch mix them with their palette and paint using these mixtures using their physical brushes.

Printed Sketches: When printed sketches are placed on the surface a canvas appears underneath. The canvas is moved and rotated following the movement of the printed sketch and children can draw on top of them but actually drawing on the canvas underneath.

Freeform Painting: Placing the canvas tag on the surface initiated a freeform painting session when children can paint whatever they like.

8.3.1.2 The Paint-it for children collection of augmented physical objects

Brushes

The variety of artist's brushes offered by Paint-it is presented in Figure 161.

Figure 161: Children's brush set

An augmented physical painting palette

A painting palette is a fundamental tool of their work for artists but for children it can be considered as an item that could enhance the overall game play as they do not just paint in a computer application but rather use real objects for their interaction in a world where physical object get "magic" abilities when placed on a surface. This augmented object consists of a standard wooden palette with slots in the areas where colours are placed or colour mixing occurs. Through these slots the screen underneath can display colours allowing young children to select and mix colour from their "magic" palette of colours.

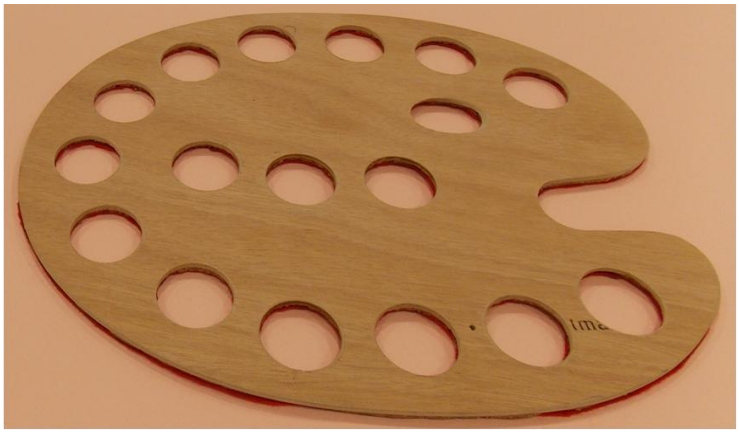


Figure 162: A physical augmented painting palette

Printed Sketches

Printed tracing sketches are introduced to the Paint-it application for allowing children to select the desired sketch and then paint on top of it. These sketches have been printed into standard transparent sheets and tagged.

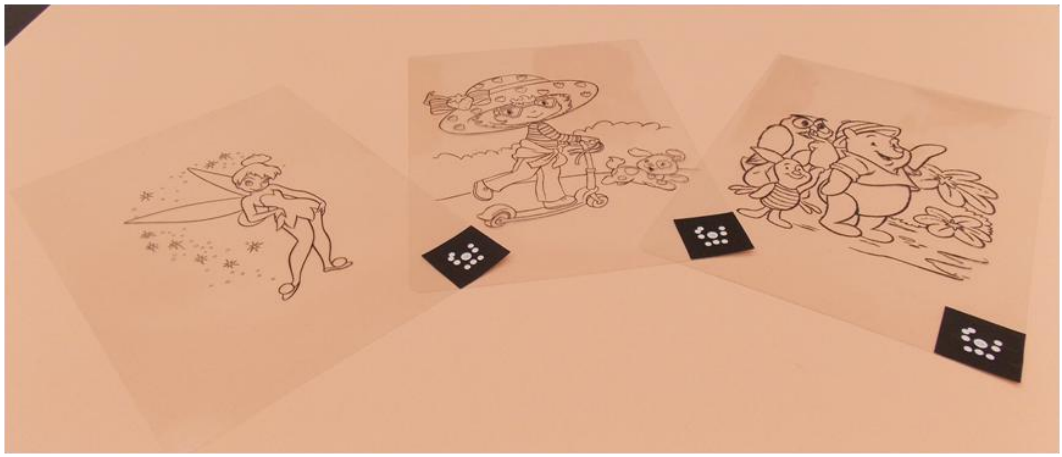


Figure 163: A set of augmented paint Sketches

Implementation Framework	• Microsoft Visual C# [232] • Microsoft surface SDK 2.0 [230] • Windows Presentation Foundation (WPF) [231] • "PhotoPaint" Surface SDK 2.0 sample [339]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service
Libraries Used	• "AmiForArtUIToolkit"

	○ Colour Manipulation and Mixing ○ Painting canvas control ○ Image library containers • "ColorSpaces" • "PigmentColorMixing"
Hardware supported	• Microsoft PixelSense – Samsung SUR-40
Interaction Schemes	• Multi Touch & Gestures • Augmented objects ○ Painting material (paint tubes, brushes, mediums) ○ Printed transparent sketches ○ Physical palette ○ Augmented phydgets

Table 33. Implementation details for the "Paint it" for young artists

8.3.2 Game lab

Studying the Masters is one of the most important advices that an accomplished artist can provide. The "Game lab" allow young artists to discover the secrets hidden within a painting through the usage of various image processing techniques. At the same time young children can find through this prototype a fascinating game where objects (such as an old photograph, a sponge etc.) can be used to alter the appearance of a painting making their visit to an art gallery a fascinating experience. An example of the results produced through the application of augmented objects to a painting is presented in Figure 164.

Figure 164: Applying a pencil and an old camera to a painting

The complete set of implementation details for the "Game Lab" application is presented in Table 33.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231] • Aforge image processing library [226] • "PixelShaders" library
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service
Libraries Used	• "AmiForArtUIToolkit" ○ Image filters control • "ArtFilters" • "ArtShaders"

Hardware supported	• Desktop pc • Short throw projector

Interaction Schemes	• Touch
	• Augmented objects
	  ○ Pencils
	  ○ Flash light
	  ○ Sponges
	  ○ Colour Cards
	  ○ Charcoal sticks
	  ○ Old camera
	  ○ Sculpt

Table 34. Implementation details for the "Game Lab"

8.3.3 Guess the colour

"Guess the colour" builds upon one of the most important aspects of artistic creation which is the ability to approximate the colours of the subject matter and produce the appropriate colour mixes. Frequently novice artists with limited experience in colour mixing tend to use colours just because these colours are mixed on their palette (colours are expensive for them to dispose when an inappropriate mixture occurs so they use it anyway). The "Guess the colour" application is an interactive game of experimentation where users can select a colour from a painting or photo (this colour is separately presented for avoiding the simultaneous colour contrast effects) and try to make the appropriate colour mixtures for reproducing the selected colour. An example of mixing colour to produce a deep red colour located in Santa Maria's dress is presented in Figure 165.

Figure 165: “Guess the Colour”

The complete set of implementation details for the “Guess the Colour” application is presented in Table 34.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• “AmiForArtModel” Service • “UserAwareness” service • “ContextAwareness” service • “artServer” service
Ami Services implemented	• “artClient” service

Libraries Used	• “AmiForArtUIToolkit”
	  ○ Colour Manipulation and Mixing
	  ○ The painting canvas
	  ○ Local colour isolator

Hardware supported	• Desktop pc with touch screen • Microsoft PixelSense – Samsung SUR-40 • Touch panel pc • Tablet pc

Interaction Schemes	• Touch
	• Augmented objects
	  ○ Brushes
	  ○ Paint tubes
	  ○ Magnifying glass

Table 35. Implementation details for the "GuessTheColour" Prototype

8.3.4 Art Puzzle

The "Art Puzzle" is an interactive application puzzle application running on multi-touch screens. The concept of the game is quite straightforward. Children can select among a vast collection of paintings stemming from the knowledge base the one to be used for generating a puzzle game. At the same time the difficulty of the game can be selected altering the number of puzzle pieces that will be generated. The puzzle pieces can be in turn manipulated through touch (moved and rotated). Children have to place the correct pieces to the correct location within the puzzle in order to complete the game. The Art Puzzle can be also integrated into general purpose applications such as the "Museum Coffee Table". The art puzzle when operated in the context of a Microsoft Pixelsense device can extract paintings using tagged objects that represent famous artists. Figure 166 presents the initial screen of the game prompting the user to place an augmented artist tag on the surface. An example of a puzzle game as generated using the portrait of "Don Fernando Niño de Guevara" by El Greco is presented in Figure 167.

Figure 166: The Art Puzzle start screen.

Figure 167: A puzzle game using the portrait of "Don Fernando Niño de Guevara" by El Greco.

The complete set of implementation details for the "Art Puzzle" application is presented in Table 35.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231] • Microsoft surface SDK 2.0 [230] • "ScatterPuzzle" Surface SDK 2.0 sample [340]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service
Libraries Used	• "AmiForArtUIToolkit"
Hardware supported	• Microsoft PixelSense – Samsung SUR-40 • Desktop pc with touch screen • Touch panel pc • Tablet pc
Interaction Schemes	• Touch • Augmented objects (artists tags)

Table 36. Implementation details for the "Art Puzzle" game

8.3.5 Pick & Match

The "Pick&Match" Prototype is a memory game with cards where users are intended to locate the same pairs of cards within a collection of initially hidden cards. It is a basic memory game that gets added value through the existence of a large ontology of Art that contains a great number of items such as paintings artists etc. Players are initially prompted to select their desired game mode (see Figure 168) and cards are dynamically populated from the ontology in a random fashion. This allows the game to have a potential unlimited number of variations. An example of a completed game level is presented in Figure 169. Pick and match can be also integrated into general purpose applications such as the "Museum Coffee Table".

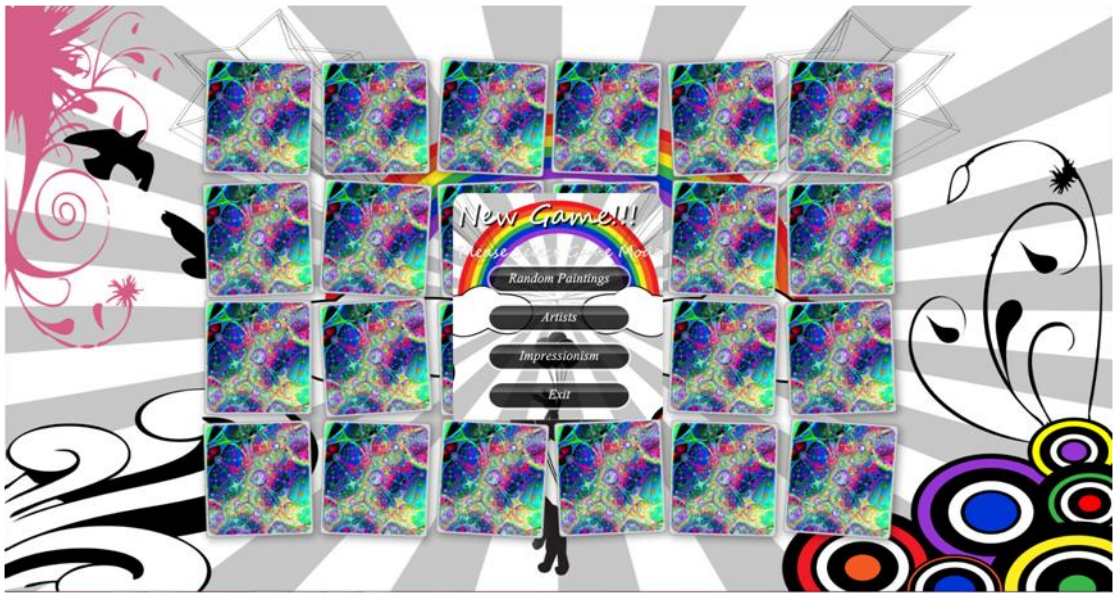


Figure 168: The "Pick&Match" start-up screen

Figure 169: Successful completion of a game stage

The complete set of implementation details for the "Art Puzzle" application is presented in Table 37.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231] • Microsoft surface SDK 2.0 [230]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service
Libraries Used	• "AmiForArtUIToolkit"
Hardware supported	• Microsoft PixelSense – Samsung SUR-40 • Desktop pc with touch screen • Touch panel pc • Tablet pc
Interaction Schemes	• Touch • Augmented objects (artists tags)

Table 37. Implementation details for the "Pick&Match" Prototype

8.4 Art within museums and Art Galleries

8.4.1 State of the art

Nowadays museums and cultural institution are starting to discover the potential benefits for introducing modern technology for augmenting the experience people get from museum visits. As already discussed in depth in section "2.4 Augmenting Art with Modern Technology" such attempts include the usage of mobile devices, the creation of web pages and social application an in limited extend the introduction of modern technologies within museum. Especially in this domain existing applications are most of the times limited to the production of standalone digital exhibits or alternative museum experiences.

8.4.2 Augmenting the museum experience

This work advances the state of the art in a number of directions. As highlighted in this section the proposed approach introduces novel means of presenting digital and physical exhibits through inline augmentation of paintings or through the integration of various mobile devices. At the same time the museum unoccupied spaces are transformed into information spots supporting alternative means for presenting context dependent information. At the same time the museum experience is extended within the museum leisure spaces and within our living environments.

8.4.2.1 Presenting Digital Exhibits

The process of understanding art entails a deeper understanding of the artist's emotions, state of mind, general political or social implications raised by the period where art was made and many other issues such as the goal of the artist, the specific qualities of his subject matter etc. Moreover understanding art becomes even more daunting when innovative art forms are encountered. Although understanding of art is meant to be subjective and not objective there is a vast amount of information available for aiding as, at forming our own impression. This knowledge when employed by digitized art can offer an interactive learning experience.

8.4.2.2.1 The Digital Exhibit

The "Digital Exhibit" is an application developed in order to present exhibits in a digital form when the original artefact is not physical present. In this sense the digital exhibit is acting as a placeholder to the original artefact in order to fill in a collection that should be presented as a whole. The "Digital Exhibit" employees the annotated regions of the painting as created using the "Artefact annotator" application presented in the previous chapter. These annotated regions of the painting are controlled through the viewer's location in relation to the exhibit. The "Digital Exhibit" employs localisation data coming from skeleton tracking through kinect to identify the location of the viewer. Areas within the field of view of the viewer are highlighted and information regarding the specific location is presented in place. An example of the "Digital Exhibit" presenting information about the horse within the painting Guernica created by Pablo Picasso is presented in Figure 170. As shown in this figure multiple users can access information from the digital exhibit concurrently and each user is represented by a triangle in the upper most side of the painting.

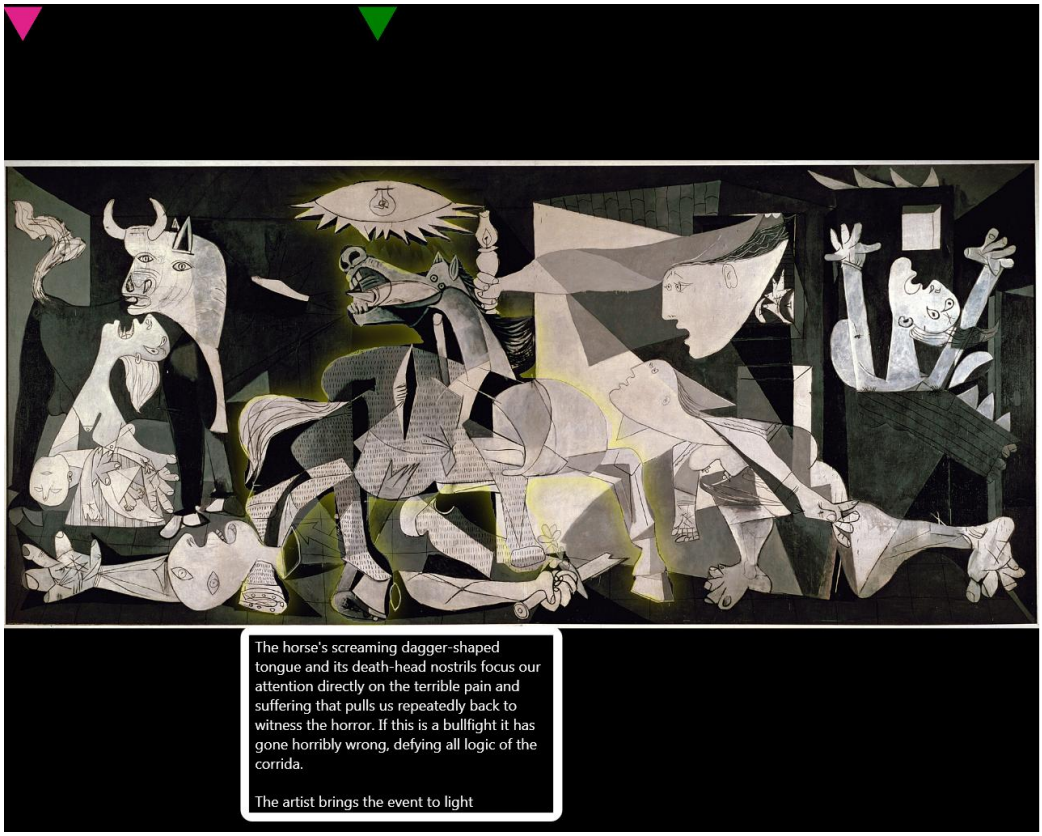


Figure 170: Presenting information about the horse within Guernica

The complete set of implementation details for the "Digital Exhibit" application is presented in Table 38.

Implementation Framework	• Microsoft surface SDK 2.0 [230] • Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service

Libraries Used	• "AmiForArtUIToolkit"
	  ○ Regions of interests presenter
	  ○ User mapping control

Hardware supported	• Desktop pc • Kinect Sensor • Short throw projector
Interaction Schemes	• Spine tracking

Table 38. Implementation details for the "Digital Exhibit"

8.4.2.2.2 The Mobile Exhibit Browser

The "Mobile Exhibit Browser" is an application running on a Windows Phone 7 device which allows visitors of the exhibition to access valuable information. Several views are available from the main application screen and the users can simply slide to change the view of interest, or interact with the currently loaded view to get more information. "Mobile Exhibit Browser" provides access to a number of views for (a) accessing a list of all the artists of the exhibition, (b) displaying the list of exhibits that can be accessed through a specific exhibition room and (c) access details regarding the artefact that currently has user's focus. These facilities are integrated through QR code scanning (QR codes are integrated on the entrances and on the exhibits). An example presenting the list of artists participating with their works in the exhibition is presented in Figure 171 while Figure 172 presents a list of artefact for a selected Artist.

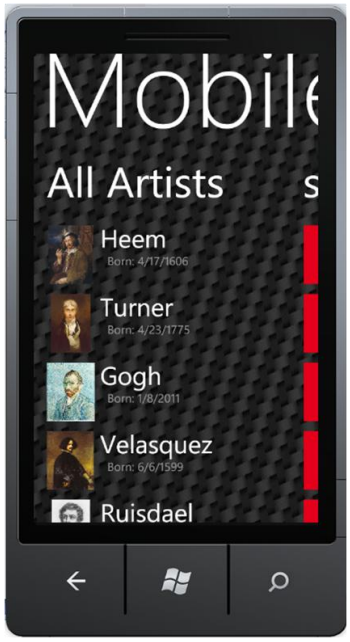


Figure 171: Browsing a list of artists through the "Mobile Exhibit Browser"

Figure 172: A list of painting in the Exhibition created by Vincent Van Gogh

The complete set of implementation details for the "Mobile Exhibit Browser" application is presented in Table 39.

Implementation Framework	• Microsoft Visual C# [232] • Silverlight for Windows Phones SDK [235] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" web-service
Libraries Used	• "AmiForArtUIToolkit" ○ Mobile image gallery • "QRCodeScanner"
Hardware supported	• Windows Phone
Interaction Schemes	• Multi Touch & Gestures-

Table 39. Implementation details for the "Mobile Exhibit Browser"

The "Mobile Exhibit Browser" is also the place for users to enter their profile (see Figure 173). This profile is in turn used by application to perform personalisation and UI adaptation. Each of the aforementioned processes is presented in the following sub-sections.

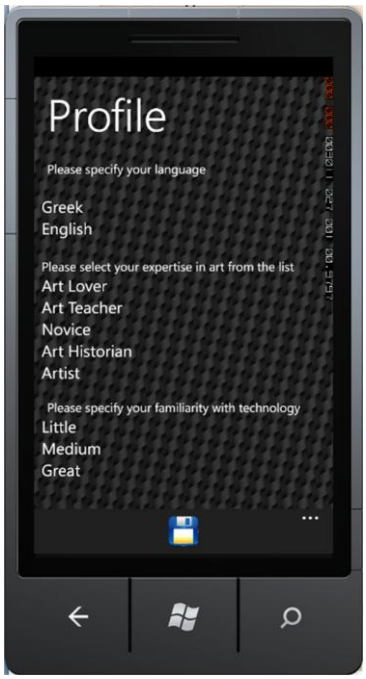


Figure 173: Filling-in user's profile

Personalisation

This section presents an overview of the content personalisation workflow as implemented through the usage of the aforementioned applications and the underling system architecture (see Figure 174).To this end initially the museum visitor downloads and installs the "Mobile Exhibit Browser" to his smart phone using the museum Wi-Fi connections. Then when the application launches it prompts the user to fill-in an anonymous user profile with preference that are extracted from the ontology model but stored in the form of user preferences in the smart phone's local storage. This profile can be in turn used at a first level for presenting personalised information from the smart phone. To do so all queries formed by the mobile application to the ontology model carry with them the required profile attributes and the scanned, by the user, QR code of the exhibit. Using this information the content personalisation engine generates the appropriate queries and retrieved ready to be used personalised results. Continuing the scenario users can use the "Mobile Exhibit Browser" to generate a QR code representation of their profile. This QR code representation is in turn scanned by other interactive applications so as to identify user preferences. For example the user is in front of an augmented artefact caption and browses information. He shows the QR code generated from his mobile phone to the tablet, the QR code is scanned and the tablet personalises the information to the profile selections of the user.

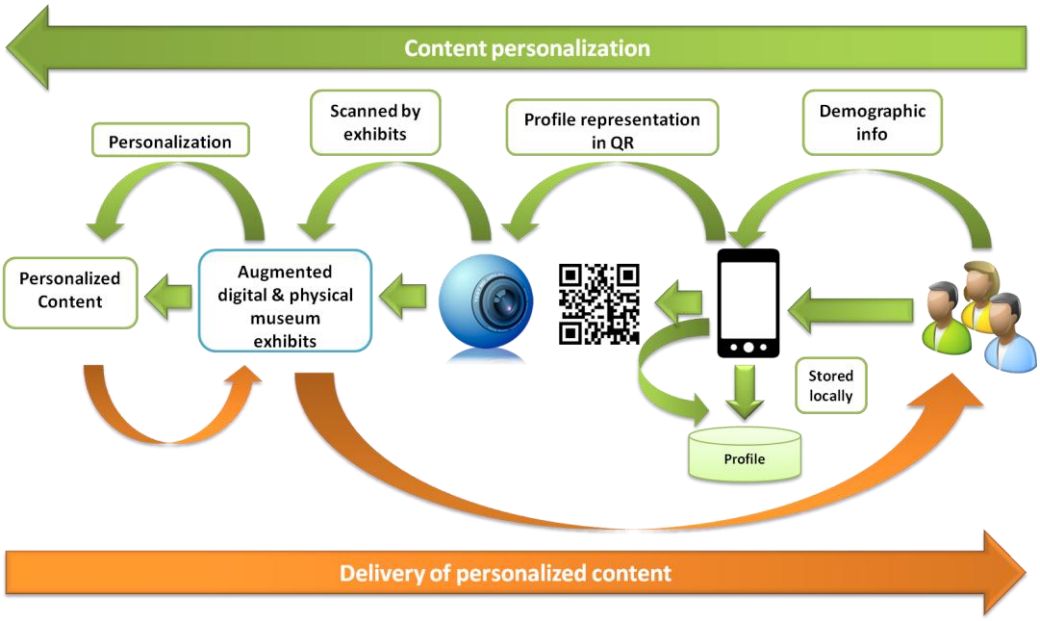


Figure 174: Content personalisation workflow

UI Adaptation

In the case of static rule based user profile adaptation the mechanism presented in Figure 175 is employed. As shown in this figure each interactive application comes to its initialisation state by following a process involving the retrieval of the application specific RuleSet from the rules store, the application of this RuleSet by the UI adaptation engine using a default user profile (the average user's profile). When this process is concluded the application is ready to be accessed and used. At the same time a QR recognition service is initiated and run on the background. Each of the users can in turn use their Smartphone to generate the QR code representation of their profile point this representation to the application so as to transfer their preferences to the application. The transmitted preferences are used to alter several application properties. This results to the re-evaluation of the RulesSet by the rule engine and the generation of adaptation decisions that are directly transferred from the Rules Engine to the application. This result to the generation of an adapted UI that matches the user preferences as recorded to the profile.

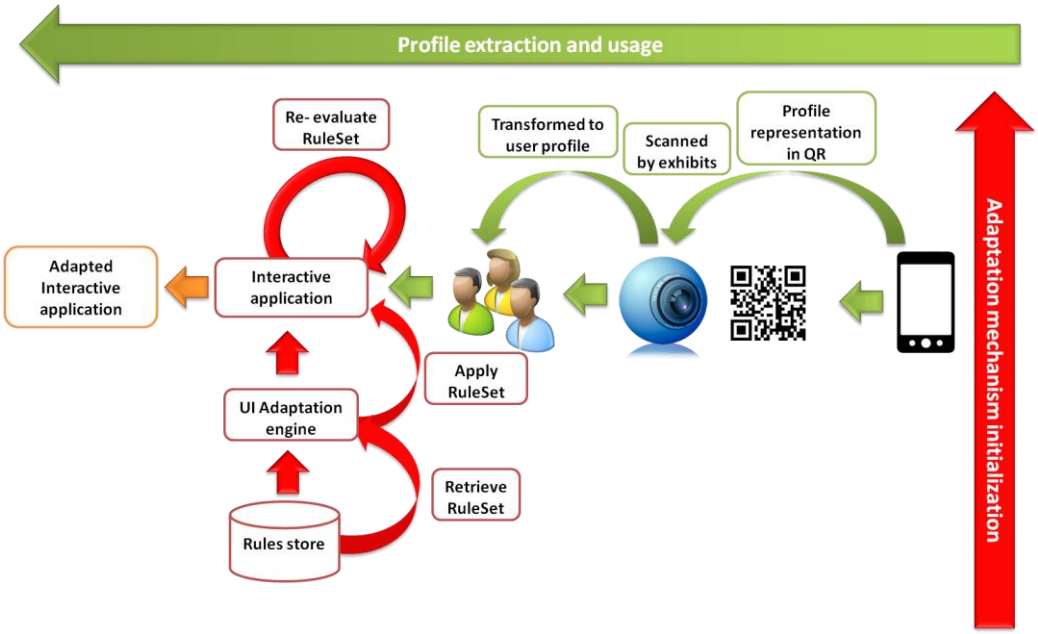


Figure 175: UI adaptation workflow

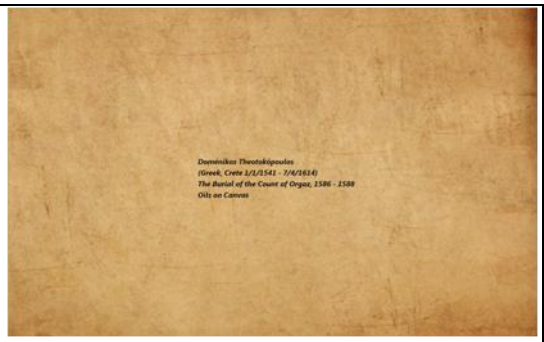
8.4.2.3 Augmented physical Exhibit

When augmenting physical exhibits attention should be paid to not intruding into the relation that is formulated between the viewer and the artefact. To ensure this two approaches are followed by this research work. The first one is to use side displays for presenting information about the artefact that are activated on user demand and the other one is to rely on mobile devices for presenting information. To this end two

applications have been developed for this purpose the “Augmented artefact caption” and the “Exhibit tablet browser”.

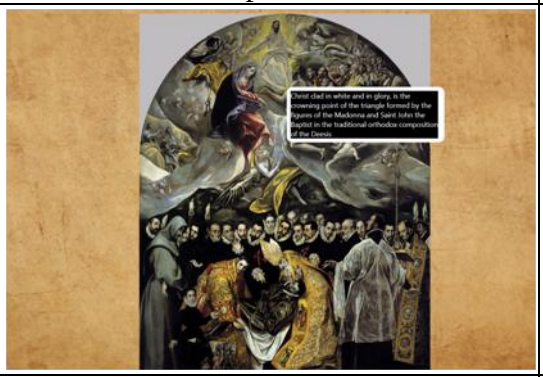
8.4.2.3.1 The Augmented artefact caption

The “Augmented artefact caption” is an application activated when the visitor is located on either side of the artefact. The application in its inactive mode presents only the typical caption today seen on museums around the world displaying the artefact title and the author information. When activated, the visitor can access information about the artefact by manipulating the caption (see Figure 176).



Caption

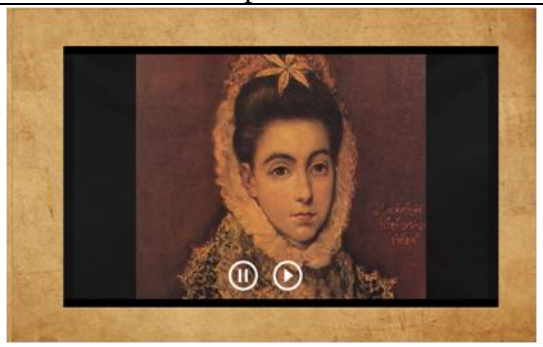
Description



Points of Interest

Deep Zoom

Full painting info



Painting video

Figure 176: The “Augmented artefact caption”

The complete set of implementation details for the “Augmented artefact caption” application is presented in Table 40.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service
Libraries Used	• "AmiForArtUIToolkit"
Hardware supported	• Touch panel pc • Tablet pc
Interaction Schemes	• Multi Touch & gestures

Table 40. Implementation details for the "Augmented artefact caption"

8.4.2.3.2 The Tablet Viewer

The "Tablet Viewer" is an interactive application running on a tablet device. It is meant to present information about physical artefacts based on user's location (the location of the user relative to the artefact). To do so a skeleton tracking service is running on the physical artefact (though the integration of a kinect device below the exhibit). The skeleton tracking service reports the location of the user and the currently browsed artefact. This contextual information is in turn used by the "Tablet Viewer" to extract and presents the points of interest that are located directly in front of the visitor. An example of "Tablet Viewer" presenting information regarding the points of interest located on the left side painting Guernica by Pablo Picasso is shown in Figure 177.

Figure 177: Presenting information about points of interest

The complete set of implementation details for the "Tablet Viewer" application is presented in Table 41.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "KinectSpineTracking" • "artServer" service
Ami Services implemented	• "artClient" service

Libraries Used	• "AmiForArtUIToolkit" ○ Regions of interests presenter • "CompositionDesignElements" • "ColorSpaces" • "PigmentColorMixing" • "PhysicalMediaDigitizer"
Hardware Supported	• Tablet pc
Interaction Schemes	• Multi Touch & gestures • Augmented physical objects ○ Sketches

Table 41. Implementation details for the "Tablet Viewer"

8.4.2.3.3 The "Artists Timeline"

The "Artists Timeline" is designed to present timeline information on a touch enabled screen using an interactive visual representation. The screen is spitted into two horizontal spaces the one presenting the life of the artist and the other one the artistic accomplishments of his life. The ontology is used to extract information from Artefacts in a chronological order in order to dynamically form the Artist's timeline from its creations. At the same time the specific representation of "life events" in the ontology is used to gather information regarding events of interest in his lifetime. The user can manipulate through touch these timelines using basic gestures (touch from left to right to move the timeline forward and from right to left to move the timeline backwards). By simply touching an event from the timeline the user can access more details of the event. An example of a timeline for the life and works of Vincent Van Gogh is presented in Figure 178.

Figure 178: The "Artists Timeline" presenting information about Vincent Van Gogh

In the context of this research work the "Artist Timeline", is also embedded within the "Museum Coffee table" application. The complete set of implementation details for the "Artists Timeline" application is presented in Table 42.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231] • Silverlight & WPF Timeline Control [225]
Ami Services Used	• "*"AmiForArtModel" Service* • *"UserAwareness" service* • *"ContextAwareness" service* • "artServer" service
Ami Services implemented	• "artClient" service
Libraries Used	• "AmiForArtUIToolkit" ○ Timeline Control
Hardware supported	• Desktop pc • Desktop pc with touch screen • Microsoft PixelSense – Samsung SUR-40 • Kinect Sensor • Short throw projector • Touch panel pc • Tablet pc

Interaction Schemes	• Multi touch • Kinect Gestures

Table 42. Implementation details for the "Artists Timeline"

8.4.3 Art within museum unoccupied spaces

This work aims at extending the museum experience in a number of directions. From the one hand this can be achieved by facilitating unoccupied spaces such as corridors and auxiliary spaces and from the other by extending the museum experience into museum leisure spaces such as cafeterias restaurants etc.

8.4.3.1 Exhibition Browser

The "Exhibition Browser" is an application designed to run is public spaces such as museum entrances or autonomous museum spaces where there is the need to advertise the exhibits located within the museum or within the specific space (see Figure 179). In this sense this is an application that focuses on attracting the passing by visitor and provides him with additional information. The "Exhibition Browser" employees hand tracking based on kinect skeleton tracking in order to project a virtual hand within the application. This virtual hand is magnetised by interactive elements and can be used to select or activate them. The visitor can browse the collections of the museum in a number of alternative ways (by artist, movement, location within the museum etc.) as presented in Figure 180.

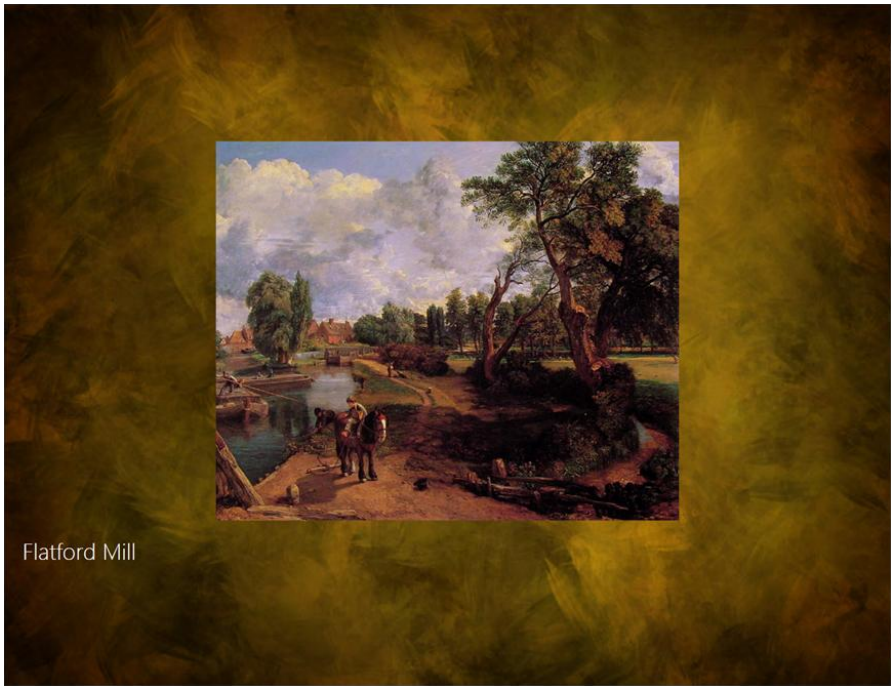


Figure 179: The attract screen of "Exhibition Browser"

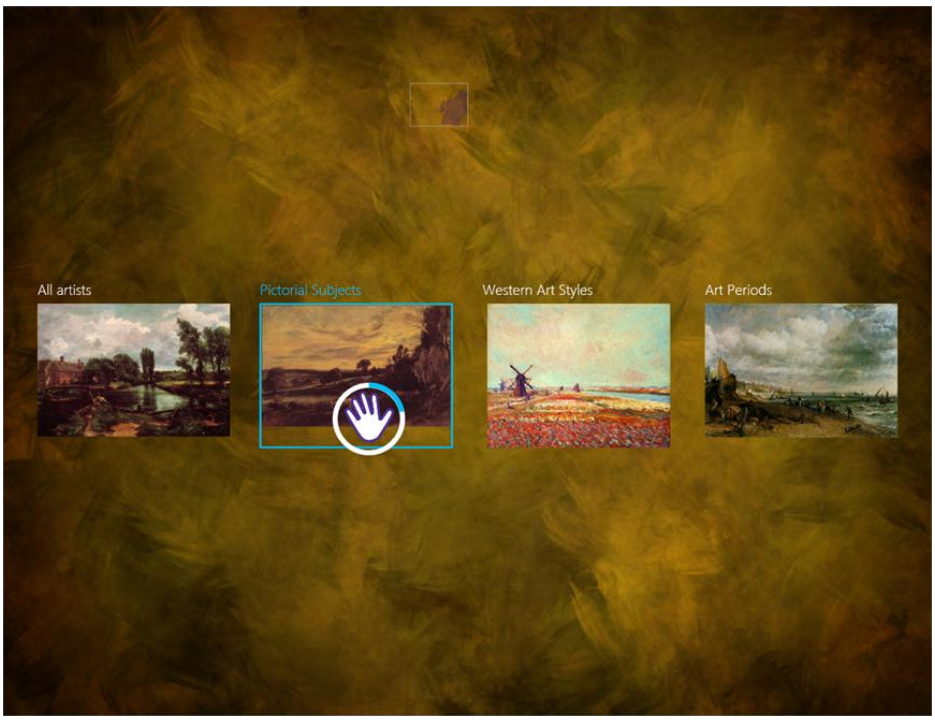


Figure 180: Browsing alternatives provided by the "Exhibition Browser"

The selection of one of the aforementioned categories presents the collections of artists and their works (see Figure 181).

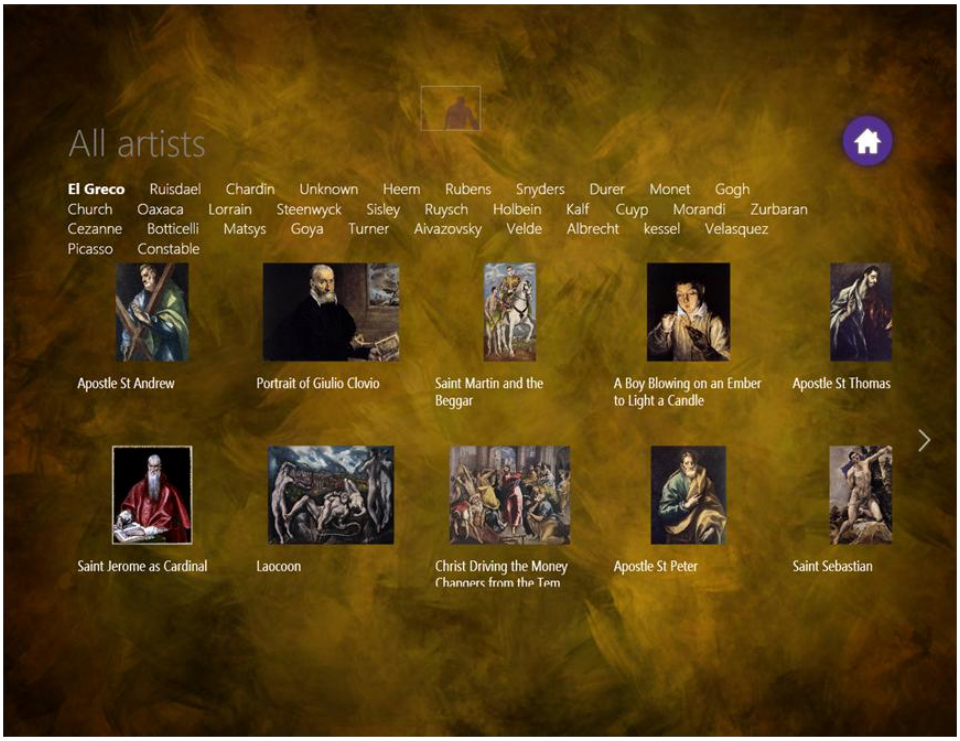


Figure 181: Displaying artworks by Artist

At the same time when an artefact is selected information is presented in a number of directions. Initially visitors' access general information about the painting such as the

artist, its creation date etc. At a second level visitors can browse through the annotated locations of the painting. And finally the option to manipulate the painting through zooming is available (see Figure 182).

Figure 182: The Artefact's main screen

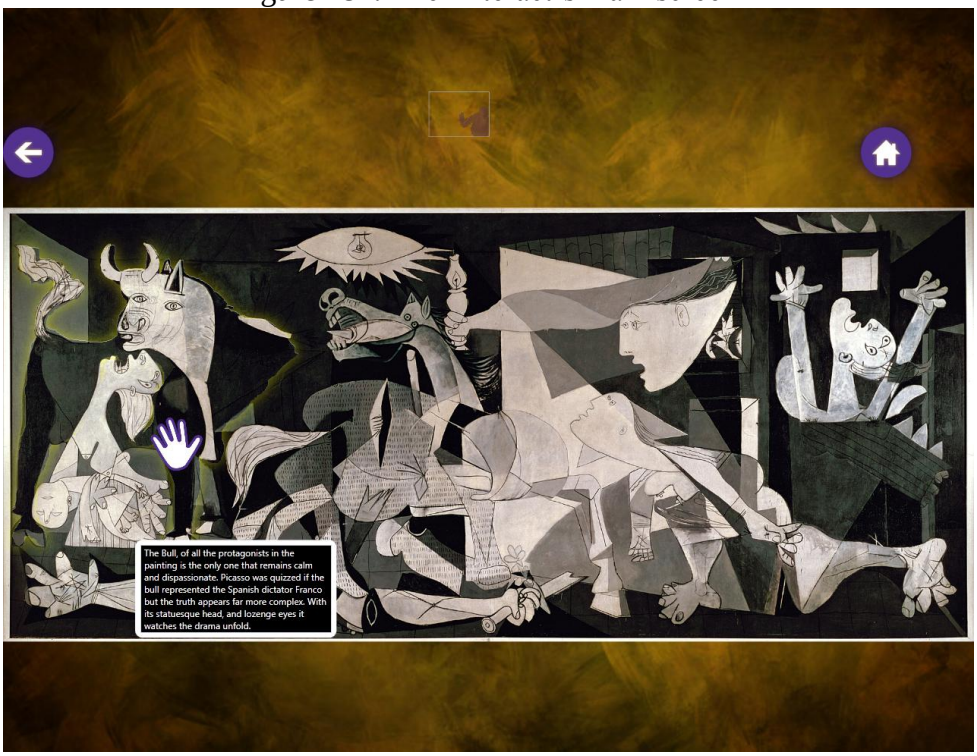


Figure 183: Points of interest within an Artefact

It is traditionally argued that no digitally rendered equivalent of an art object can ever surpass the feeling of viewing art itself. The zooming functionality is handling exactly the issue of information loss occurring when a physical artefact is transformed from the actual word to the digital one. To do so digital representations of extremely large resolution are required (several giga-pixels). These digital representations using the Microsoft Deep Zoom Composer [224] are transformed to a hierarchy of grid-based representations. Each grid contains a number of picture segments that are composed to form the actual picture for a specific picture resolution. These digital grid-based representations are saved on a web server and can be accessed through an xml based description stored in the ontology. An example of deep zooming within Vincent Van Gogh's Starry Night is presented in Figure 184. This figure also presents the detail that such an approach can provide.

Figure 184: Deep zooming within Vincent Van Gogh's Starry Night

The complete set of implementation details for the "Exhibition Browser" application is presented in Table 43.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]

	• Deep Zoom Control Library [223] • Microsoft Deep Zoom Composer [224]
Ami Services Used	• *"AmiForArtModel"* • *"UserAwareness"* • *"ContextAwareness"* • "KinectHandTracking" • "artServer" service
Ami Services implemented	• "artClient" service

Libraries Used	• "AmiForArtUIToolkit"
	  ○ Multi-scale image control
	  ○ Regions of interests presenter
	  ○ Hand mapping control
	  ○ Magnifying Glass

Hardware supported	• Desktop pc • Kinect Sensor • Short throw projector
Interaction Schemes	• Hand tracking

Table 43. Implementation details for the "Exhibition Browser"

8.4.3.2 Art River

The "Art River" is an application designed to provide multi-user access to Art collections. The main concept of this application is that users have simultaneous access to a stream of information. Items floating within the stream can be extracted when selected by a user. At the same time the stream by itself is dynamic. The collections floating within the stream are interconnected with rocks that users have on their disposal. Each of these rocks represent a collection of items and when placed on the stream result to the loading of its content within the stream. In this sense users have the option to share a stream of information and at the same time new users can integrate new information to the stream. An example of the augmented rocks used for allowing users to insert information within the stream is presented in Figure 185 while Figure 186 presents items floating within the stream while some of them have been extracted and manipulated by users.

Figure 185. Collection of augmented rocks

Figure 186. Items are floating within the stream while users are manipulating some of them

The complete set of implementation details for the "Art River" application is presented in Table 44.

Implementation Framework	• Microsoft surface SDK 2.0 [230] • Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231] • "Social Stream" Surface SDK 2.0 [341]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service

Libraries Used	• "AmiForArtUIToolkit"
Hardware Used	• Microsoft PixelSense – Samsung SUR-40
Interaction Schemes	• Multi Touch & gestures • Augmented physical objects ○ rocks

Table 44. Implementation details for the "Art River"

8.4.4 Art within museum leisure spaces: The museum coffee table

The Museum Coffee Table expands the museum experiences to leisure spaces such as cafeterias and restaurants. The Museum Coffee Table facilitates the beverage coaster metaphor to provide access to the life and works of famous artists. A number of augmented beverage coasters have been developed integrating tags to be recognised by the Microsoft SUR40 surface device. This augmented beverage coasters present on their front side (where the beverage is placed) a famous artist while on the back side the tag for object recognition (see Figure 187).

Figure 187. Collection of augmented beverage coasters

When a coaster is placed on the augmented surface it is augmented by a digital menu. This menu offers access to the life and works of the selected artist but also to games for children (see Figure 188). These games extract content by the collection of works of the artists shown on the coaster.

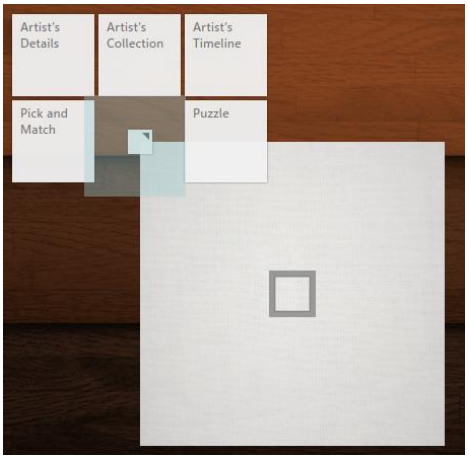


Figure 188. The augmented beverage coaster menu

Learning about artists

Through the augmented artist menu a variety of information can be accessed including demographic details (name, movement, art period etc.), the artist's collection of works and the timeline of the artist. The Artist's collection is a library bar that contains the works of the selected artist (see Figure 189). This library bar container presents a list of thumbnails containing all the artistic accomplishment of an artist's lifetime. From this library users can select and manipulate paintings using rich touch based interaction.

Figure 189. The Artist's collection library bar

The Artist's timeline is designed to present important events of the artist's life in accordance to his artistic accomplishments (see Figure 190). Users can manipulate through touch these timelines using basic gestures (touch from left to right to move the timeline forward and from right to left to move the timeline backwards). By simply touching an event from the timeline more information about the event is presented. At the same time the timeline itself provides information through the timeline bars about the duration of each event.

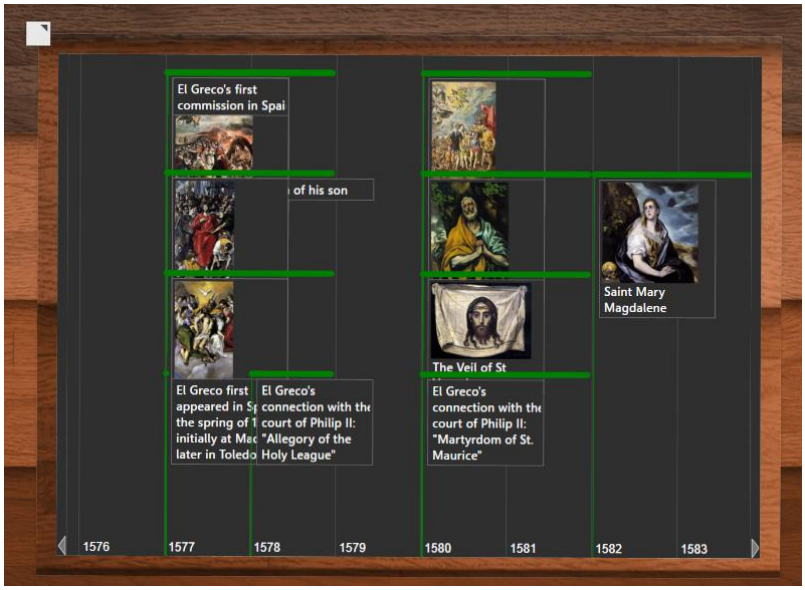


Figure 190. El Greco's timeline

Information about Paintings

A manipulated painting enables the extraction of additional information by using the embedded menu as in Figure 191. Such information includes details about its creation, the techniques used by the artist, the composition scheme followed etc. At the same time users can access a very large scale digital image of the painting where deep zooming can be employed to present the details of the original masterpiece (that are traditional lost by low resolution digital copies).

Figure 191. The painting's menu

Games

Games are considered an important add-on to the "Museum Coffee Table" as long as they allow parents to get more information about art while children are entertained

through games. In this sense the "Museum Coffee Table" is a facility for the whole family and a valuable partner of their museum experiences. "Museum Coffee Table" currently supports two games a cards based memory game and a puzzle game.

The "Pick&Match" is a simple memory game of cards where children are prompted to locate the same pairs of cards within a collection of initially hidden cards (see Figure 192). It is a basic memory game that gets added value when integrated to the museum coffee table. Within this table the game cards are coupled with the coaster used. For example if the coaster used pictures Domenikos Theotokopoulos a game is randomly generated by his works. The "Art Puzzle" extracts information from the currently selected artist (the beverage coaster used for loading the game) to produce a collection of puzzles from the painting displayed on the coaster (see Figure 192).

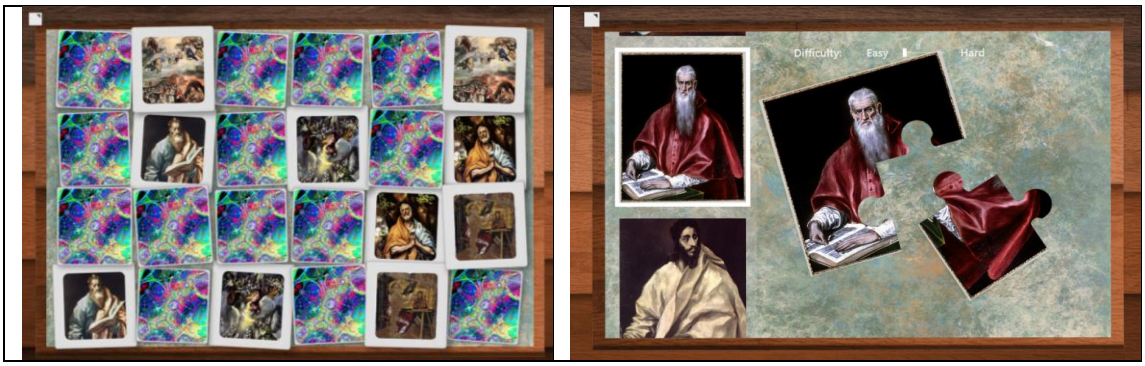


Figure 192. The "Pick & Match" and the "Art Puzzle" within the museum coffee table

Personalisation

The museum coffee table employs another set of augmented beverage coasters which are smaller in size and more playful in terms of appearance (circle, triangle, star, rectangle etc.). These beverage coasters are meant to be used by children and are employed by the table to adapt and personalise its content to children. Among the adaptations currently supported is the limitation of menu options (only collections, pick and match and puzzle are available for children) and the adaptation of information presented (only a lexical description of the painting is presented to children).

The complete set of implementation details for the "Museum Coffee Table" application is presented in Table 45.

Implementation	• Microsoft surface SDK 2.0 [230]

Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service

Libraries Used	• "AmiForArtUIToolkit"
	  ○ Timeline Control
	  ○ Menus
	  ○ Image library containers

Hardware Used	• Microsoft PixelSense – Samsung SUR-40
Interaction Schemes	• Multi Touch & gestures • Augmented physical objects ○ Augmented beverage coasters
Interaction Schemes	• Multi Touch & gestures • Augmented physical objects ○ rocks

Table 45. Implementation details for the "Museum Coffee Table"

8.5 Art within living spaces

8.5.1 State of the art

Nowadays Art when considered in the context of everyday environments is perceived simply as the existence of aesthetic material that enhances the overall feeling of the living environment. This purpose of Art is probably the most important. This research work aims at enhancing the way that art is encapsulated in the fabric of our living environments but also providing brand new directions for facilitating art in our everyday lives. At the same time important aspect of the research conducted in this field is the ability offered by this research work to transfer museum experience at home.

8.5.2 The Living Room Painting

Current approaches in elaborating art in the context of ambient applications for smart homes mainly elaborate art for achieving the need for information, usability,

accessibility etc. Although these aspects are important little work has been directed towards setting the mood of people and thus transforming the leaving environment to a pleasant environment. In this context art can be employed to transform space to achieve the creation of a unique visual and sensory environment. Therefore using this philosophy artwork becomes an integral part of the overall visual, tactile and emotional experience of the space. According to [35] this is mainly achieved through the usage of colour to affect psychology. The human reaction to colour is based on nature's symbolism but the human psyche is what interprets these colours and gives them meaning. More specifically different colours can produce different emotions and can be used for different purposes [35, 41]:

- **General Reds (Encompassing colours: Mauve, Pink, Crimson, Scarlet, and Bright Red):** Reds convey charged emotions like anger, love, or passion. It is the flow of life through our veins. People notice red first. It is used to catch attention and give definition.
    - **Rich Red:** sophisticated and welcoming
    - **Romantic Red:** innocence
    - **Vital Red:** cheerful and energetic
    - **Earthy Red:** homey and relaxed
- **General Pink:** calming; used in prisons to control violent criminals
- **Yellows (Encompassing colours: Coral, Orange, Amber, Gold, and Yellow):** Yellows are simulating and can act like a warning. Lemon yellow is associated with sour. Yellow flames say, "don't touch", and the high contrast of yield signs immediately catch our attention. Like the sun yellows are uncomfortable to look at for an extended period of time.
    - **General Yellow:** cheerful, sunny, attention-getter; most difficult colour to take in, overpowering; concentration; speeds metabolism
    - **Sun Yellow:** expansiveness, happiness, high spirits; demands attention; good for highlighting
    - **Elegant Yellow:** yellow white or gold; opulent, expensive, good taste
- **Greens (Encompassing colours: Lime, Leaf Green, Sea Green, Emerald, and Teal):** The human eye is most sensitive to greens. Humans see more shades of green than any other colour. Greens represent life, like trees, grass, and plants, and give us a calm natural feeling.

- **General Green:** symbolic nature; improve vision; calming, refreshing; fertility symbol; pastoral; also envy and jealousy; should not be overused
- **Traditional Green:** conservative, masculine, ancient
- **Refreshing Green:** healing, youthful, happy
- **Tropical Green:** serene, relaxing, sensuous, casual

- **Blues (Encompassing colours: Cyan, Sky blue, Dark Blue, Violet, and Purple.):** Blues are tranquil and cold. Blue is open and wide like the sky or deep and cold like a lake. Blue is a colour of distance and is effectively used as a background colour.
    - **General Blue:** opposite of red; stimulating and calming; strength, dignity, calm, trustworthy; depth, integrity, authority; classic beauty; older audience
    - **Dependable Blue:** navy blue; reliable and responsible, conforms
    - **Calm Blue:** cooling and soothing; meditative, spiritual, restful
    - **Regal Blue:** authoritative, strong, courageous, implied sensuous richness

Taking into account these considerations you should not be surprised by the emotional wave produced by art such as The Red Vineyard by Vincent van Gogh (Figure 193).

Figure 193: The Red Vineyard by Vincent van Gogh (November 1888)

The complete set of implementation details for the "Living room painting" application is presented in Table 46.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service
Libraries Used	• "AmiForArtUIToolkit"
Hardware Used	• Touch panel pc • Desktop pc • Short throw projector
Interaction Schemes	• Postures

Table 46. Implementation details for the "Living room painting"

8.5.3 Presenting information: The Augmented Digital Frame

Informative art is a term that defines the usage of art for altering the way that information is visualised and transmitted to the user. For example an e-mail application can add or subtract elements in a painting to denote the number of new messages in a mail box. These applications are gaining increasing importance and are welcomed with great comments from their target context. In this section a number of applications proposed for incorporation in the various instantiations of the art enabled ambient facility are presented focussing both on the functional and information encoding aspects to be considered during their creation. The "Augmented Digital Frame" is designed to present different types of information encoded within paintings:

Mailbox: Mailbox information is presented by employing the concept of informative art together with mailbox monitoring. The Informative art display initially presents an abstracted view of the painting where several elements such as grapes, apples, etc., have been removed. In turn the infrastructure of the application tracks a mailbox (through the "emailer" service) and generates events that affect the painting (elements

appear or disappear). The painting “Basket of Fruit” by Michelangelo Merisi da Caravaggio (see figure Figure 194) is a great example of this concept.

Figure 194: “Basket of Fruit” by Michelangelo Merisi da Caravaggio

Clock and schedule: Clock and schedule information is presented by employing one the most important aspects of painting, light. As already described light either directly projected on an object or reflected by another object is the key for understanding the world around us. If there was a man that dedicated his carrier on understanding the attributes of light was Claude Monet. Beginning in the 1880s and 1890s, through the end of his life in 1926, Monet worked on "series" paintings, in which a subject was depicted in varying light and weather conditions. His first series exhibited as such was of Haystacks, painted from different points of view and at different times of the day and seasons. Fifteen of the paintings were exhibited at the Galerie Durand-Ruel in 1891. He later produced several series of paintings including: Rouen Cathedral, Poplars, the Parliament, Mornings on the Seine and the Water Lilies that were painted on his property at Giverny [124]. It was at the Salon of 1865 that his paintings of the Seine were very well received and prompted Cezanne to call Monet “only an eye, but my God what an eye” [69]. These series can be employed for presenting an art enabled clock in the informative art display by presenting the painting, from a series of Monet, that encompass the specific time of the day. Some indicative paintings from the series of Rouen Cathedral are presented in Figure 195.

Figure 195. Paintings from the series of Rouen Cathedral from Claude Monet

Weather: Weather Forecast is monitored through extracting data from a weather service and presenting a painting that simulates the current weather conditions. Sound effects are employed to capture user's attention when status changes occur. These data can be used in conjunction with time of the day information for presenting for example a morning storm etc.

Stock Market prices: The concept of visualizing stock market prices via informative art has been already employed in the context of previous efforts. For example InfoCanvas visualize the day's change for Coca-Cola stock by either a sea shell when stock is up or a watermelon when stock is down [67]. The approach followed in the context of this work is visualizing stock market prices through the usage of a web service for retrieving stock values and the mapping of changes in stock to paintings related to prosperity or poverty. Vincent Van Gogh's art was his vocation and the means by which he could bring consolation to humanity. In keeping with his

humanitarian outlook he painted peasants and workers [109] rather that sticking with the idealistic approach of his contemporaries.

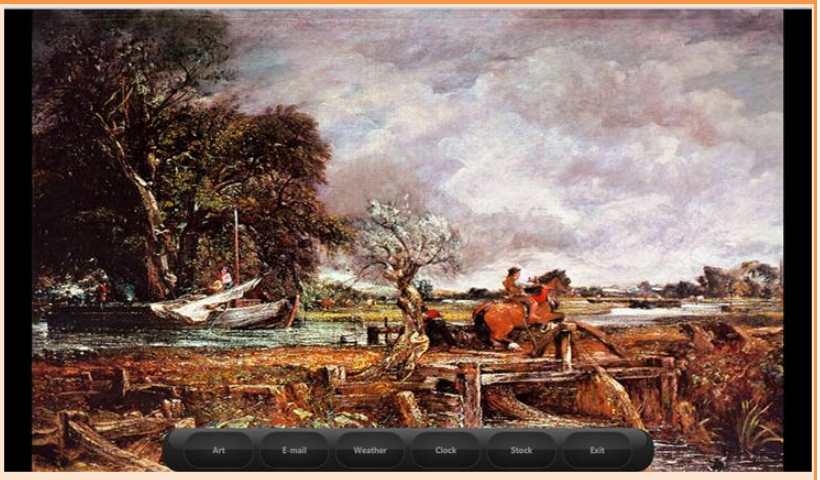
Figure 196: The Potato Eaters by Vincent Van Gogh (1885)

On the other hand the Jan Van Eyck's Arnolfini "Wedding" (see Figure 197) is a clear depiction of prosperity. These two examples could be used of a wonderful representation of poverty versus prosperity and can be employed as a metaphor for representing financial measures such as the stock market. Together with a service for monitoring the activity of the stock market the potato eaters can appear when the stock is down while the Arnolfini Wedding appears when stock is up.

Figure 197: Arnolfini "Wedding" by Jan Van Eyck (1434)

In all these visualizations there is an option to select additional output using speech synthesis. At the same time the “PredominantColourCalculator” service can extract useful information from the prototype for adjusting lighting according to the

predominant colour of each presented painting. An overview of the digital frame employing different painting and visualisations to represent the information described above is presented in Figure 198.

State	Screenshot
Paintings	
Weather	
Clock	

Stock	
Email	

Figure 198: Encoded information within the "Augmented Digital Frame"

Controlling Multiple Informative Art applications from a single Information Display

Although the approaches followed to date focused on presenting multiple information on a single canvas or having several canvases for different information it is argued that the first approach leads to information overload and the second to spatial information distribution that leads to the need for concentrating on many information sources. In this context this research work proposes the facilitation of a gesture based interaction technique for facilitating the incorporation of various information sources in the same canvas. In this context a single information source is displayed on the canvas presenting abstracted information (for example a painting of Monet). When a person approaches the canvas the information displayed gets concrete (for example a schedule appears, or the stock market prices). For changing between information sources (change from the schedule to weather forecast, email etc.) the person has to make a gesture representing next or previous (right movement of his hand is next left is previous).

The complete set of implementation details for the "Digital Frame" application is presented in Table 47.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtDataAccess" Service • "emailer" service • "stockMarket" service • "localWeather" service • "predominantColourCalculator" service • "KinectGestures" • "artServer" service
Ami Services implemented	• "artClient" service
Libraries Used	• "AmiForArtUIToolkit"
Hardware supported	• Desktop pc • Desktop pc with touch screen • Short throw projector • Touch panel pc • Tablet pc
Interaction Schemes	• Touch • Kinect based gestures

Table 47. Implementation details for the "Digital Frame" application

8.5.4 The Art Collector

The "Art Collector" is a board game that can be played by two to four players. The main concept of the game is to present a map of a country or a continent as it was during a specific art period (for example Europe during renaissance, modern Europe etc.). In this map a track is presented passing from the main focal points of the specific period. The interaction with players is carried out through (a) augmented dices, (b) augmented player avatars, (c) on-board touch screen controls, (d) physical controllers with four switches and (e) speech recognition. Each player throws the dices and the system based on the location of player's pawn generates questions that are related to the specific art period and to the specific location where player's avatar is located. Correct answers allow the player to re-throw the dices while wrong

answers give the turn to the next player. The player that manages to pass the finishing line first wins the game. An indicative game board is presented in Figure 199. The life cycle of the "ArtCollector" (see Figure 200) prototype includes the generation of the game map through the tIDE map editor (see Figure 201), the definition of the track (Background, POIs, attachment of properties to POIs etc) and the loading of the new game track to the prototype. Question generation is dynamic based on the retrieval of information from the POIs and the forming of SPARQL queries to be submitted to the ontology.

Figure 199: The "ArtCollector" prototype

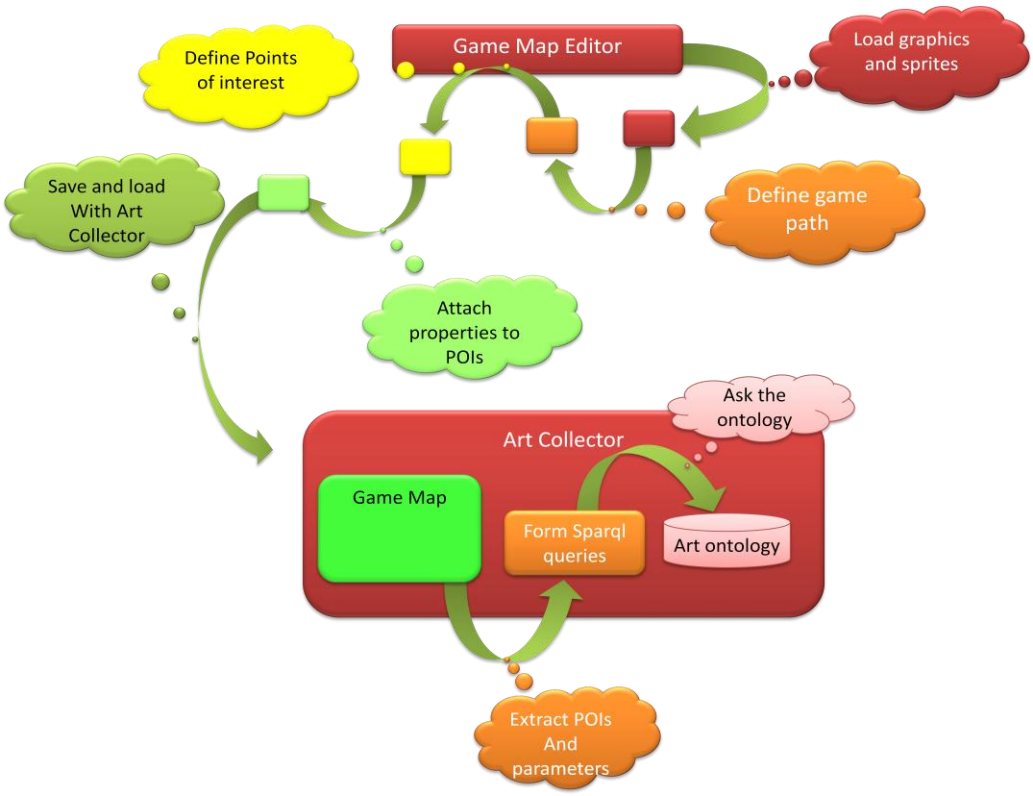


Figure 200: The "ArtCollector" map creation and game cycle

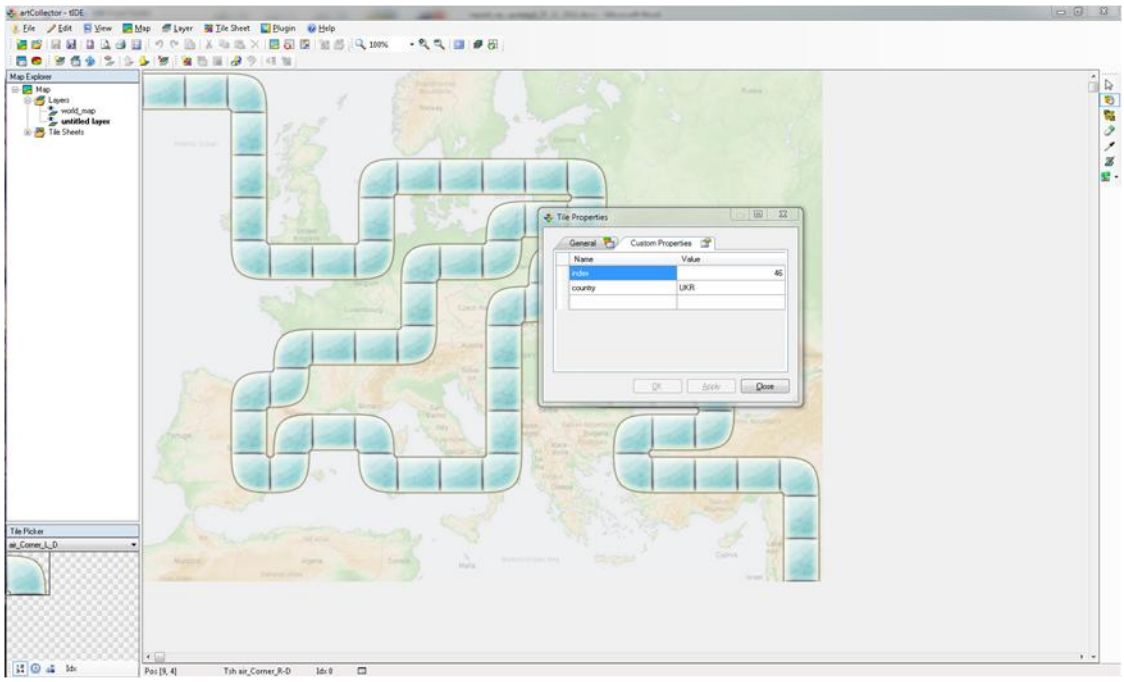


Figure 201: A game map loaded to the tIDE Map Editor

Question	**Answer**
Question + Ontology Binding	Answer + Ontology Binding
Question: The painting displayed has	Answer: • Actual Artist

been created by an author following the art style of + ArtStyle	• Artists from the same style/ period
Question: Which is the title of the painting displayed?	Answer: • Actual Title • Titles from paintings from the same artist
Question: Who has commissioned the paintingTitle by artistName	Answer: • ActualArtPatron • Patrons from the same period
Question: Which was the painting surface used by artistName to create paintingTitle	Answer: • ActualSurface • Other painting surfaces used at the same period
Question: Which painting medium was used by artistName to create paintingTitle	Answer: • Actual Medium • Mediums used by artists at the same period
Question: The painting displayed is the famous painting paintingTitle by artistName. Which one from the following paintings has not been created by artistName	Answer: • One painting from another artist of the same period • Three painting from the same artist
Question: The painting displayed is the famous painting paintingTitle by artistName. Which one from the following paintings has been created by the same artist	Answer: • Three paintings from other artist of the same period • One painting from the same artist
Question: Which of the following techniques have been used for the creation of paintingTitle by artistName	Answer: • Three paintings from other artist of the same period • One painting from the same artist

- **In Red: Ontology Bindings**
- **In Black: Static content**

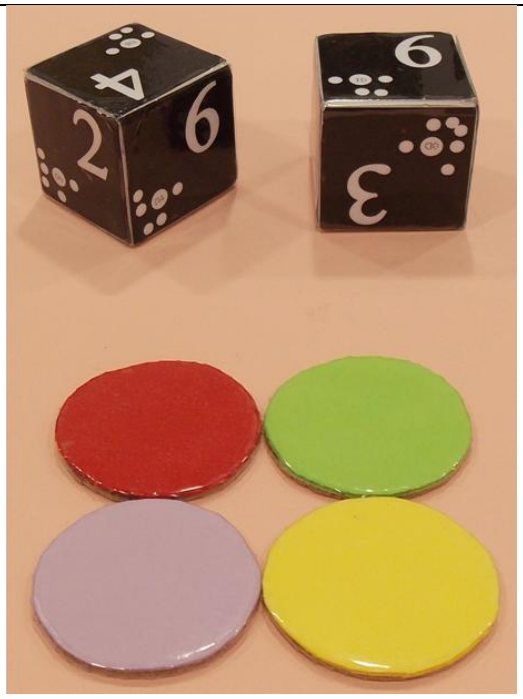
Table 48. Examples of the structure of Questions and Answers

Augmented Physical Objects

Art Collector employs augmented physic objects for allowing the important parts of the game to reside on the physical world while the game functionality is transferred to the digital world. The augmented objects created and used in the context of this research work include pawns, dices and player identifiers. Two variations of pawns were created one set for children and another one for adults. These variations together with alternative game maps are used to adapt art collector to the age of its players. Pawns were created from sketch using polymer clay Figure 202. For the dices stretch cubes were used while the areas of the dice were printed glued and laminated. Finally user identifiers were created using coloured carton and cork leaves. Carton was glued on-top of a cork leave and then the result was laminated. All the materials are recognised used embedded printed byte tags. The collection of augmented physical objects used by Art Collector is presented in Figure 202.

Top: Pawns for children

Bottom: Pawns for adults



Top: Augmented dices

Bottom: User identifiers

Figure 202: Augmented physical objects used by Art Collector

Personalisation

Art collector facilitates the collection of augmented physical objects to personalise the game to its players. To do so the collection of pawns for children is used to identify a child within the game and adapt the questions. The adaptation currently supported by Art Collector involves limiting the possible replies of a question (from four to two)

and in some cases where the subject is considered advanced for children making the questions binary (children should just reply yes or no).

The complete set of implementation details for the "ArtCollector" application is presented in Table 49.

Implementation Framework	• Microsoft Visual C# [232] • Microsoft XNA framework [229] • tIDE Tilemap Integrated Development Environment [227] • xTile Tile Rendering Engine [228]
Ami Services Used	• "AmiForArtModel" Service • "UserAwareness" service • "ContextAwareness" service • "artServer" service
Ami Services implemented	• "artClient" service
Libraries Used	
Hardware supported	• Xbox360 • Microsoft PixelSense – Samsung SUR-40 • Windows Phone
Interaction Schemes	• Touch • Speech recognition • Physical 4-switch controller

Table 49. Implementation details for the "ArtCollector" Prototype

8.5.5 Art Documentary

The "Art Documentary" is an interactive application capable of generating interactive documentaries from museum visits. The concept of this application is based on the fact that users have a mobile device with them during the museum visit. This mobile device is used to get information about museum exhibits and thus capable of recording the user's interaction with exhibits. This interaction history is in turn used by the "Art Documentary" to automatically generate a documentary based on the specification of the artefacts on the ontology and parameterised to the user's profile. The users have the option to either let the documentary play without their intervention or use gestures to control the flow of the presented information. Figure 203 presents a

documentary presented based on a collection of paintings by el-Greco. The documentary supports three types of playback:

- Automatic movie style playback
- Semi-automatic gestures operated playback
- Touch screen selection playback

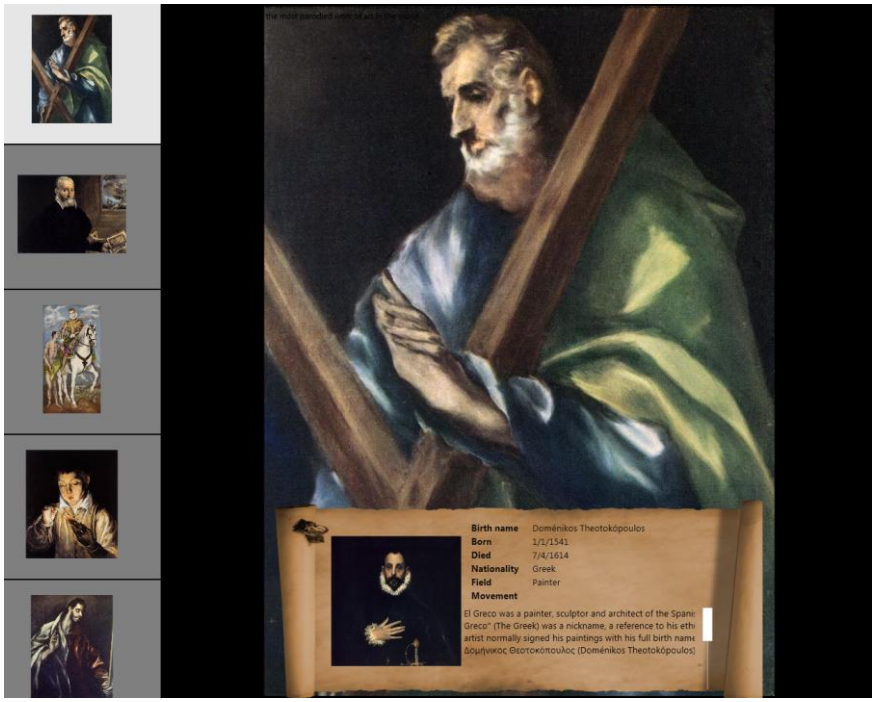


Figure 203: The "Art Documentary" is playing a documentary based on the last museum visit of the family

The complete set of implementation details for the "Art Documentary" application is presented in Table 50.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231]
Ami Services Used	• "AmiForArtDataAccess" Service • "artServer" service
Ami Services implemented	• "artClient" service
Libraries Used	• "AmiForArtUIToolkit"
Hardware supported	• Desktop pc with touch screen • Short throw projector • TV

Interaction Schemes	• Touch • Kinect based gestures

Table 50. Implementation details for the "Art Documentary" Prototype

8.5.6 The Paintings Plane

The "Painting's Plane" is a game designed to immerse a person in the magical space of the painting and it is based on the creative idea of an online game developed by Educational Web Adventures [45]. This is achieved by creating the illusion to the person sitting in from of the painting that he is actually in the painting itself. An example of a scenario involved for the painting of Van Gogh presented in can contain the following steps:

1. The person is presented with an impressionistic painting
2. The imaginary voice of the viewer is heard transforming him in the plane of the painting (for example "I wake up in a Wheat Field…")
3. In each round of the game the person is prompted by a number of questions and a set of answers (for example Question: "What do you think he was trying to do when he painted this scene?", Answers "Make a painting as detailed and accurate as a photograph?, Capture the momentary effects of sunlight and colour?, Express his own mood or emotion with strong colours and brushstrokes?")
4. The selection of an answer leads to another iteration of the game that in stages unfolds the complete artistic history of the painting both regarding the artist's intentions and the art style of the painting

In this game we resemble the way that Socrates was teaching his students to allow players to learn through an exploratory process. In this game no correct or wrong answers exist. Each user answer is a question for the system that must be replied before the system is in a position to prompt the user with another question.

Figure 204: Van Gogh's, Wheat Field with Crows 1890

The same concept can be used not for allowing the user to get in touch with the artist responsible for a Masterpiece but allowing him to access information that the artist has incorporated to the painting. This can be of applied in several subjects such as historical paintings or paintings that use historical figures as their subject matter. An magnificent example of such a painting is the School of Athens or Scuola di Atene in Italian, one of the most famous paintings by the Italian Renaissance artist Raphael (see Figure 205). This painting can be a magnificent gateway for presenting to users a several of the most important philosophers of the ancient world such Aristotle and Plato.

Figure 205: The school of Athens by Raphael

Figure 206: Close view of the painting together with numbering depiction of the philosophers presented on the painting

1	Zeno of Citium	12	Socrates
2	Epicurus	13	Heraclitus (Michelangelo)
3	Federico II of Mantua	14	Plato holding the Timaeus (Leonardo da Vinci)
4	Anicius Manlius Severinus Boethius or Anaximander or Empedocles	15	Aristotle holding the Ethics
5	Averroes	16	Diogenes of Sinope
6	Pythagoras	17	Plotinus
7	Alcibiades or Alexander the Great	18	Euclid or Archimedes with students (Bramante)
8	Antisthenes or Xenophon	19	Strabo or Zoroaster
9	Hypatia (Francesco Maria della Rovere or Raphael's mistress Margherita)	20	Ptolemy
10	Aeschines or Xenophon	21	Protogenes (Il Sodoma, Perugino or Timoteo Viti)
11	Parmenides		

Table 51: 21 information sources for the “Painting’s Plane” when the painting “The school of Athens” by Raphael is used

Questions prompted to user relate with POIs in the presented artefact. In this context deep zooming is used for allowing the game to focus of the area of painting which is of interest while explain the user and prompting him with a new question. An example of a game setup using the Van Gogh’s Starry Night is presented in Figure 207.

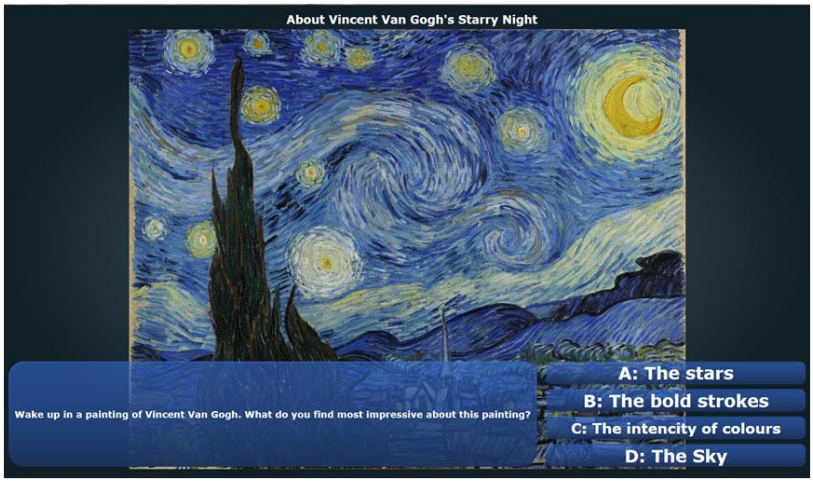


Figure 207: The "PaintingsPlane" prototype

The Questions/Answers structure used to represent such a game scheme is presented in Figure 208. As presented in this figure this concept results to a Questions/Answers tree that can get immensely so a way to loop back to the game tree is required and will be supported in the future.

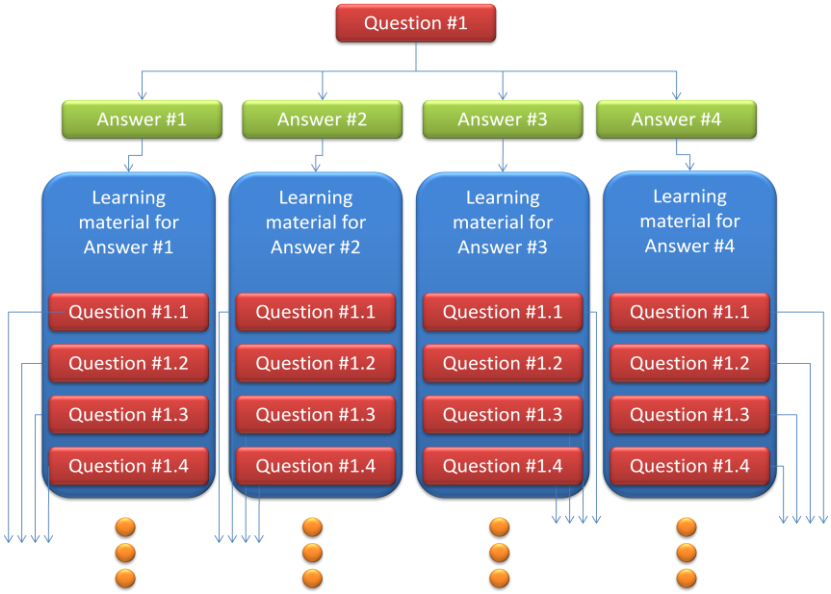


Figure 208: The "PaintingsPlane" Questions/Answers structure

The complete set of implementation details for the "Paintings Plane" application is presented in Table 52.

Implementation Framework	• Microsoft Visual C# [232] • Windows Presentation Foundation (WPF) [231] • Deep Zoom Control Library [223] • Microsoft Deep Zoom Composer [224]
Ami Services Used	• "AmiForArtModel" Service

	• "UserAwareness" service • "ContextAwareness" service • artServer" service
Ami Services implemented	• "artClient" service
Libraries Used	• "AmiForArtUIToolkit"
Hardware supported	• Desktop pc • Desktop pc with touch screen • Microsoft PixelSense – Samsung SUR-40 • Kinect Sensor • Short throw projector • Touch panel pc • Tablet pc
Interaction Schemes	• Touch • Multi touch • Speech recognition • Physical 4-switch controller

Table 52. Implementation details for the "Paintings Plane" application

9 Implemented Scenarios

This chapter presents the outcomes of this research work as deployed within an Ami Simulation Space. To this end this chapter presents the way that the implemented by this research work infrastructure and applications are used to facilitate the needs of the scenarios conceived during the conceptual design of this research work. To achieve this, the envisioned scenarios were "run" within the simulation space. During this process cameras were set up in focal points in order to capture the essence of the interaction. Each of the following sections presents one of the envisioned scenarios in terms of their intermediate steps and results. In this stage no actual paintings were created. On the contrary the purpose was to simulate the usage of the applications in order to evaluate the feasibility of conducting the envisioned scenarios. Based on this initial deployment and testing of the envisioned scenarios a second feasibility study was conducted. This study included the developed of four works of Art from scratch by employing the deployed applications. Each of these feasibility studies was conducted using a different art creation style and process employing different aspects of the deployed infrastructure.

9.1 Virtual simulation of the scenarios

9.1.1 A walk to the national garden

This scenario presented in section "4.1.1 A walk to the national garden" begins by synchronising pictures from mobile devices with the design space. As shown in Figure 209 to do so the artist place his mobile phone on the Samsung SUR-40 and the

material collected during his walk in the national garden is downloaded for editing using the design space.

Figure 209: Synchronising pictures with the design space

Following the artist browses reference material and uses the material collected from the device and the material browsed to create a new composition. This is achieved by selecting material and applying artistic concepts on them (see Figure 210). The application of such concepts reveals qualities of the material that allow the artist to decide whether the evaluated material can be successfully used as a composition for painting.

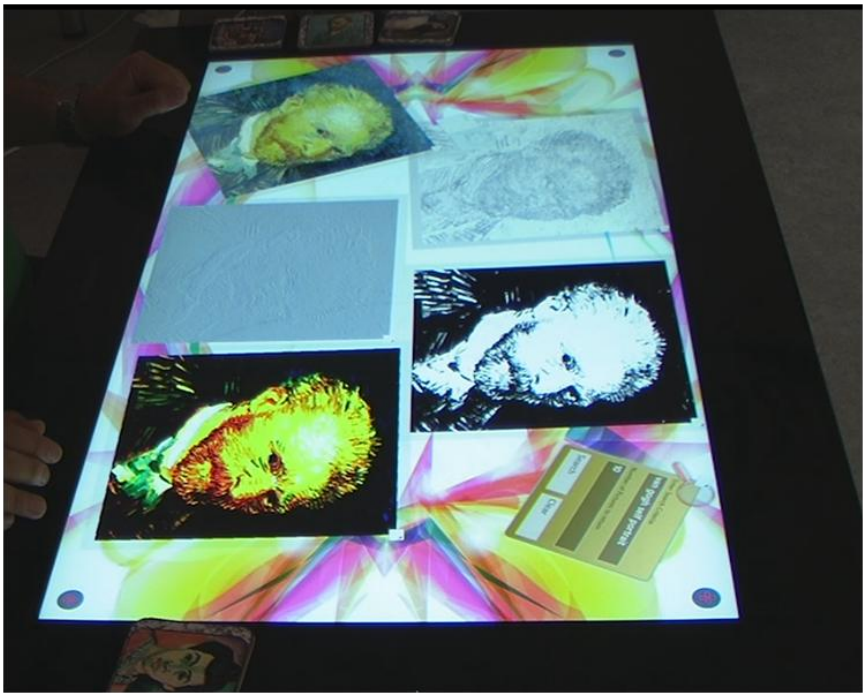


Figure 210: Creating compositions using digital media

This composition is in turn transferred to the Painting Plane where the painting area is adjusted to the requirements of the selected painting canvas (see Figure 211).

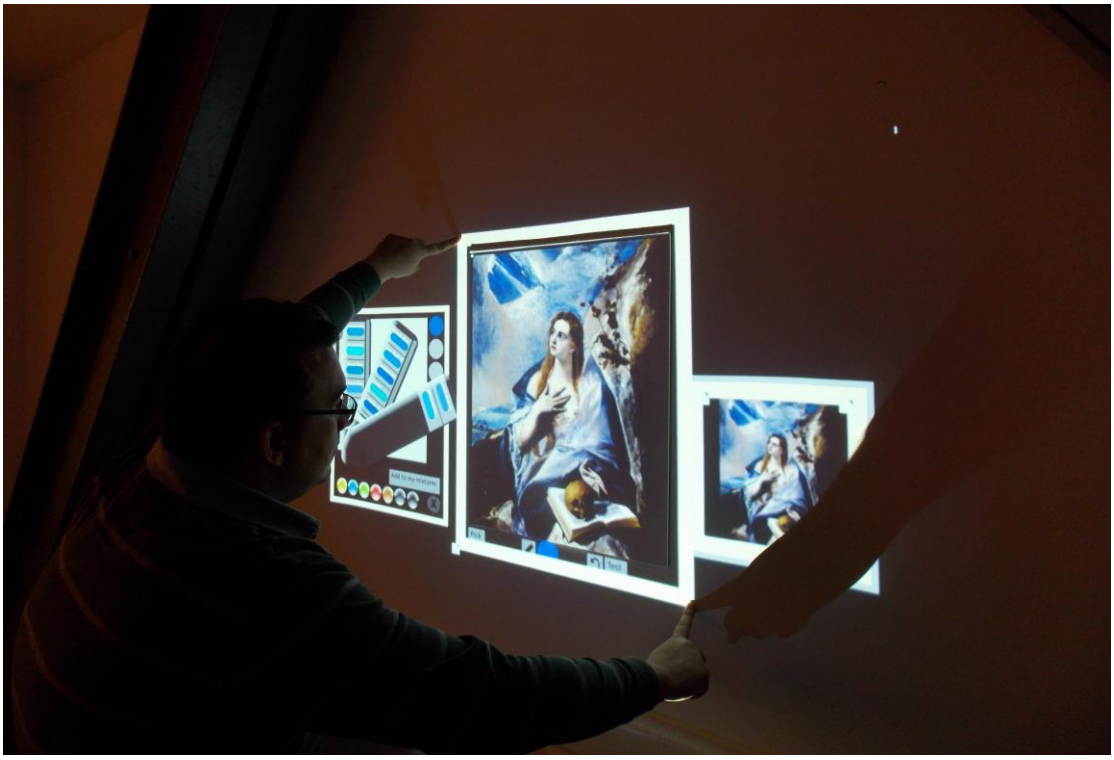


Figure 211: Adjusting the projection to the canvas size

The initiation of a new painting session also results to the loading of real time assistants on the side displays. The artist applies image processing filters in the

created composition in order to transfer the underling sketch of the composition to the augmented painting canvas (see Figure 212).

Figure 212: Accessing the composition in grey scale

The artist is using the painting assistants to evaluate colours and for creating virtual colour mixtures (see Figure 213).

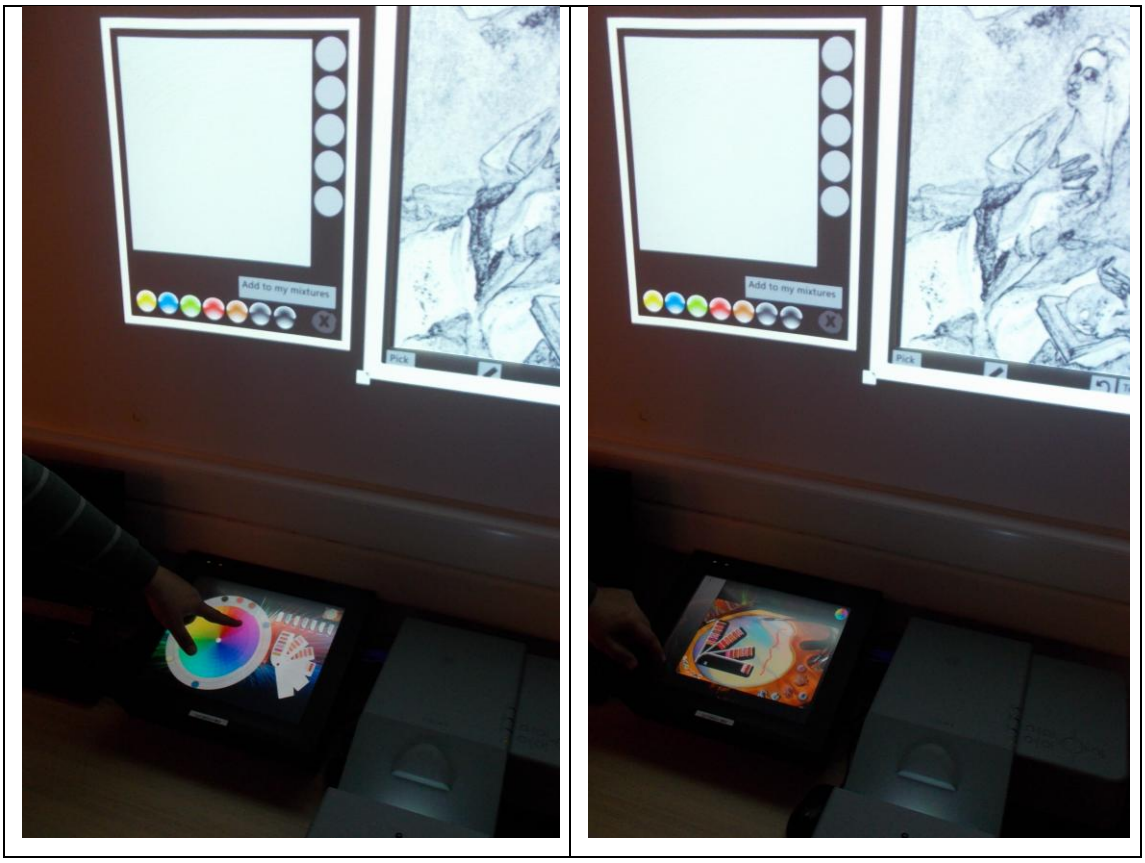


Figure 213: Evaluating colour and Creating Colour Mixtures

These created colour mixtures can be transferred and used on the augmented painting surface. To do so the artist drags the mixture towards the surface, select it from the colour mixtures wheel and uses a paint brush to virtually apply the mixture on the

canvas as shown in Figure 215. This is important for previewing the appropriateness of the mixtures prior to their creation using pigment paints.

Figure 214: Virtual applying colour mixtures to the canvas

After selecting all the appropriate mixtures the artist is using his design space for selecting painting supplies (see Figure 215). The supplies picked are the ones contained in the created mixtures but also the artist is interested into learning the qualities of some of the selected colours in terms of pigments, transparency and light fastness.

Figure 215: Selecting colours using the Art Supply Wizard

After collecting the supplies the artist creates actual mixtures using paint tubes and proceeds into creating the painting. During art creation the artist continues to use his augmented painting surface for testing concepts before the application of colour while the side screen display is used for browsing reference material. After the completion of the painting he has the desire to select the most appropriate frame for his finished work. To do so he is using the framing assistant that presents a virtual frame around the finished painting allowing the artist to test several colour schemes for finding the most appropriate (see Figure 216).

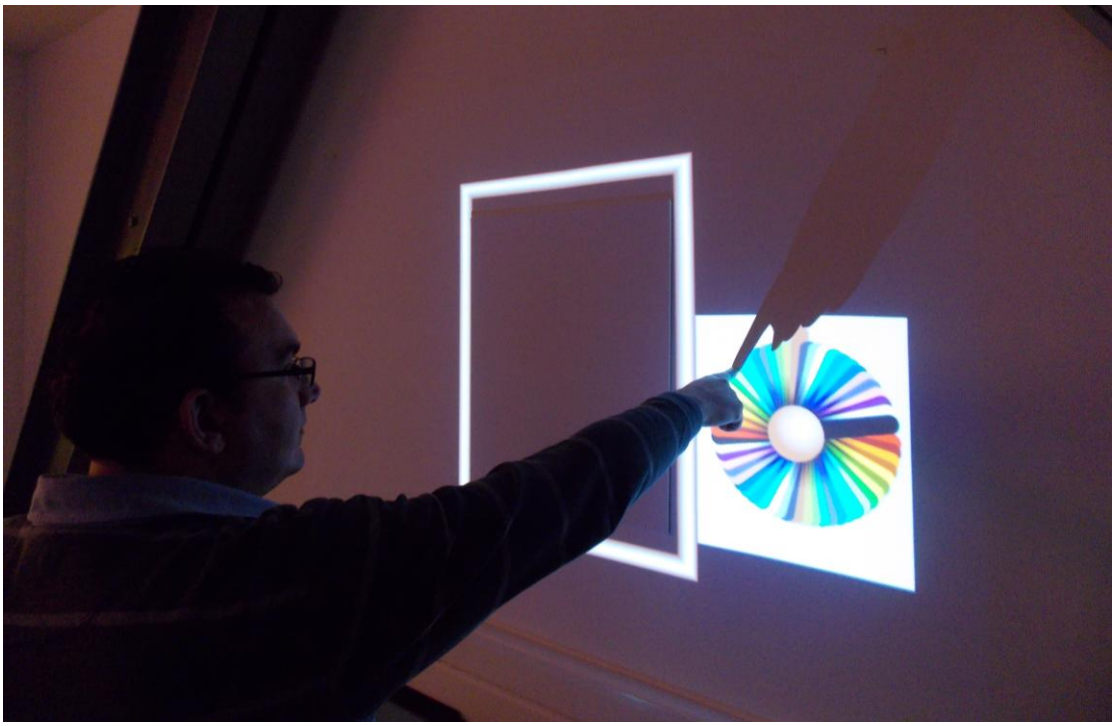


Figure 216: Selecting the most appropriate frame

9.1.2 A portrait commission

This scenario presented in section "4.1.1 A Portrait commission" starts with a meeting between the patron and the artist. Together they are browsing through artist's works in order for the patron to select a scheme for the portrait to be created by the artist (see Figure 217). The artist is logging the material preferred by the artist in order to have background information while creating the portrait.

Figure 217: The patron and the artist are browsing through artist's works

After having collected enough reference material for the artist to have sufficient information regarding the taste of his client on portraits (in terms of painting detail, colour schemes for the background, pose etc.) the artist request his client to proceed to the models plane. The artist is arranging the lighting accordingly. Lighting is important for highlighting basic features of the model after half of the portrait is about placing facial features in the correct location and with the correct analogies. The artist after the setting up of the model and the adjustment of lighting is using the painting plane to frame the composition. Framing is about selecting the part of the composition that will be painting out of the "big picture". While framing the artist is also considering important issues of composition such as negative space. After testing several framing options the artist is previewing the framed composition within the augmented painting surface. He places a canvas that matches the proportion of the selected framing scheme and adjusts the projected frame to the canvas size (see Figure **218**).

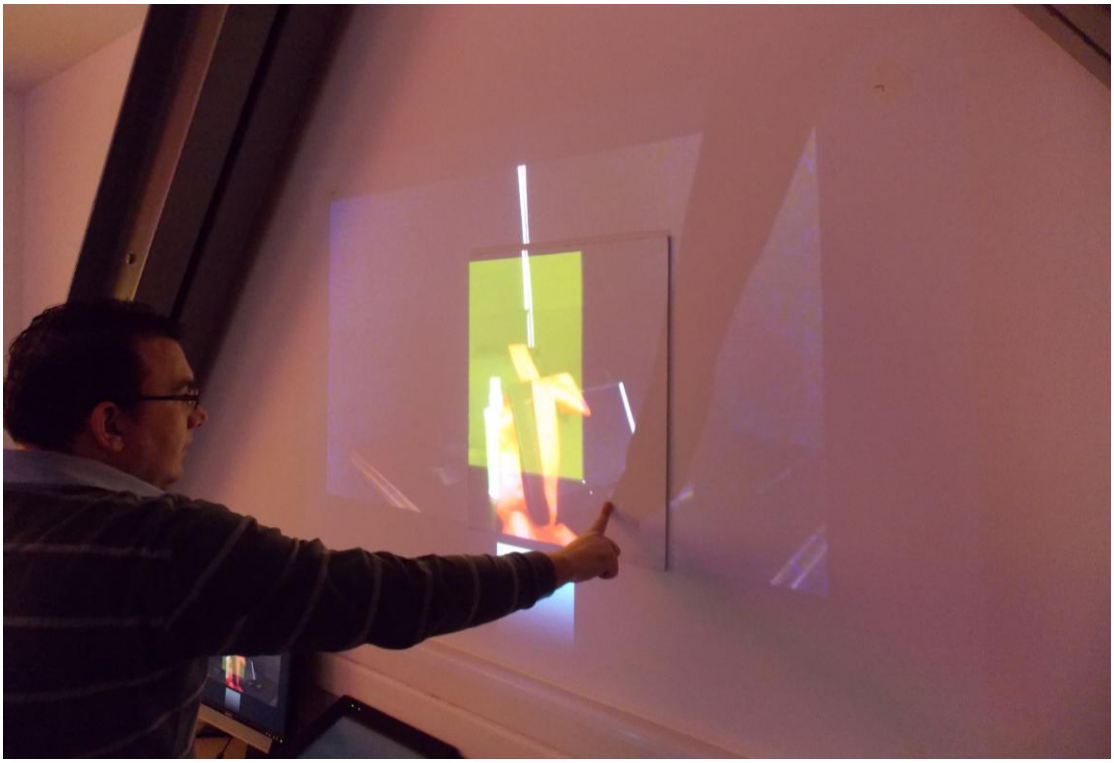


Figure 218: Framing the composition

Then the appropriate art supplies are selected and the artist proceeds to the creation of the portrait using the same basic principles as discussed in the previous section. After the portrait is completed the appropriate frame for the painting is selected as shown in Figure 219.

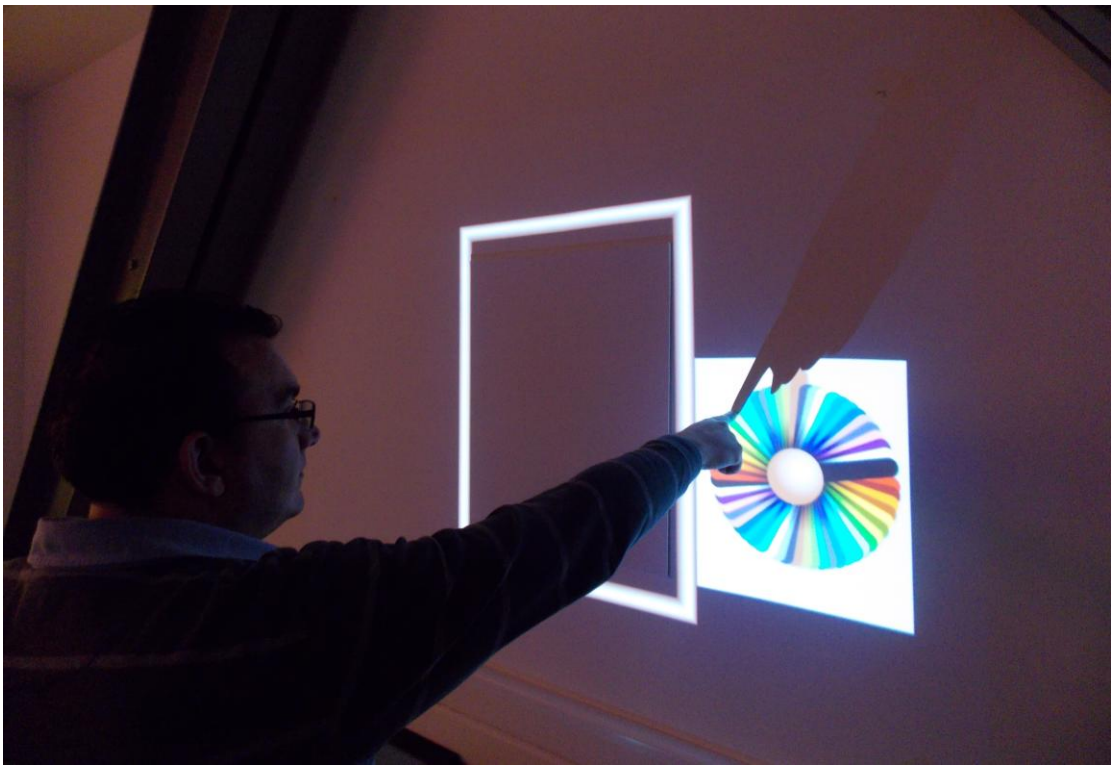


Figure 219: Select painting frame

9.1.3 Jack Luis the Art Student

In the context of this presented in section "4.2.1 Preparing for the exams" the art student is using the design space to create a three dimensional composition as shown in Figure 220. To do so he is using several virtual geometric shapes and arranges them within the selected plane. He is also selecting the appropriate lighting scheme and takes care of the rotation and zooming of the composition so as to be easily framed for painting.

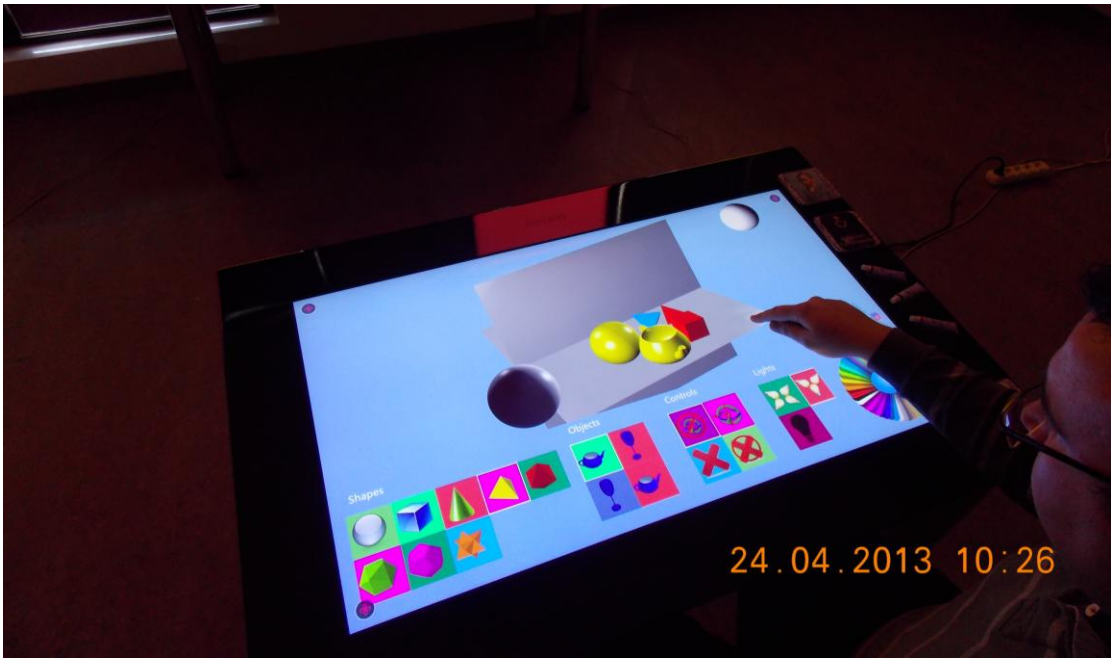


Figure 220: Creation of 3D composition

After completing the composition he thinks about colour. Colour is not required for performing this assignment but being excited with his uncle's workshop he decides to uses the surface to select some painting supplies.

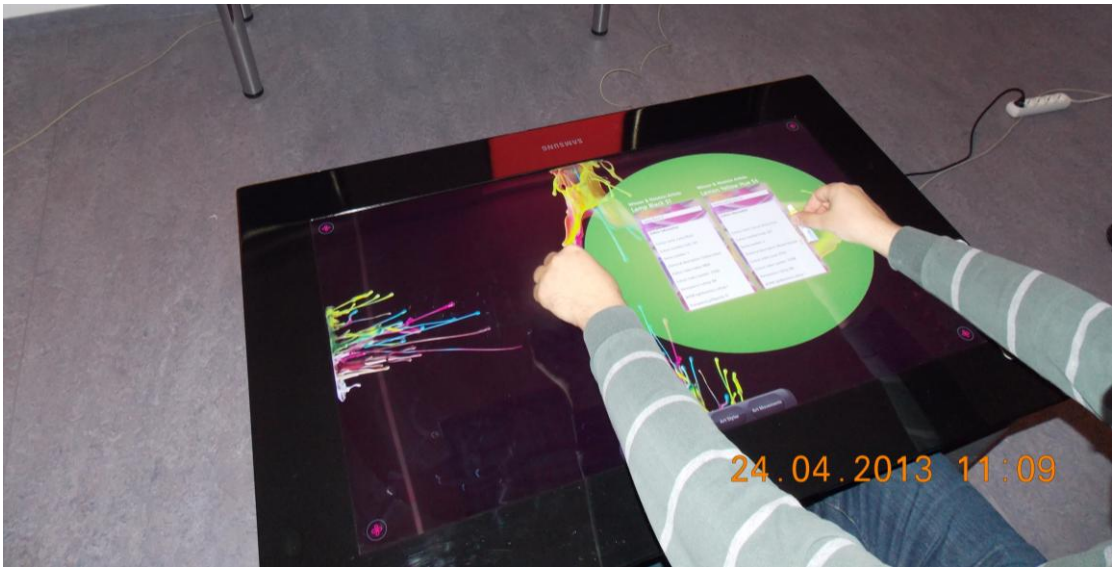


Figure 221: Selecting painting supplies

Having the art supplies handy he is using the Paint Lab for young artists to experiment on colour theory and mixing the selected paints for preparing himself for painting as shown in Figure 222. He prefers using the lab than the painting assistants because he can take his time and experiment on various concepts such as transparency without having the anxiety to paint.

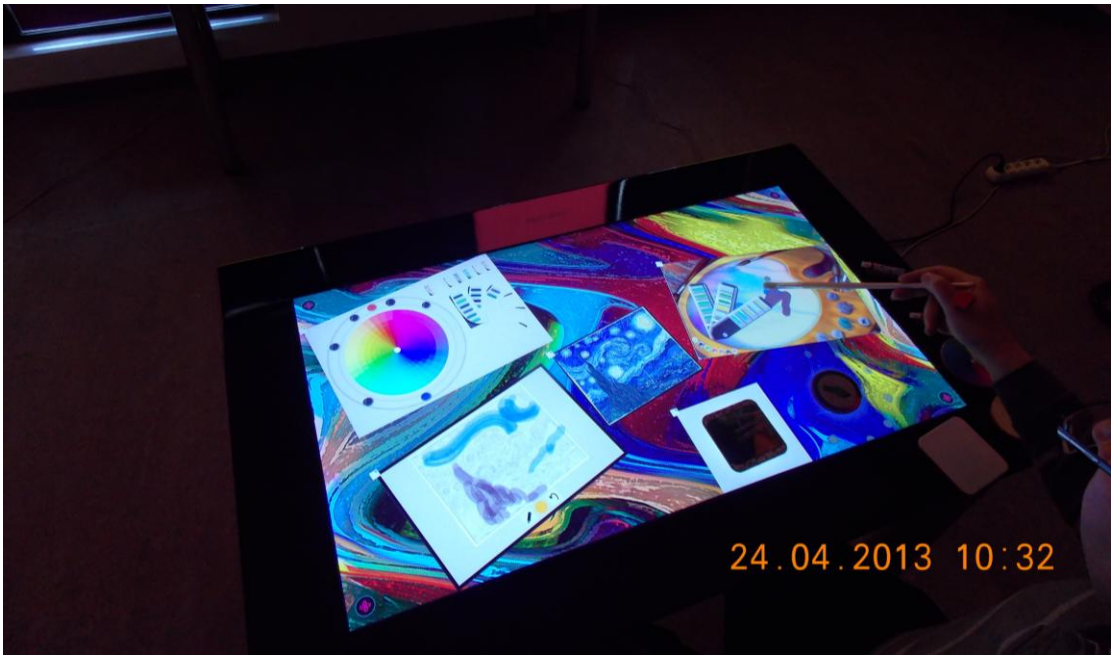


Figure 222: Experimenting using the Paint Lab for young artists

After the selection of colour he moves to the augmented painting surface, places a canvas and adjusts the size of the virtual canvas to the actual one. Then he projects the created composition on the side of the canvas and uses a charcoal stick to duplicate the composition on canvas. Afterwards he creates the appropriate colour mixtures and moves into painting his assignment.

On the second day Jack Luis moves directly to the design space to learn more about the impressionists as shown in Figure 223. This is important for his assignment because he must carefully examine the qualities of colour, brushstrokes and movement which are important for achieving the desired results.

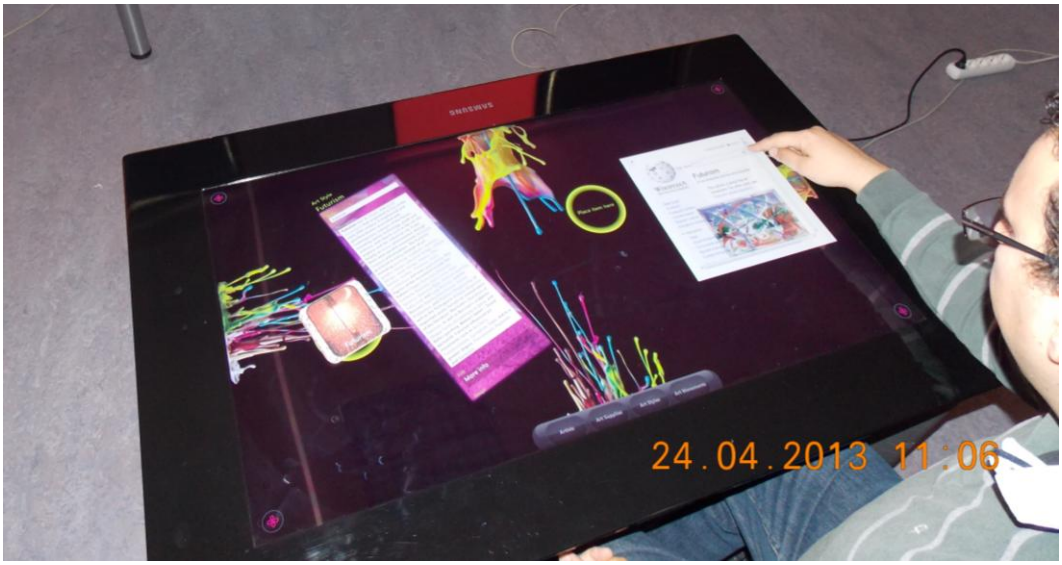


Figure 223: Learning more about the impressionists

After completing his background research he moves to the paintings plane to set-up the still-life. To do so he arranges the subject matter and the camera pointing to the model's plane to achieve the optimum visual arrangement (see Figure 224).

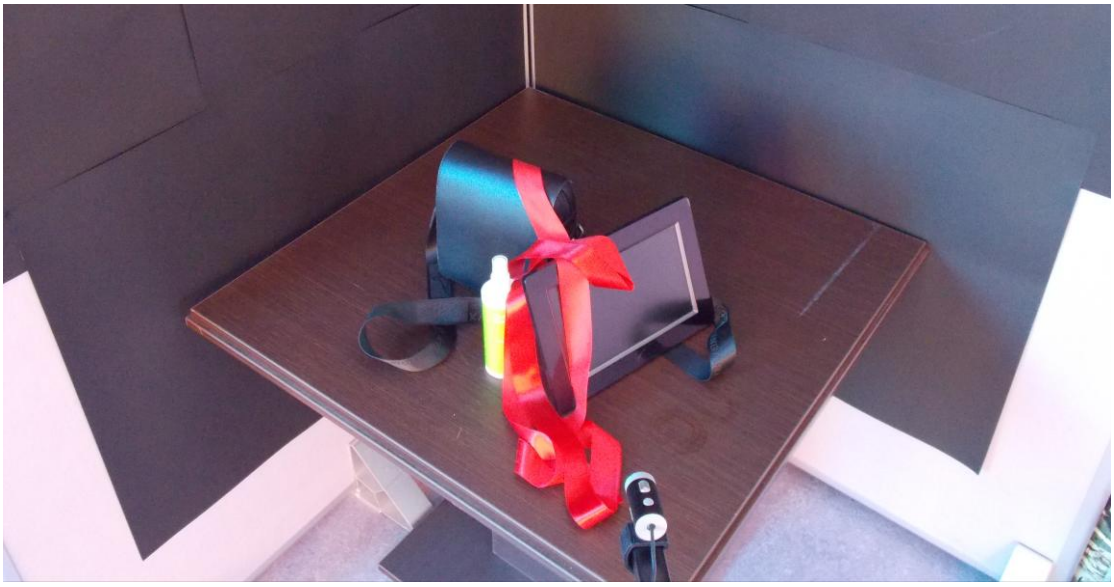


Figure 224: Arranging the subject matter at the model's plane

When being confident about his set-up he moves to the augmented painting surface and frames the composition. He in turns loads this composition to the painting surface selects a painting canvas. He decides to use the painting assistants to create colour mixtures and when satisfied by the result creates actual mixtures. He transfers the composition on the surface using a grid (a grid is presented on both the canvas and the composition) in order to get the visual arrangement of elements correctly (see Figure 225) and then moves into applying the created mixtures on the surface.

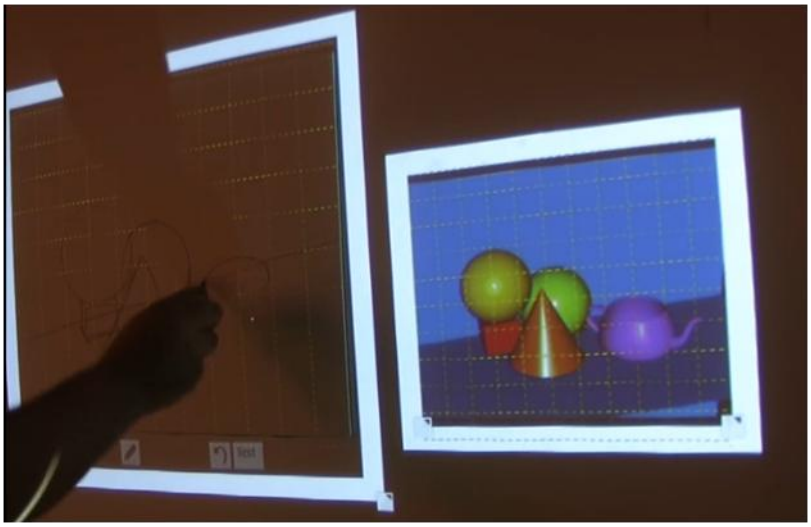


Figure 225: Transferring the composition using a grid

9.1.4 Anna the Art Tourist

In the context of this scenario presented in section "4.5 Anna the Art Tourist" the museum visitor when entering the museum is using a mobile phone select one of the available virtual tours and requests the personalization of information according to his interests and knowledge. While browsing through the museum exhibits he notices that on the rear of paintings information is presented while he has the option to scan the exhibit's QR code to access information from alternative sources (see Figure 226).

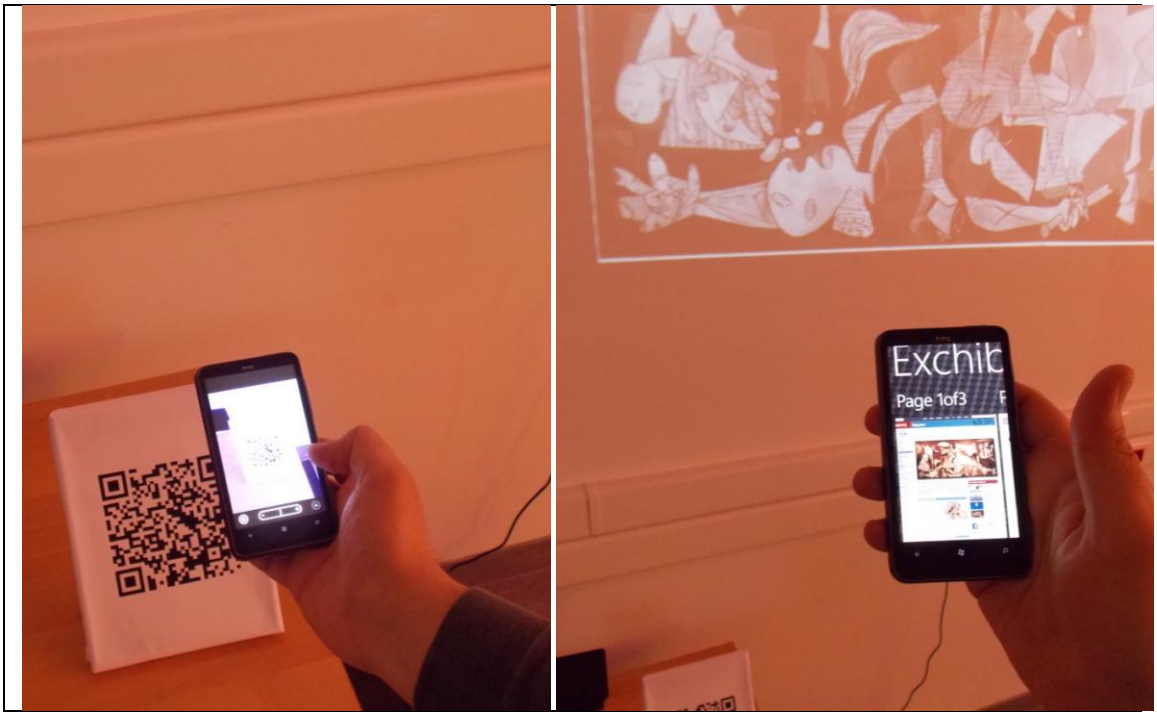


Figure 226: Getting access to information from various sources using QR code scanning

At the same time the option to download this information is available. When entering a section of the museum a welcome screen can be used to access all the works that are exhibited in the specific area as shown in Figure 227. This is very helpful for quickly identifying areas of interest within a museum but also for browsing extra information about exhibits is you are not carrying a compatible mobile device.

Figure 227: Accessing information about a museum region from a welcome screen

When a collection of paintings by a specific artist is enriched with digital exhibits the visitor can locate using his hands points of interest within the exhibit while also having the option to zoom in a great extend to see that exhibit in great detail as shown in Figure 228.

Figure 228: the visitor is using his hand to locate areas of interest within an exhibit

At the same time large digital exhibits can map the location of the user in front of the painting in order to present information about the region of the painting that the visitor is standing as shown in Figure 229.

Figure 229: Mapping the visitor's location within a painting and presenting information

Finally the visitor can use a tablet provided the museum to access additional information about the location of a physical painting that he is standing in front as shown in Figure 230.

Figure 230: Using the tablet to access information

The unoccupied spaces of the museum such as corridors and entrances are populated by educational games and interactive surfaces where visitors can access a stream of information as shown in Figure 231.

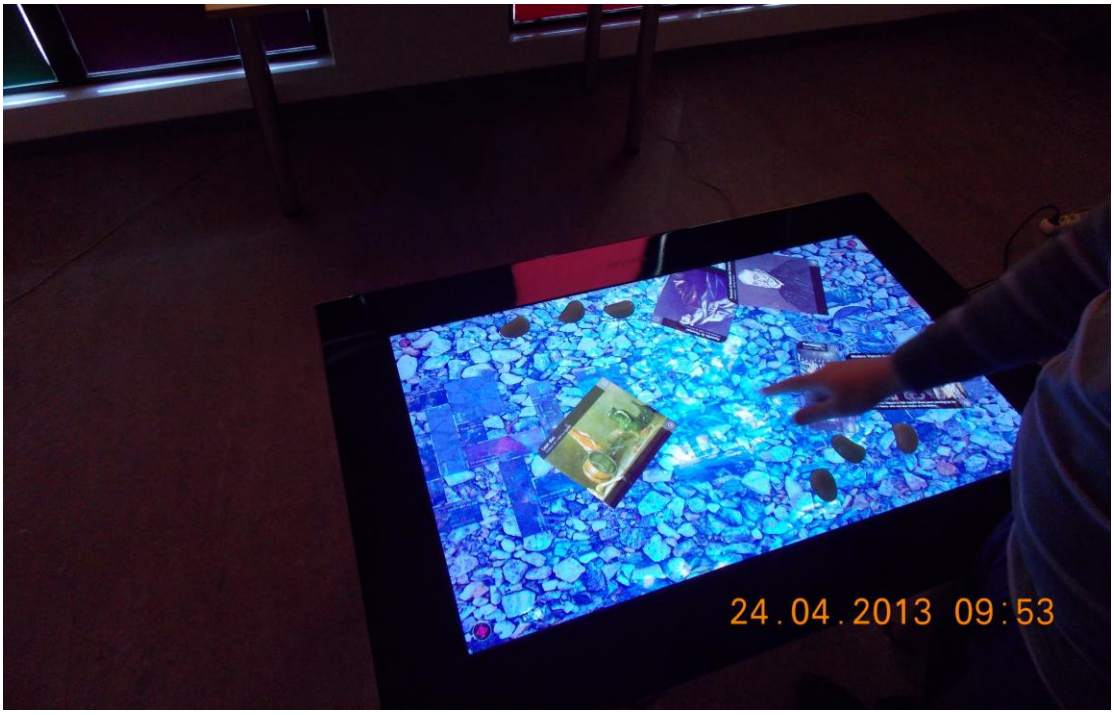


Figure 231: Accessing a stream of information

The museum cafeteria offers interactive tables for the whole family that can be used for accessing more information about the museum exhibits while the children are playing a number of arts inspired educational games (see Figure 232).

Figure 232: A museum coffee table for the whole family

The museum experience continues at home allowing the visitor to access an interactive documentary of his visit (see Figure 233).

Figure 233: An interactive documentary generated from the museum visit

The exhibits accessed during the museum visit are also available as new artefacts within the home's art repository. These artefacts can be facilitated by the interactive surface located at the game's spot to enrich the available art games. Figure 234 presents an augmented table top game deployed within the games' spot while Figure 235 presents an interactive puzzle game with artefacts viewed during the museum visit while also the memory games has also new generated new rounds containing the browsed artefacts.

Figure 234: Art Collector running at the games' spot

Figure 235: Art puzzle – Pick and match

9.1.5 An online course

In the context of this scenario presented in section "4.3.1 An online course" the teacher starts browsing resources about Monet, the initiator of the Impressionist movement and selects the ones to be the included in his demonstration. After collecting reference material for his presentation he decides to finish his demonstration presenting a real life scenario of creating an impressionistic painting.

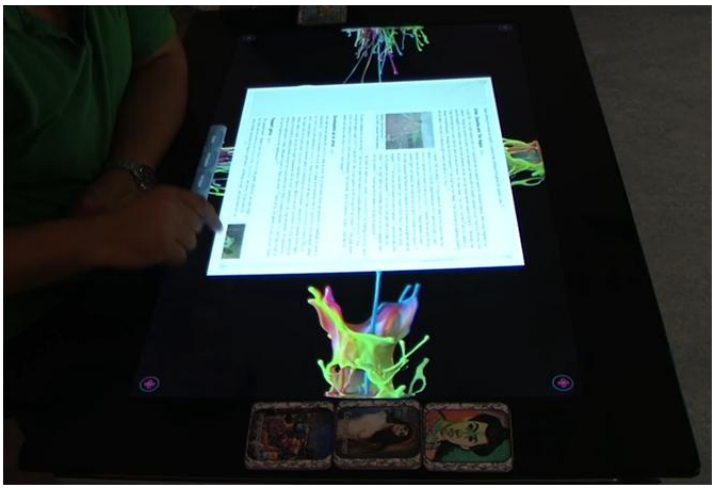


Figure 236: Collecting reference material

He browses the collection of painting by Monet from the design space and selects one as the source of his presentation. Based on the system's recommendations selects his materials and moves to the art creation process and requests the production of educational material to be included in his demonstration such as video screen-shots sound files etc. To this end, the recording application appears on the application

screen on the left side of the art creation area. Christian starts the painting process and requests the system to take snapshots of the canvas at specific moments, allowing him to record instructions representing the step in question while having also the ability to use the text entry component for including notes. When the painting is completed, Christian can use the video recording of the painting session, the snapshots taken, audio recording and notes to complete the demonstration or just request the system to automatically incorporate this data to the demonstration created and saved through the i-table.

9.2 Feasibility Studies

This section presents four painting projects created from scratch within the AmI simulation space. Each of these projects employs different aspects of the deployed hardware and software for demonstrating the concept and at the same time exploring in real life conditions the feasibility of the proposed approach. To this end each of the following sections presents initially an overview of the general scenario followed for creating the specific painting followed by a description of the way that the workshop's infrastructure is employed to augment and assist artist's creativity. The paintings presented in this section were all created and recorded in a time span of two to three hours. Four cameras were set up for this purpose one on the Design space, one on the Model's plane and two on the Art Creation space (distant and close view recording).

9.2.1 Reproducing a self-portrait by Vincent Van Gogh

The process followed for reproducing the self portrait of Vincent Van Gogh involves an initial step where the artist is doing a background study of the related art movements for getting general information about the main concepts followed by his contemporaries. The process is followed by a study of the painting itself to reveal several secrets of its creations and continues with the actual reproduction. This section builds on this generic scenario to present the aforementioned activities as facilitated through the workshop.

For this study the artist is initially using the Art Supply Wizard to access information about Van Gogh but also about relevant art styles such as Impressionism, Expressionism and Fauvism (see Figure 237).

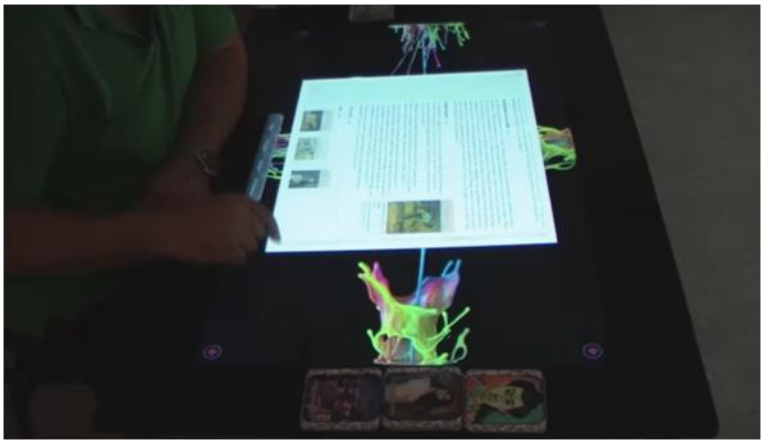


Figure 237: Collecting information about Impressionism, Expressionism and Fauvism

After being satisfied with the gathered information the artist is studying the painting to be reproduced. To do so he is applying image processing filters to reveal attributes of the painting such as brush strokes, colour, morphology and shadows as shown in Figure 238. Doing so he can extract information about the painting such as the direction, intensity and texture of brush strokes, the locations where the most intense highlights should be placed, the locations of shadows and more. This is important for the experience artist to get a quick understanding of the painting but also for the inexperienced one whose eye is not yet fully trained. These filters are specifically designed for artists by combining several image processing techniques and have been appropriately named using naming conventions understood by them.

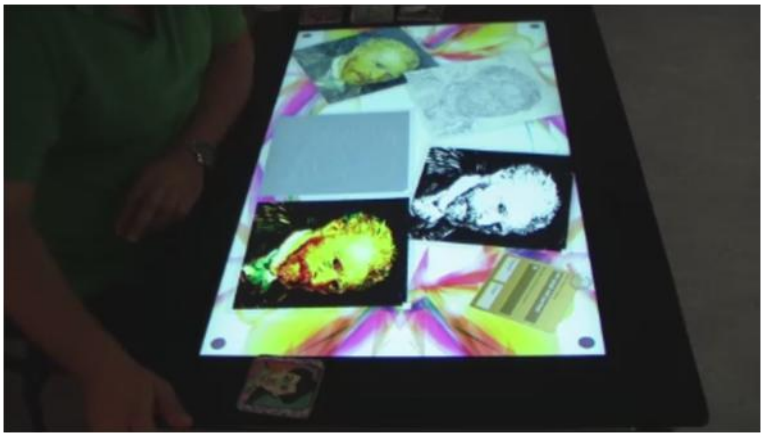


Figure 238: Study of the painting

Having decoded the structural information of the painting the artist request the composition to be transferred within the augmented painting surface and projects a processed version of the painting within the canvas (see Figure 239). As shown in this figure this version of the painting is a ready to use sketch for the artist. In this specific case where the painting technique does not requires the creation of a sketch before

painting, or requires a rough sketch with a painting brush, having the representation projected on the canvas is important for understanding the scale, location and size of facial features but also as a runtime assistant for determining the direction weight and intensity of brush strokes.

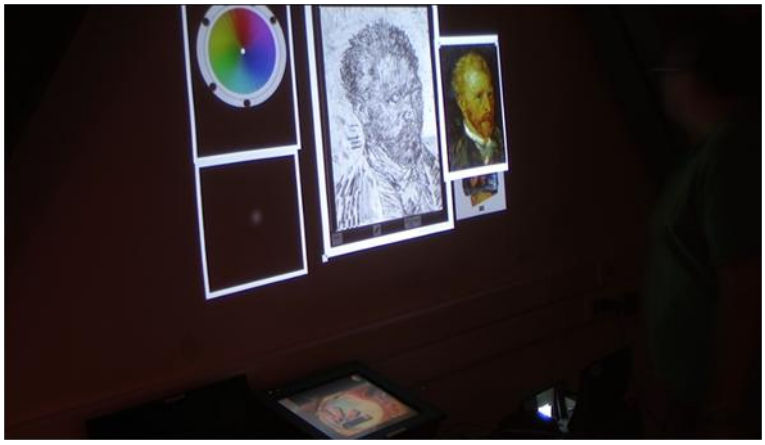


Figure 239: Projecting the processed version of the composition within the canvas

Before initiating the painting session the artist is using his virtual painting palette to create colour mixtures (see Figure 240). The mixtures are happening by mixing colours from a series of a well-known manufacturer which is the same brand also preferred by the artist. These mixtures are transferred to the painting surface to form the palette of mixtures for this painting session. To transfer these mixtures the artist in performing a swipe up gesture on the Artist's Colour Mixer after being satisfied with a mixture. This virtual painting palette of colour is in turn used for creating the actual mixtures. The artist is selecting a mixture from the palette and the Modern Painting Studio presents the colours that should be mixed to create the mixture.

Figure 240: Creating mixtures on the virtual palette

This virtual painting palette of colour is in turn used for creating the actual mixtures (see Figure 241)

Figure 241: Creating actual colour mixtures reference material

The final stage of artistic creation involves the production of the painting reproduction. From this stage on the Modern Painting Studio and the provided tools are used when needed by the artist so as not to intrude to the painting process. Some intermediate steps of the painting process together with the completed reproduction of the painting are presented in Figure 242.

The artist has completed the background and moves to painting clothing

The artist has almost completed the painting and is finishing some facial features

Figure 242: Intermediate steps of art creation and the final reproduction

9.2.2 Setting up and creating a Still Life

For this painting session the artist initially studies a number of still life compositions to select the most appropriate visual arrangement for a composition under development. Having done so he is setting up the still life composition by using

material that represent everyday object but also technology gadgets. After having completing the composition he adjusts lighting accordingly so as to achieve balance between highlights on objects and on the background aiming at achieving a dramatic chiaroscuro effect. Then he transfers the composition to his canvas using a charcoal stick and moves to the actual creation process. This section presents the way that this typical composition scenario is facilitated through the workshop.

For this second composition the artist is initially using the Artist's Portfolio to review several still-life arrangements. In this stage he is not interested on subject matter But on the visual placing of objects so as to achieve a solid and pleasant Composition. He concludes with a strong triangular composition (see Figure 243). As shown in this figure the composition selected by the artist is dominated by a large shape in the middle while other objects are located on either side to complement the triangular effect. This kind of composition is the most solid in nature because of the large size of the base of the triangular.

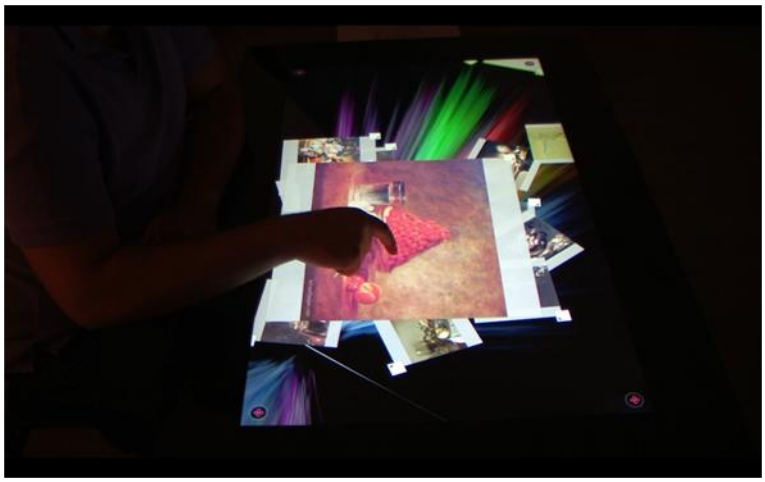


Figure 243: Reviewing several still-life arrangements

He decides to move to the Model's Plane to create a composition with a similar setup. The Model's Plane has been appropriately formed so as to minimise light reflections (the vertical surfaces have been covered with black non-reflective material). He is interested on the arrangement of subject matter but also with the interplay of light with the composition and the background (see Figure 244). The light is very important because it is responsible for bringing out of the darkness the objects of the composition and thus determining the areas of light, reflected light and generated shadows. At the same time as light hits the background it completes the dramatic chiaroscuro effect providing also clues about its direction to the viewer. The interplay

of highlights and light on the background will create the visual path that the viewer's eye will follow to enjoy the painting.

Figure 244: Setting-up the composition on the model's plane

Having completed the placement of subject matter the artist moves to the Modern Painting Studio and previews the composition within the canvas. The camera located in front of the composition is projecting the composition to the Composition Framer. The artist is using the swipe right gesture to freeze the camera when satisfied with the composition. He in turn frames the part of the composition to be painted (see Figure 245) by dragging his finger on the projection to select the area of the composition to be painted. Upon completion of this process the composition is loaded within the augmented painting surface.

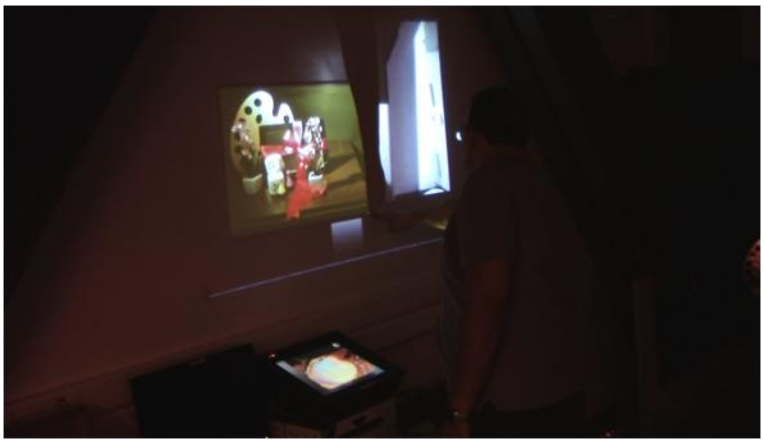


Figure 245: Framing the composition

After having decided the part of the composition to paint the artist is using an image processing filter to reveal the sketch of the composition and then projects it on the canvas as shown on Figure 246. Then he uses a charcoal stick to trace the composition within the canvas. Having done so, the transferring of the composition happens quickly without the need of measurements by the artist. Alternatively the

artist could have used a painting grid to simplify measuring or skip the entire process and do the appropriate measurements himself without involving the facilities of the Modern Painting Studio.

Figure 246: Transferring the composition on canvas

Finally the artist is painting the composition. In this scenario colour mixtures are made by the artist without using the Artist's Colour Mixer. The artist uses the application only when he is not sure about a mixture and wishes to make a test before mixing. After having completed painting the artist is using the Painting Frame application to select the most appropriate framing style and colour for his finished painting as shown in Figure 247.

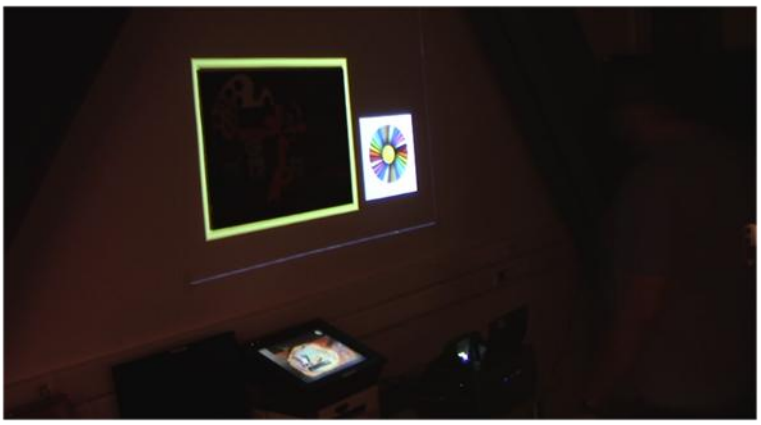
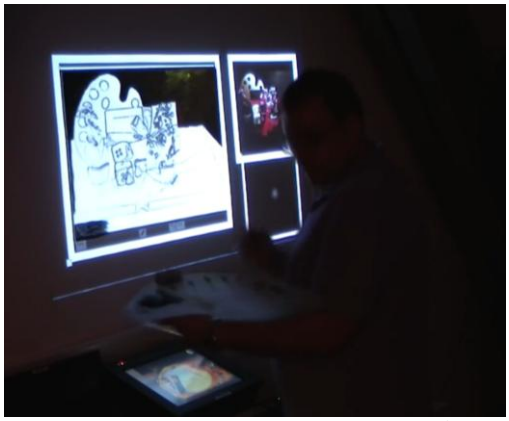
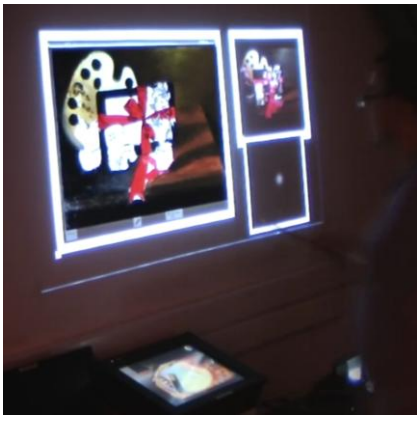


Figure 247: using the painting assistant to select the most appropriate frame colour

The application projects a virtual frame around the painting and the artist has the option to alter the colour of the frame using a palette of predefined framing colours. This allows the selection of the most appropriate frame and colour in ideal conditions for the painting (the painting is hanged and virtually framed). The intermediate steps of the painting process and the completed work of art are presented in Figure 248.



The artist is working on the dramatic background of the painting



The artist is shaping the ribbon using highlights

Figure 248: Intermediate steps of Art Creation that resulted to the finished painting

9.2.3 Setting up and creating a composition in 3D

For creating this painting the artist is using geometric shapes such as the sphere the cube and the cone to create a still life composition. At the same time the artist is interested both on the placement of these objects so as to achieve a pleasant composition but also on the interplay of objects with light and reflected light. The way that such a composition exercise can be created and painted using the workshop is presented in the rest of this section.

For this third composition the artist is using the 3D Composition editor to create a composition using 3D models. Such composition exercises are very valuable when studying geometric shapes, placement, composition, light and shadow. To do so, he is selecting a still life setup where the objects will be placed. He is interested on reproducing light effects so he is selecting an unnatural lighting scheme with three spot lights lighting the scene. Then he imports shapes of different colour to the composition that are manipulated to be placed on the desired location. Finally he

inserts a mauve teapot on the lower right side of the composition. The composition as created in this stage is presented in Figure 249.

Figure 249: Creating a composition in 3D

After having completed the composition he request to be transferred to the Modern Painting Studio. The artist is using a Grid projected both on the composition and on the canvas to trace the composition as shown in Figure 250. The Grid is important to determine the placement, size and shape of objects within the composition.

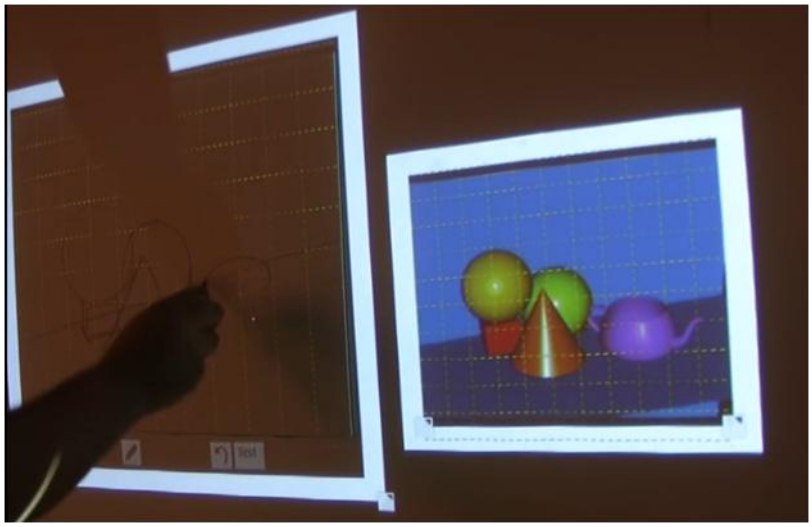
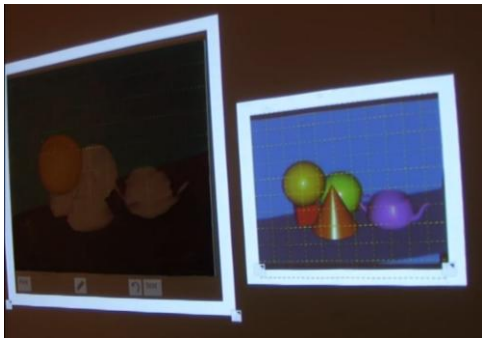


Figure 250: Transferring the composition on canvas using a grid

In this stage the artist is painting the composition. The painting assistants remain available while painting. The intermediate steps and the completed painting are presented in Figure 251.



The artist has completed the background and is working on the sphere

The artist is painting the last part of the composition which is the teapot

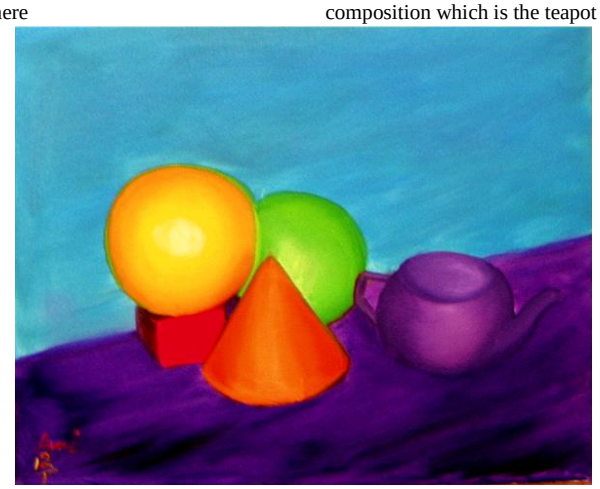


Figure 251: Intermediate painting steps and the completed painting exercise

9.2.4 Painting a traditional geometric composition

For this painting study the artist generates a geometric composition by employing the golden rectangles arrangement to determine the location of the primary point of interest within the painting. He is thinking about a rock formation dominating over a stormy seascape. To exaggerate this concept he is thinking of employing rough textured surfaces on the rocks allowing the light to play within the surface creating dramatic effects. The larger left rectangle is dominated by a great wave that breaks on the upper most side of the canvas within the smaller rectangle formed by a set of rotated golden rectangles. This forms the second point of interest within the painting. In this sense the viewer's eye will travel within a virtual curve formed by the two points of interest. At the same time the sky playing a secondary role to this composition is paler in colour and smoother in texture. This section presents the way that the presented composition was generated, transferred and painted with the workshop.

For this session the artist is creating a traditional geometric composition using the Geometric Composition Suite. For doing so the artist is using geometric elements such as golden rectangles and perspective grids. The golden rectangles divide the plane in two parts the right side is smaller than the left side and is the location that the primary point of interest will be located. The left side is larger hosts the secondary point of interest which is the big wave. The perspective grids is a tool for representing, within the composition, the vanishing point of the viewer's eye and at the same time the lines moving from the viewer's location to this point. The artists also imports semantic information to the composition to determine the locations where texture is rough or smooth, the direction of light within the composition, colour values and hues. Finally a rough sketch of the composition is created for guiding the artist while sketching. The resulting composition is presented in Figure 252.

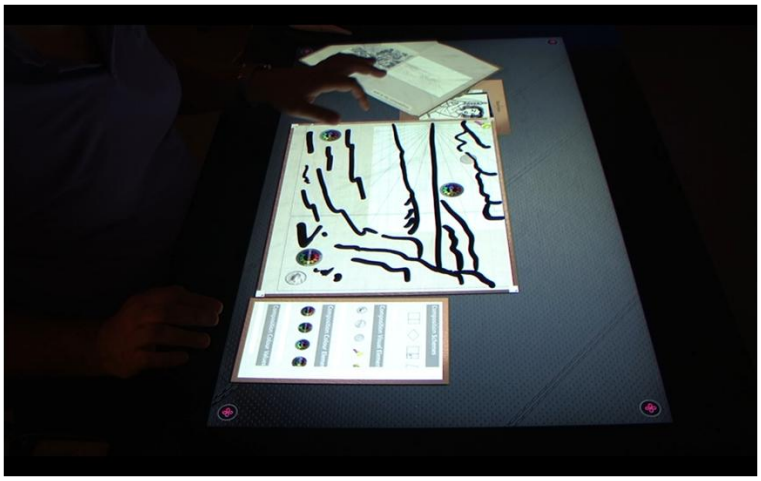


Figure 252: The created geometric composition

The composition is transferred to the Modern Painting Studio and the artist is using the inline assistants to create colour mixtures. To create the mixtures the artist is using the colour wheel and the colour mixer. Created mixtures can be previewed within the canvas so as to make the colour study of the painting Figure 253. The colour study is achieved by putting the mixed colours in the locations that will appear in the finished painting and then evaluating these mixtures (to determine that when used together result to a harmonious whole). Having everything planned the artist is ready to transfer his conceptual work within the canvas. To do so, he initially creates a rough sketch of the composition within the canvas to determine the locations of the wave, the rock formations etc. While doing so he decides to alter a little bit the composition

by placing another small rock formation on the left side of the canvas to balance the composition.

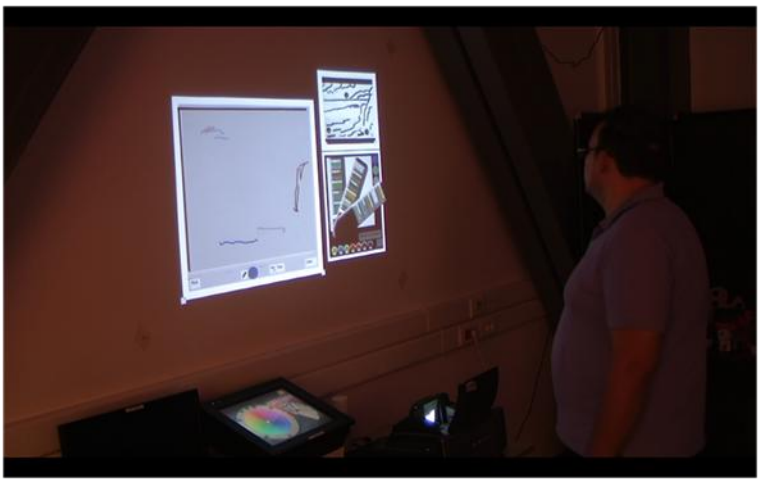
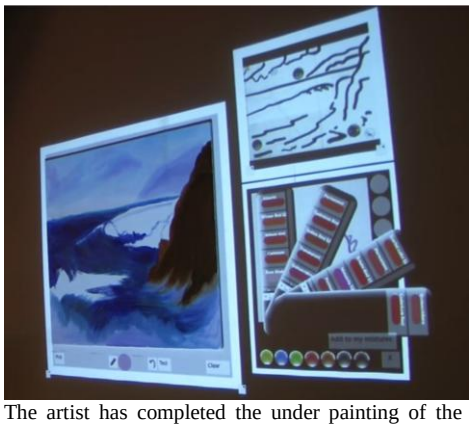
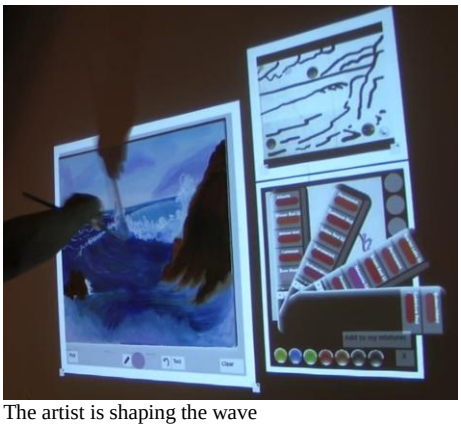


Figure 253: The created geometric composition

Afterwards having everything planned he mixes the created colour mixtures and moves into creation the painting following the wet on wet painting style (wet paint is overlaid over wet paint allowing them to mix on the canvas). The intermediate steps of the painting process and the completed work of art are presented in Figure 254.



The artist has completed the under painting of the painting



The artist is shaping the wave

Figure 254: Intermediate steps of Art Creation that resulted to the finished painting

9.3 Small scale comparative study

In order to get some preliminary indications about the efficiency of the proposed process of painting within the augmented art workshop a small scale experiment was conducted. In this experience a user was requested to perform sequentially two painting studies the first using the augmented art workshop and the second one using a traditional painting method. The tasks requested by the user for each case were:

- Painting using the augmented art workshop
    - Use a picture of a created composition
    - Create a similar composition in 3D using the 3D composition editor
    - Transfer the composition to the Augmented painting surface
    - Use the grid system to trace the composition
    - Create colour mixtures using the colour mixer painting assistant
    - Create actual colour mixtures using paint tubes
    - Paint the created composition
- Traditional painting
    - Use a picture of a created composition
    - Draw Grid within the picture and the composition in equal proportions
    - Use the grid to trace the composition on canvas
    - Paint the composition using a traditional painting setup

For capturing the painting process three cameras were set within the simulation space. The recordings were in turn used to measure the time required by the test subject to perform each of the requested tasks. The results of this process are summarised in Table 53.

Stage	Traditional Painting	AmI Painting
Create composition	0	3
Trace composition	15.5	6
Create color mixtures	0	1.5
Painting	20	17
	35.5 minutes	27.5 minutes

Table 53. Results of the comparative study

As shown in this table there are preliminary indications regarding the potential to increase painting efficiency through the usage of the proposed workshop. This should be further investigated in the context of a larger scale experiment and is provided here only as a potential methodology for measuring the efficiency of the developed infrastructure. The paintings create din the context of this study are presented in

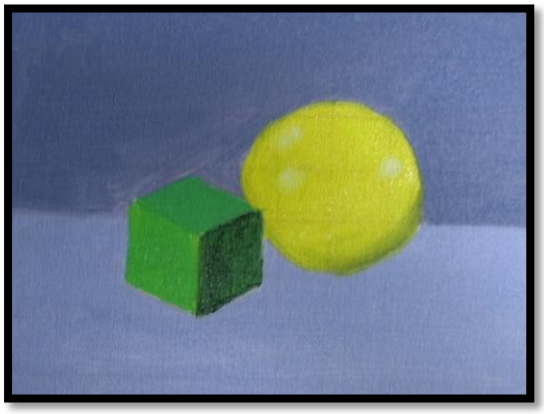
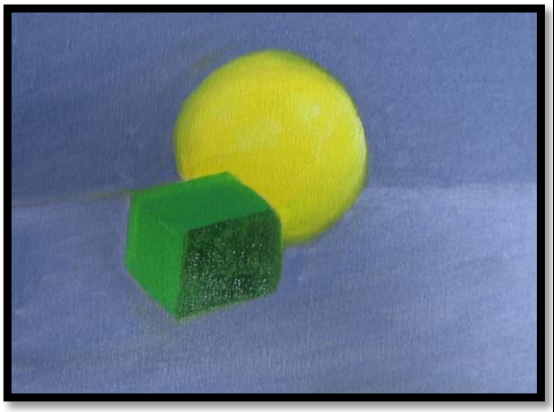
	
A painting created using a traditional tracing technique using a grid system and painting in a normal painting setup.	A painting created using the augmented art workshop

Figure 255: Intermediate steps of Art Creation that resulted to the finished painting

10 Evaluation

This chapter presents the actions performed for evaluating the created infrastructure. For that purpose, two evaluation approaches were adopted: heuristic evaluation and user testing. The strategy followed (see Figure 256) was to initially perform a pre-production evaluation in the context of the "Virtual simulation of scenarios" and "Feasibility studies" presented in depth in the previous chapter. These feasibility studies concluded that the implemented system has reached the maturity to be run in the context of real life scenarios and therefore is ready to move to the next phase for evaluating its usability.

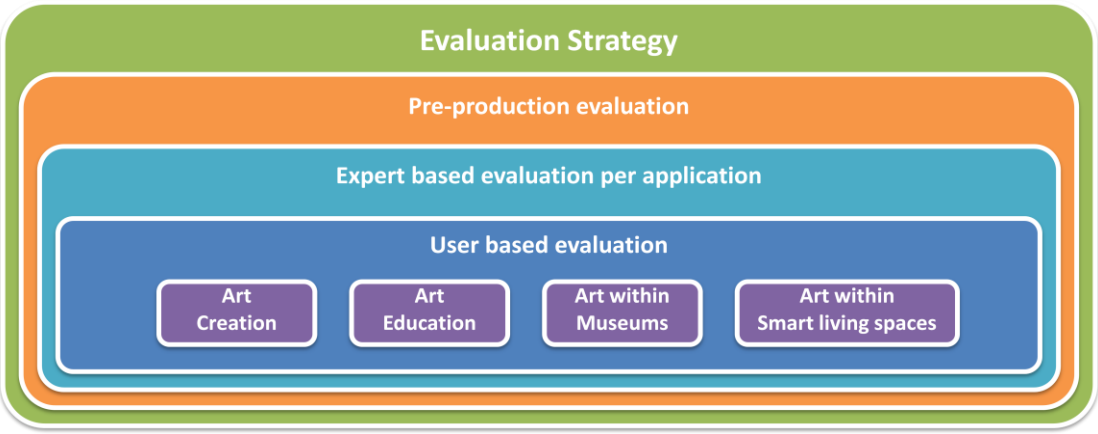


Figure 256: Evaluation strategy

10.1 Heuristic evaluation

Heuristic evaluation - one of the most popular usability inspection methods - is a usability engineering method for identifying usability problems in a user interface design. Heuristic evaluation involves an inspection from a small group of expert evaluators who examine the interface and judge its compliance against recognized usability principles (the heuristics). In general, heuristic evaluation is difficult for a single individual to carry out, because one person will never be able to find all the usability problems in an interface. Experience has shown that different people find different usability problems. More specifically, it has been proved [324] that the sets of usability problems found by different evaluators are in large part non-overlapping. Some usability problems are so easy to find that they can be detected by almost everybody, but there are also some problems that are found by very few and experienced evaluators. Furthermore, one cannot just identify the best evaluator and rely solely on that person's findings, since it is not necessary that the same person will be the best evaluator every time, while some serious usability problems are found by evaluators who may not find other common usability problems. Therefore, it is necessary to involve many evaluators in a heuristic evaluation in order to significantly improve the effectiveness of the method. The ideal number of evaluators that should be used in a heuristic evaluation has been calculated by Nielsen and Landauer [324], who presented a model based on the following prediction formula for the number of usability problems found in a heuristic evaluation:

$$\textbf{ProblemsFound}(i) = N\,(1 - (1-l)\,i)$$

where **ProblemsFound(i)** indicates the number of different usability problems found by aggregating reports from **i** independent evaluators, N indicates the total number of usability problems in the interface, and l indicates the proportion of all usability problems found by a single evaluator.

This formula clearly shows that there is a good payoff from involving more than one evaluator. It is recommended to use three to five evaluators in the procedure, since fewer evaluators cannot detect an adequate number of problems, while using a larger number of evaluators does not provide additional information concerning the usability of the system. The evaluation will be performed by allowing each individual evaluator to inspect the interface alone. After the completion of all evaluation sessions, the

evaluators will communicate and aggregate their findings. This procedure is important in order to ensure independent and unbiased evaluations from each evaluator. The results of the evaluation can be recorded either as written reports from each evaluator or by having the evaluators verbalize their comments to an observer as they go through the interface. During the evaluation session, the evaluator examines the interface several times, inspects the various dialogue elements and compares them with a list of recognized usability principles (the heuristics). These heuristics, which are presented below in more details, are general rules that describe common properties of usable interfaces. In addition to the checklist of general heuristics, the evaluators can also consider any additional usability principles or results stemming from their expertise. Furthermore, it is possible to develop category-specific heuristics that apply to a specific class of products as a supplement to the general heuristics. The output of the heuristic evaluation method is a list of usability problems related to the system's user interface, with references to those usability principles that were violated by the design according to the opinion of the evaluators. It is not sufficient for evaluators to simply say that they do not like something; they should explain why they do not like it with reference to the heuristics or to other usability principles.

Many advantages are claimed for heuristic evaluation. One of the most important is that the method provides quick and relatively inexpensive feedback to designers, while the results generate good ideas for improving the user interface. On the other hand, the development team will also receive a good estimate of how much the user interface can be improved.

Additionally, there is a general acceptance that the design feedback provided by the method is valid and useful. Heuristic evaluation can lead to many usability improvements to take place before a release deadline that would not permit an extensible usability testing involving end users. If the development team is open to new ideas, heuristic evaluation can be an excellent investment of usability resources. One of its great advantages is that it can be performed early on the design process since earlier discovery of usability problems during the development lifecycle helps in identifying and correcting obvious usability problems with very limited costs. Furthermore, carrying out a heuristic evaluation on early prototypes, before actual users are brought in to help with further testing, provides a focus for later usability testing and decreases users' time and effort spent in the usability test.

10.1.1 Rating usability problems

Usability problems' rating according to their importance is a fundamental phase of the heuristic evaluation procedure. As a result, redesign resources will be allocated so as to eliminate the most severe problems first. A problem's severity may be described as a combination of three issues (a) the frequency of its appearance (i.e., frequent vs. rare), (b) the impact of its occurrence (i.e., the difficulty encountered by the user in overcoming the problem), and (c) its persistence (i.e., whether it is a problem that users may overcome if the run into it once, or if they will be repeatedly bothered by it).

In order to determine the severity of usability problems, the following scale is used:

0: It is not a usability problem.

1: It is an aesthetic problem only: unless there is available time, redesigning is not necessary.

2: It is a minor usability problem: eliminating such problems will be assigned a low priority.

3: It is a major usability problem: removing such problems will be given a high priority.

4: It is a usability catastrophe: such problems should be definitely eliminated.

10.1.2 Heuristic rules

The ten general heuristic rules that have been used for the evaluation of this research work are the following [325]:

Visibility of system status: The system should always keep users informed about on-going procedures, through appropriate feedback and within reasonable time from the relevant actions of the user.

Match between system and the real world: The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than using system-oriented terms.

User control and freedom: Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state, without having to go through an extended dialogue.

Consistency and standards: Users should not have to wonder whether different system messages, situations, or actions mean the same thing. Thus, their interpretation should be unique and intuitive for the users.

Error prevention: A careful design, which prevents a problem from occurring in the first place, is even better than helpful error messages.

Recognition rather than recall: Objects, actions and options should be visible. The user should not have to remember information from one part of the interface dialogue to another. Instructions for use should be visible as well, or easily retrievable when appropriate.

Flexibility and efficiency of use: The system should cater to both inexperienced and experienced users.

Aesthetic and minimalist design: Information that is irrelevant or rarely needed should not be presented at first level.

Help users recognize, diagnose and recover from errors: Error messages should be expressed in plain language (no codes), precisely indicating the problem, and constructively suggesting a solution.

Help and documentation: Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

10.1.3 Results of the heuristic evaluation

For performing the evaluation three usability experts used the applications and recorded the identified usability problems. These problems were gathered per applications and graded based on their severity. The following sections present these results:

10.1.3.1 Artist's Portfolio

Issue 1. Severity score= 3: When large collection are visualised for a certain category items may appear cropped (mainly on the borders of the collection)

Issue 1. [Suggestion]: Consider limiting the maximum size of collections or having a dynamic space expansion strategy

10.1.3.2 Artist's Composition Suite

Issue 1. Severity score= 3: Dragging items from the toolbox to the design area sometimes fail.

Issue 1. [Suggestion]: Dragging should be more fluent and responsive.

Issue 2. Severity score= 3: When resizing items within the design area users should point with their finger in one of the corners. This action sometimes requires more than one attempt from the user.
Issue 2. [Suggestion]: Consider enlarging the manipulation points

Issue 3. Severity score= 2: When turning pages of the Artist's Sketchbook the user should touch the lower right corner of the book. If not turning fails.
Issue 3. [Suggestion]: Consider enlarging the area of the page that when dragged result in a turning operation.

Issue 4. Severity score= 2: The Design space contains three different menus each one responsible for different functions. Users are required to remember which menu does what.
Issue 4. [Suggestion]: Consider rearranging menus so as to be more usable and more clearly categorised.

Issue 5. Severity score= 3: When cropping large images in some cases the cropped image doesn't correspond to the selected cropping region.
Issue 5. [Suggestion]: This is considered a software issue and should be fixed.

Issue 6. Severity score= 3.5: When digitising physical media users may not always understand that the physical sketch should be placed within the container.
Issue 6. [Suggestion]: Provide a textual indication within the digitising container.

Issue 7. Severity score= 3.5: The user cannot drag items within the design space when ink is activated. So the users have to first deactivate ink then drag the item and activate ink again to continue.
Issue 7. [Suggestion]: Consider providing this option or if not feasible have a top most function outside the menu to toggle ink activation.

Issue 8. Severity score= 2: The erasing function doesn't erase the complete stroke but rather the erasing happens point by point. This is not usable for cases that the complete stroke is to be deleted.

Issue 8. [Suggestion]: Consider either providing an additional function to erase complete strokes or make the entire stroke erasing function the default erasing function.

Issue 9. Severity score= 2: In order for users to rearrange elements of the design space the element should be selected and then the rearrangement menu should be opened to select the desired function (bring to top, send to back etc.). This is time consuming.

Issue 9. [Suggestion]: Consider providing some form of context menu should be provided.

10.1.3.3 Augmented painting surface

Issue 1. Severity score= 3.5: There is some input lag in the augmented painting surface. In particular, in some occasions users should wait for around a second in order to get feedback from the system.

Issue 1. [Suggestion]: The touch events rate should be improved.

Issue 2. Severity score= 2.5: In some cases touch event were slightly misplaced from the actual touching point.

Issue 2. [Suggestion]: The misplacement should be minimised so as to not exceed the area occupied by user's finger.

Issue 3. Severity score= 2: When importing mixtures from an external application, these mixtures cannot be previewed with the painting surface.

Issue 3. [Suggestion]: Mixtures should provide the same functionality regardless from their origin.

Issue 4. Severity score= 1.5: When mixing colours within the surface colour swatches are very large for the size of the mixing palette. As a result users should first close the swatch and then test the mixture within the mixing palette.

Issue 4. [Suggestion]: Consider reducing the sizes of the swatches or enlarging the palette so as always to contain the appropriate space for previewing mixtures.

Issue 5. Severity score= 2: When previewing colours within the painting surface there is only the option to undo the last stroke. There is no way for users to empty the painting surface from their previewed strokes.
Issue 5. [Suggestion]: Consider providing a clear function that removes all strokes from the canvas.

Issue 6. Severity score= 2: The dragged items filters menu contains a large number of options. Submenus may sometimes puzzle users about their contents.
Issue 6. [Suggestion]: Consider rearranging menus and providing more self-explained headers.

Issue 7. Severity score= 2.5: Inexperienced users may find it difficult to start using the application.
Issue 7. [Suggestion]: There should be some kind of guidance for using the surface especially for new and inexperienced users.

10.1.3.4 The Composition Framer

Issue 1. Severity score= 3.5: The touch panel on the bottom size of the painting surface supports two types of gestures the “swipe right” and “swipe up”. Users have no clue about what gestures are supported and more importantly about what these gestures do.
Issue 1. [Suggestion]: Consider providing some kind of guidance about the supported gestures.

Issue 2. Severity score= 3.5: In order for a user to select the area of the composition to be painting he should drag his finger on the surface and select the desired cropping for his composition. There is no guidance for doing this action.
Issue 2. [Suggestion]: Upon freezing the composition using the up gesture on the gestures panel users should be prompted to select the region of the composition and be provided with guidance of how to do so.

Issue 3. Severity score=2.5: When the selection of the area to be painted is completed the application is closed and the composition is transferred to the "Augmented painting surface" there is no way to undo this action.

Issue 3. [Suggestion]: When the selection is completed the user should be prompted to decide whether to continue with art creation or continue framing the composition.

10.1.3.5 Artist's Concepts Designer

Issue 1. Severity score= 2.5: The search window contains a menu to access the collections of Art contained in the system or locate Art from online collections. These two different options are not well defined.

Issue 1. [Suggestion]: Consider providing more descriptive header for menu elements.

Issue 2. Severity score= 2.5: The dragged items artistic operations menu contains a large number of options. Submenus may sometimes puzzle users about their contents.

Issue 2. [Suggestion]: Consider rearranging menus and providing more self-explained headers.

Issue 3. Severity score= 3: Users may not understand the purpose of the "drop item" menu item.

Issue 3. [Suggestion]: Consider altering the header of this menu item.

Issue 4. Severity score= 2.5: The artistic operations menu contains a large number of options. The results of each of these options in not always clear.

Issue 4. [Suggestion]: Consider providing more expressive headers and if possible icons that depict the result of each function.

10.1.3.6 The painting frame

Issue 1. Severity score= 3.5: When framing a painting it is important for users to know the name of the selected colour.

Issue 1. [Suggestion]: Full colour information should presented making easier for someone to order a picture frame painted in this hue.

Issue 2. Severity score= 3.5: When framing the area within the painting is not lighted. This results to poor results when the Ambient Workshop doesn't have enough light.

Issue 2. [Suggestion]: Consider projecting a transparent grey within the surface.

10.1.3.7 Art Compare

Issue 1. Severity score= 3 [Art Compare]: Users have to select the category of information prior to placing tags on the surface. This results to increased error rate.

Issue 1. [Suggestion]: Consider identifying automatically the category of a placed tag.

Issue 2. Severity score= 3 [Art Compare]: When a browser is presenting for accessing information within the screen the swipe up and swipe down gestures result to selecting text rather than scrolling. This is confusing because all other applications running on the Microsoft Surface Samsung SUR-40 use the opposite metaphor.

Issue 2. [Suggestion]: The same metaphors should be used for all UI elements.

10.1.3.8 3D Composition

Issue 1. Severity score= 3.5: The manipulation of cameras within the composition may pose usability problems. Zoom-in and Zoom-out occurs very natural but the rotation of camera implies the movement of user's touch within a limited space in the bottom right comer of the composition.

Issue 1. [Suggestion]: Consider enlarging camera control and provide guidance on how it should be used.

Issue 2. Severity score= 3: Not all action image-buttons have easy to understand images.

Issue 2. [Suggestion]: Consider creating new icons for at least five buttons (one plane, two planes, delete, save composition and start painting). Also consider placing headers in all buttons.

Issue 3. Severity score= 3.5: The manipulators of some elements (such as pyramid) are not properly aligned with the model (the manipulators are on the default position but the object is rotated)

Issue 3. [Suggestion]: All the objects when imported on the surface should appear in their equilibrium state.

Issue 4. Severity score= 3.5: Users may wish to scale 3D elements when placed on the composition.
Issue 4. [Suggestion]: Considered adding one extra manipulator for scaling 3D elements.

Issue 5. Severity score= 3.5: When creating a 3D composition changes in lighting are not visible until a plane is selected.
Issue 5. [Suggestion]: Considered deactivating all elements until a plane is selected.

10.1.3.9 Paint-it for children

Issue 1. Severity score= 3.5: In order for children to start painting they should place the Paint-it tag on the surface and then select the collection to get access to ready to use sketches. This is way too complex for young children especial under the age of six.
Issue 1. [Suggestion]: Consider having the collection of sketches active on the surface when the application starts.

Issue 2. Severity score= 3.5: It is not certain that children can understand what is written and then use the tag's menu.
Issue 2. [Suggestion]: Consider eliminating the tag and the menu and don't present action buttons.

Issue 3. Severity score= 3: The way that the palette is working is misleading (in order to mix colours users should select the colour and then select one of the mixtures of the palette.
Issue 3. [Suggestion]: Colour mixing should happen silently. When a child selects a colour the paint brush is filled with that colour. When another colour is selected the brush is filled with a colour resulting from the mixing of the previous with the current selection.

Issue 4. Severity score= 3: It is not clear to children how to clean their brush.

Issue 4. [Suggestion]: Provide a metaphor such as a glass of water that when touched clears the currently created mixture.

Issue 5. Severity score= 2.5: A palette of colour is available both on the surface and on the canvas. This sometimes is confusing.

Issue 5. [Suggestion]: Consider providing only than large palette of colours and remove the one from the painting canvas. A metaphor such as a glass of water that when touched clears the currently created mixture.

10.1.3.10 Game lab

Issue 1. Severity score= 3.5: The game is played with four gestures. When the game starts no information is provided to the player about these gestures.

Issue 1. [Suggestion]: Consider having a visualisation of the gestures appearing when the game starts so as to assist the players.

10.1.3.11 Art Puzzle

Issue 1. Severity score= 3: The game requires from the players to place a tag of an artist in order to start playing this is difficult to understand for young children.

Issue 1. [Suggestion]: Consider starting the game with a default set of paintings and then altering the collection when a new tag is placed on the surface.

Issue 2. Severity score= 3: Children may find it difficult to change the difficulty of the game.

Issue 2. [Suggestion]: Consider providing a graphical representation for game's difficulty without textual labels.

10.1.3.12 Pick & Match

Issue 1. Severity score= 3: When the game starts it requires from player to select the desired mode. This is implemented with a menu of buttons that may pose usability problems to children.

Issue 1. [Suggestion]: Consider changing the buttons to images with textual description below.

Issue 2. Severity score= 3: When the game is complete another menu is presented so as to replay or exit the game. This is implemented with a menu of buttons that may pose usability problems to children.

Issue 2. [Suggestion]: Consider changing the buttons to images with textual description below.

10.1.3.13 Digital Exhibit

Issue 1. Severity score= 3.5: When more than one person is accessing information details container may overlap.

Issue 1. [Suggestion]: Consider rearranging overlapping information panels so as information always stays visible.

Issue 2. Severity score= 3: The details container hides part of the painting when allot of information is presented.

Issue 2. [Suggestion]: Consider limited the amount of information to the size of the area bellow the exhibit.

Issue 3. Severity score= 2.5: The highlighting of artefacts is not visible (in case of projectors with low ansi lumens).

Issue 3. [Suggestion]: Consider reducing the opacity of highlights or automatic adjusting the highlights to the ambient lighting.

Issue 4. Severity score= 2.5: When more than one points of interest are focused concurrently (both POIs are in-front of the user) the information panel presents information from all the POIs together. This may be confusing for visitors.

Issue 4. [Suggestion]: Consider having only one element focused at one time or provide a visualisation that distinguishes which information is presented for which POI.

10.1.3.14 Mobile Exhibit Browser

Issue 1. Severity score= 3: The application implies that the users know what QR codes are and how to scan one.

Issue 1. [Suggestion]: Consider having the appropriate guidance on QR code scanning.

10.1.3.15 Tablet Viewer

Issue 1. Severity score= 3: In some cases there is some latency between the movement of user and the subsequent update of the tablet browser.

Issue 1. [Suggestion]: Consider optimising the propagation of events and the loading and presentation of information within the tablet in order to eliminate this lag.

Issue 2. Severity score= 3: In the case where the user is accessing information and moving at the same time it is possible that the information changes while browsing. This may confuse users (the information browsed suddenly disappears and replaced by new one)

Issue 2. [Suggestion]: Consider locking information changes while the use interacts with the Tablet Viewer.

10.1.3.16 Exhibition Browser

Issue 1. Severity score= 3: When a list of artists is presented selectable artist names are too close to each other for hand tracking based selection.

Issue 1. [Suggestion]: Consider enlarging artists' names and having some padding among names.

Issue 2. Severity score= 2.5: The interaction starts automatically when a user is detected.

Issue 2. [Suggestion]: A start-up pose or gesture would be more appropriate.

Issue 3. Severity score= 2.5: When more than one users access the browser concurrently the first one that completes an action determines the result.

Issue 3. [Suggestion]: Consider having multi user interaction enabled only when both users can interact at the same time with the application as for example in the POI visualisation screen.

Issue 4. Severity score= 2.5: When accessing the multi scale image of the painting the painting is moving to the selected direction slowly while the scaling happens very quickly.

Issue 4. [Suggestion]: Consider having the same speed for all the supported by this view actions.

Issue 5. Severity score= 2.5: Videos are presented within a small window of the exhibit's main page. Users can only pause but not resize the projection

Issue 5. [Suggestion]: Consider providing a full screen function.

10.1.3.17 The Augmented artefact caption

Issue 1. Severity score= 3: The caption is presenting the caption until someone touches the screen to activate the artefact presentation. Users may in some cases miss this fact.

Issue 1. [Suggestion]: Consider providing a small information point together with the caption or having a hot spot to touch on

10.2.3.18 Art River

Issue 1. Severity score= 2.5: It is not clear how to initiate the interaction with the river.

Issue 1. [Suggestion]: The river start with a flowing text encouraging the users to place rocks on the surface.

Issue 2. Severity score= 2.5: How to get more information about an artefact is not clear.

Issue 2. [Suggestion]: Make the information icon glowing in order to attract the attention of users.

10.1.3.19 The museum coffee table

Issue 1. Severity score=3: The menus of the application rely solely on textual descriptions which are appropriate for adults but not always for children.

Issue 1. [Suggestion]: Consider placing providing also images for menu elements.

Issue 2. Severity score= 2.5: When timeline information is presented sometimes elements of the same year appear overlapping.

Issue 2. [Suggestion]: Consider rearranging elements according to their neighbours and size.

Issue 3. Severity score= 2.5: The same menus are presented to all visitors regardless of their age and interest in art.

Issue 3. [Suggestion]: Considered employing some kind of implicit profiling for separating children from adults.

Issue 4. Severity score= 3: When a puzzle is complete no feedback is provided to players.

Issue 4. [Suggestion]: Considered creating a game over screen with the option to continue playing.

Issue 5. Severity score= 3: When all cards are matched in the pick and match control there is no way to restart the game (it must be closed and opened again).

Issue 5. [Suggestion]: Considered prompting the user to play again or change difficulty.

10.1.3.20 The Augmented Digital Frame

Issue 1. Severity score=3: The Frame supports five visualisations but there is no clear indication about which is selected.

Issue 1. [Suggestion]: Consider placing visualisation icons on the top left corner of the application.

Issue 2. Severity score=3: The Frame can adapt through postures to the user accessing the application (father, mother, children, and family). There is no indication about the selected mode except for the altered content.

Issue 2. [Suggestion]: Consider placing visualisation icons on the top right corner of the application.

Issue 3. Severity score= 3: The Frame supports interaction through gestures but no information is presented about how these gestures are used to interact with the frame.
Issue 3. [Suggestion]: Consider providing some kind of introduction when the frame starts about how is operated through gestures.

10.1.3.21 The Art Collector

Issue 1. Severity score= 3: In some cases dropping dices on the surface is considered as input.
Issue 1. [Suggestion]: Consider disabling touch when dices are expected to fall on the surface.

Issue 2. Severity score= 2.5: In some cases question exceeds the size of the question panel.
Issue 2. [Suggestion]: Consider wrapping the question text within the question container.

10.2.3.22 Art Documentary

Issue 1. Severity score= 3: The users cannot navigate within the documentary.
Issue 1. [Suggestion]: Consider providing functions for at least play, pause next and previous.

10.2 User Testing

The purpose of this user-based evaluation was to determine whether the system was usable and more specifically to assess its usefulness, effectiveness, learnability and likeability. Usefulness concerns the degree to which a system enables users to achieve their goals. If a system is easy to use, easy to learn and satisfying, but does not achieve the specific goals of a specific user, it will not be used. Effectiveness (or else ease of use) is usually defined quantitatively, either by speed of performance or error rate. Learnability concerns the user's ability to operate the system on some defined level of competence after some predetermined amount and period of training. Finally,

likeability refers to the user's perceptions, feelings and opinions of the product, usually captured through both written and oral interrogation. Users are more likely to perform well on a product that meets their needs and provides satisfaction.

10.2.1 Evaluation within an in Vitro pilot site

One of the most important considerations during an evaluation procedure is to prepare the environment in which the user testing will be performed, since the context of use can greatly affect a product's usability [325]. In the case of this research work, the test has been performed within the AmI simulation space presented earlier. Two user based evaluation sessions were conducted one targeting on the museum and smart living spaces experience and the other one on Art Creation. The results of these distinct evaluation sessions are presented in the following sections.

10.2.1.1 Usability evaluation for Museums and Smart Living Spaces

The demographic information of the users participating in the Usability evaluation for Museums and Smart Living are presented in Figure 257. Concerning the participants' gender, it came out that more male users participated in the evaluation, in percentage 80%. Regarding the age of the participants the majority was between 20 and 29 years old, also having 20% within the age group of 30-39 and another 10% on the 40-49 age group. All the participants turned out to be highly educated; all of them had at least completed a university degree, while 20% of them had completed postgraduate studies as well.

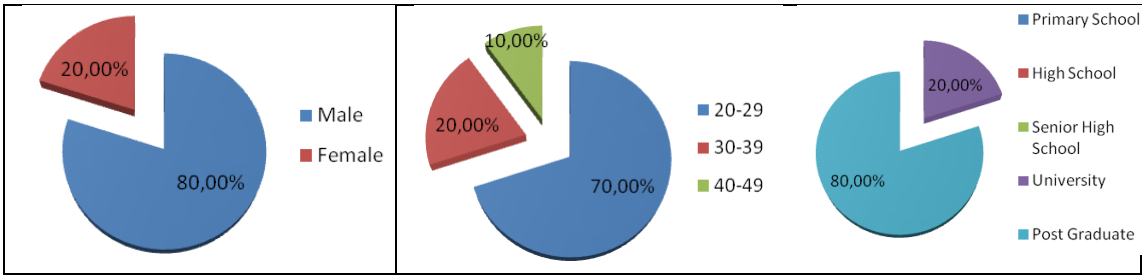


Figure 257: Demographic information of the users participating in the Usability evaluation for Museums and Smart Living

Nielsen [351] defines interaction scenarios as a description of a user who interacts with a system (or a set of systems) in order to accomplish a specific outcome in predefined conditions and within specific time duration. More specifically, the scenarios that have been given to the participants contained eleven main tasks to be completed:

Task 1: Step in front of the *Exhibition Browser*

1. Select the "All Artists" option
2. Locate "El Greco" from the list of Artists
3. Locate the "burial of Count de Orgaz"
4. Read the provided information about the painting
5. Reproduce the video of the painting

Task 2: Step in front of the *Exhibition Browser*
1. Select the "All Artists" option
2. Locate "Picasso" from the list of Artists
3. Locate the "Guernica"
4. Browse points of interest within the painting

Task 3: Step in front of the *Augmented Digital Painting*:
1. Move along the painting so as to access information about points of interest

Task 4: Locate the caption of the painting
1. Browse for the video description of the painting
2. Start the reproduction of the video
3. Pause the reproduction of the video

Task 5: Locate the caption of the painting
1. Browse for the Deep Zoom representation of the painting
2. Scale in and out the painting

Task 6: Locate the "Art River" in the corridor
1. Take one of the available rocks
2. Place the rock on the river bank
3. Extract items from the river
4. Get more information about the extracted painting

Task 7: Locate the "Museum coffee table"
1. Take one of the beverage coasters and place it on the table
2. Access the list of paintings from the coaster
3. Drag one of the painting on the surface
4. Get more information about the painting

Task 8: Locate the "Museum coffee table"
1. Take one of the beverage coasters and place it on the table
2. Access the timeline of the artists from the coaster
3. Browse the timeline

Task 9: Locate the "Museum coffee table"
1. Take one of the beverage coasters and place it on the table
2. Access the puzzle
3. Select and solve a puzzle

Task 10: Locate the "Digital frame"
1. Change Views
2. Show and hide the stock market widget

Task 11: Locate the "Digital frame"

1. Change Views until the last one
2. Change the profile using one of the available gestures (child, father, mother, family)

The questionnaires used for conduction the evaluation are presented in Appendix I.

10.2.1.1.1 Results of the Pre-Test Questionnaire for Museums and Smart Living Spaces

The results of the pre-test questionnaire are presented in Table 54. As shown in this table ~66% of the users visit a museum once a year. At the same time their interest in paintings and modern art covers a percentage of ~53% but they do not follow some specific art style or trend. More importantly ~56% of the users have visited a museum with some form of interactive exhibits. Regarding their satisfaction from museum visits ~89% are not satisfied from the information gathered from museum while ~67% feel that museum are boring due to this fact. To overcome this issue ~11% have hired in the past a museum guide and ~55% an audio guide. At the same time ~89% of the user population had experience with other forms of interaction rather than computer and mouse. Finally regarding their attitude about art at home ~77% enjoy having art at home but only 66% use painting at home for decoration.

1. How often do you visit museums?	**Once a month**	**More than once month**	**Once a semester**	**More than once a semester**	**Once a year Other**	**Other**
	0,00%	0,00%	22,22%	0,00%	66,67 %	11,11 %
2. What is your interest in Art?	**Painting**	**Sculpture**	**Ancient Art**	**Modern art**	**Other**	
	46,15%	23,08%	23,08%	7,69%	0,00%	
3. Do you follow any art styles or trends?	**Yes**	**No**				
		100,00%				
4. Have you ever been in a Museum or a location with some form of interactive exhibits?	**Yes**	**No**				
	44,44%	55,56%				
5. Are you satisfied with the amount of information you get about an artefact (mainly through	**Yes**	**No**				
	11,11%	88,89%				

museum captions)?						
6. Do you think that museum visits are boring because most of the times you don't have enough information about artefacts?	**Yes**	**No**				
	66,67%	33,33%				
7. Have you ever hired a museum guide?	**Yes**	**No**				
	11,11%	88,89%				
8. Have you ever used an audio guide?	**Yes**	**No**				
	55,56%	44,44%				
9. Have you ever used alternative forms of interaction with applications? (other than mouse, keyboard and touch)	**Yes**	**No**				
	88,89%	11,11%				
10. Do you enjoy having art at home?	**Yes**	**No**				
	77,78%	22,22%				
11. Do you have paintings at home for decoration?	**Yes**	**No**				
	66,67%	33,33%				

Table 54. Results of the pre-test questionnaire for museums and smart living spaces

The mini survey conducted with the pre-test questionnaire provided important information about the attitude of users in relation to this research work. More specifically while ~88% of the users enjoy visiting museums, they think that museum captions are inadequate and that there should be other ways of get educated from museum visits rather that museum and audio guides. In the same context the majority of the population thinks that museums can do more to provide alternative forms of information while also having a positive attitude towards interactive technology (100% scored 4 to 5). Finally the majority of the users asked would like to have some form of educational games related with art at home while also being positive with a concept of a smart painting that is an aesthetic object but also able to encode information.

	1	2	3	4	5
a. I enjoy visiting museums	0,0%	11,1%	44,4%	44,4%	0,0%
b. I think that interactive technology enriches museum visits	0,0%	0,0%	0,0%	22,2%	77,8%
c. I think that museum captions are inadequate	0,0%	11,1%	33,3%	44,4%	11,1%
d. I think that using a guide is the only way to get educated from a museum visit	22,2%	33,3%	22,2%	22,2%	0,0%

e.	**I think that using an audio guide is the only way to get educated from a museum visit**	11,1%	55,6%	33,3%	0,0%	0,0%
f.	**I think that museums have not done enough to enlighten visitors about exhibits**	0,0%	0,0%	33,3%	44,4%	22,2%
g.	**I think that a tour guide is the only way to get educated from a museum visit**	0,0%	55,6%	33,3%	22,2%	0,0%
h.	**I think that museums do no facilitate appropriately entrances, corridors and empty spaces**	0,0%	11,1%	11,1%	55,6%	22,2%
i.	**I would like to transfer my museum experience at home so as to study the exhibits more carefully**	11,1%	0,0%	0,0%	55,6%	22,2%
j.	**I would like to have games at home that are updated from my museum visits**	0,0%	11,1%	33,3%	44,4%	11,1%
k.	**I would like to have a smart painting that presents artefacts from my most liked artists**	0,0%	11,1%	11,1%	44,4%	33,3%
l.	**I would like my home to encode information within paintings**	0,0%	0,0%	44,4%	22,2%	33,3%

Table 55. Results of the pre-test questionnaire survey for museums and smart living spaces

10.2.1.1.2 Results of the Post-Test Questionnaire for Museums and Smart Living Spaces

The results gathered through the post-test questionnaire are used to calculate four factors. The OVERALL factor expresses the overall satisfaction of the users regarding the system (calculated by the average of all the answers' grades). The SYUSE factor measures the satisfaction of users when using the system (5, 6, 9, 11, 12 and 16), while the INFOQUAL measures the information quality provided by the system (calculated by the average of questions 2, 5, 6, 8, 9, 10, 14, 15 and 16). Finally, INTERQUAL is a factor that captures user satisfaction regarding the interface provided by the system (3, 4, 5, 7, 8, 11, 12, and 13).

Figure 258 represents the OVERALL factor, clearly showing that the users were generally satisfied (~87% of the users are within the range 5 to 7 while 30.56% of the users provided a grade of 7 to all questions) by the overall usability of the system. However, there are 5% of the users that state that were not satisfied.

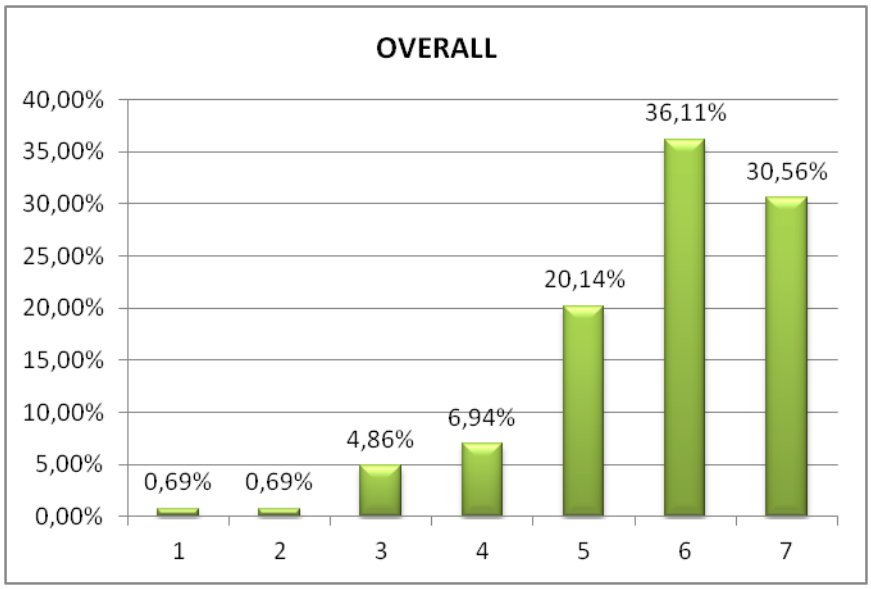


Figure 258: OVERALL factor for Museums and Smart Living Spaces

Figure 259 represents the SYUSE factor, clearly showing that the users were generally satisfied (~85% of the users are within the range 5 to 7 while 37, 04% of the users provided a grade of 7 to all questions) by the overall satisfaction by using the system. However, there are ~14% of the users that state that were little to medium satisfied.

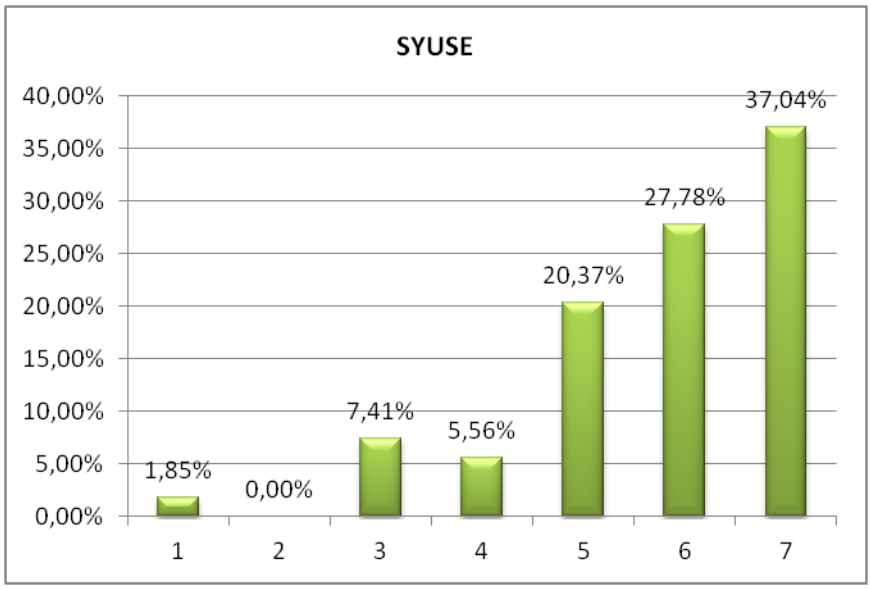


Figure 259: SYUSE factor for Museums and Smart Living Spaces

Regarding the quality of information Figure 260 clearly shows that the users were generally satisfied (~88% of the users are within the range 5 to 7 while ~25% of the users provided a grade of 7 to all questions). However, there are ~43% of the users that scored 6 which implies that are is a substantial amount of users that requires some

form of improvement in the way that information is presented. To identify this more detailed analysis of questionnaire data is conducted in the following section.

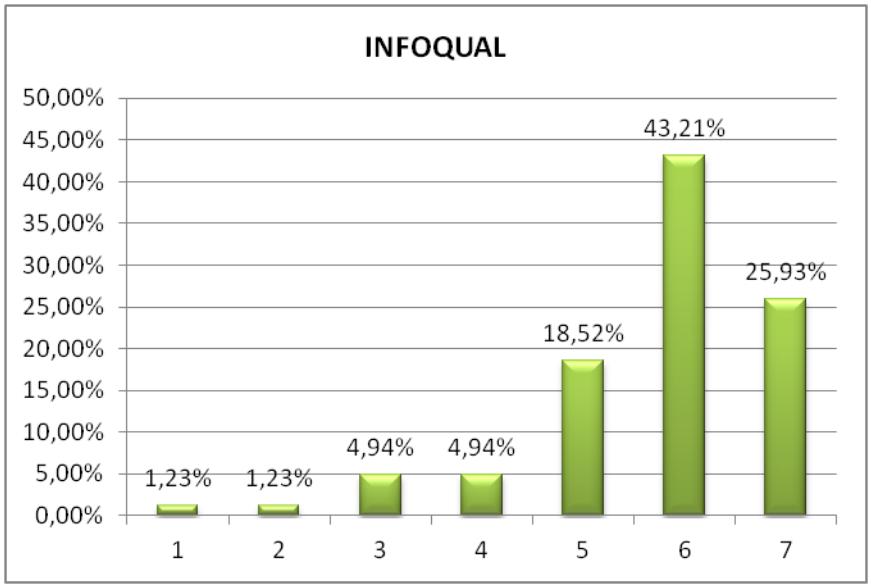


Figure 260: INFOQUAL factor for Museums and Smart Living Spaces

Finally regarding the interaction quality Figure 261 shows that the users were generally satisfied (~83% of the users are within the range 5 to 7 while ~35% of the users provided a grade of 7 to all questions). However, there are ~25% of the users that scored 5 and ~24% that score 6 which implies that are is a substantial amount of users that requires some form of improvement in the interaction.

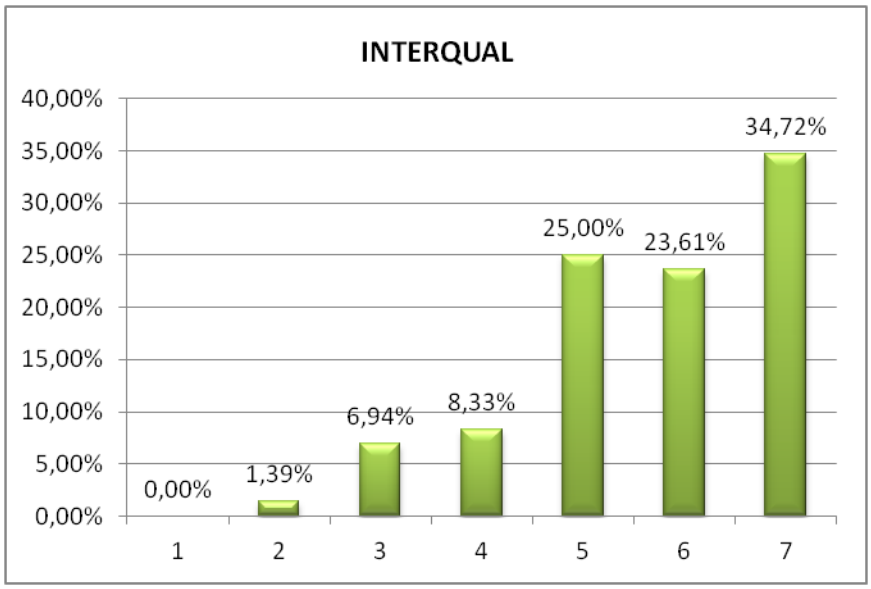


Figure 261: INTERQUAL factor for Museums and Smart Living Spaces

10.2.1.1.3 Questionnaire analysis for Museums and Smart Living Spaces

Based on the results of the aforementioned quality factors a more in depth analysis of the questionnaire data was conducted in order to highlight potential areas of improvement. To do so the questions where analysed and presented graphically. Furthermore the questions were categorised and analysed per category in order to measure the weak points of the system in each of the categories.

General User Satisfaction

As shown in Figure 262 regarding the general user satisfaction ~22% of the users score a medium satisfaction while also ~66% of score 6 while only ~11 are fully satisfied. These results also empower the need to search deeper for identifying areas of improvement.

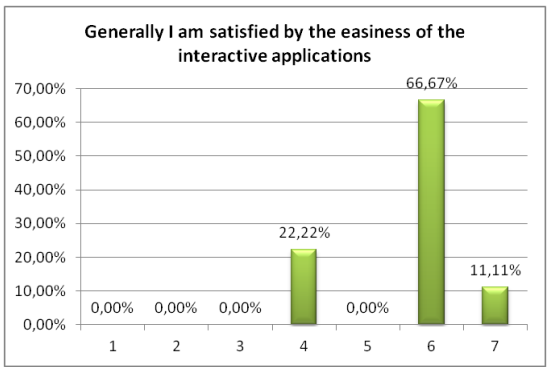


Figure 262: General user satisfaction

Interaction metaphors

In this section the questions relevant to the interaction metaphors employed by the system are presented (see Figure 263). As shown in this figure the hand tracking interaction metaphor scored lower grades in relation to body tracking and touch (~55% of the users scored 5 regarding hand – mirrored hand synchronisations and ~44% scored 5 into hand based content navigation). On the contrary body tracking and touch have better results. These results imply the need to improve the way that hand is mirrored within the application and at the same time the way that content is selected through hand tracking. In this direction the analysis of user comments provides important feedback regarding the aspects of the interaction that could be improved.

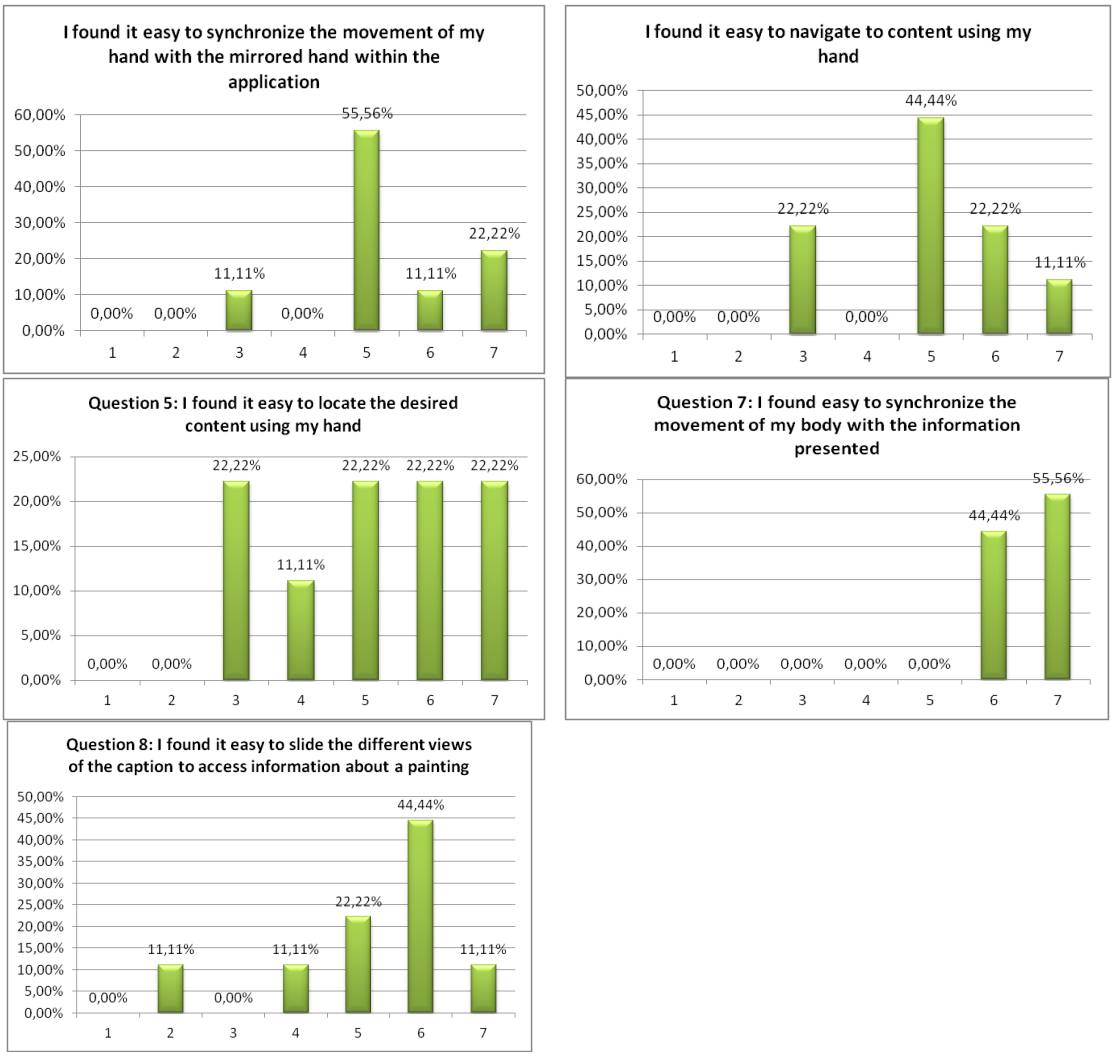
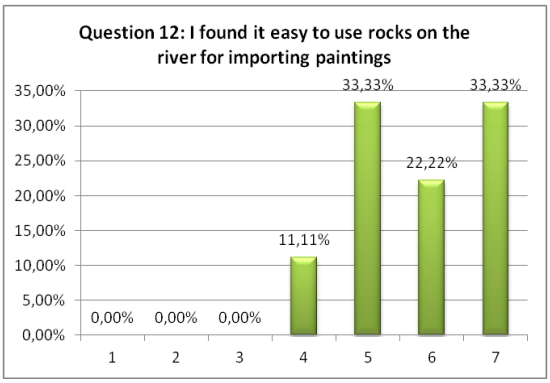


Figure 263: Questions about the acceptance of the employed interaction metaphors

Augmented Objects for interaction

As long as augmented objects are used for interaction users were in general very satisfied (~90% in question 12 and 100% in question 9 scored within the range 5 to 7). In both cases there is a percentage of ~33% that scored 5 which means that the way that augmented objects is used may require improvement.



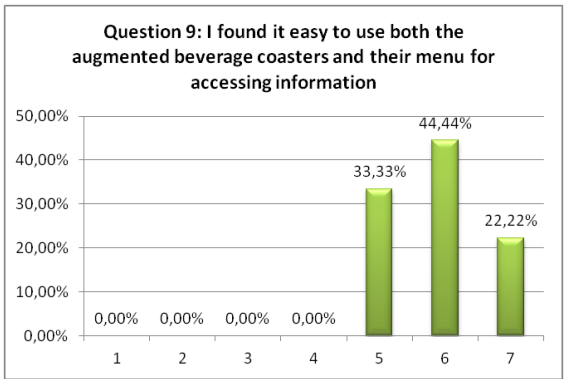
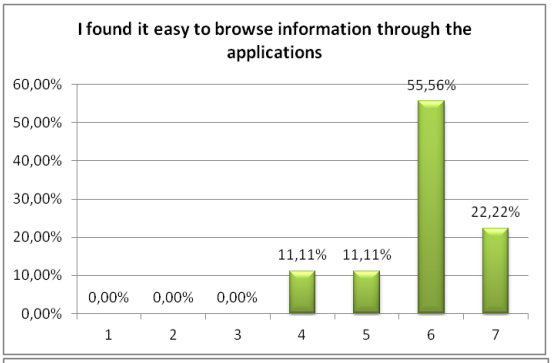
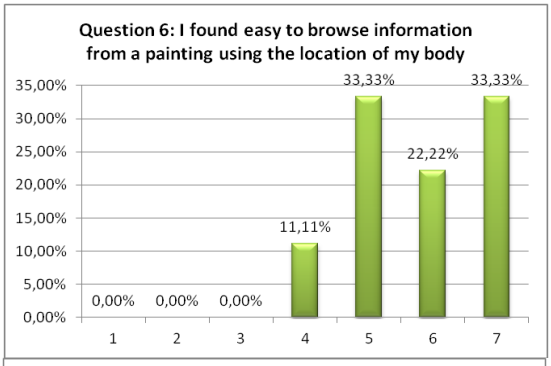


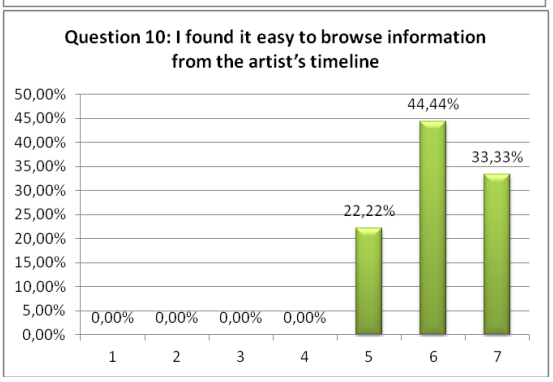
Figure 264: Questions about the acceptance of interactive objects as interaction metaphors

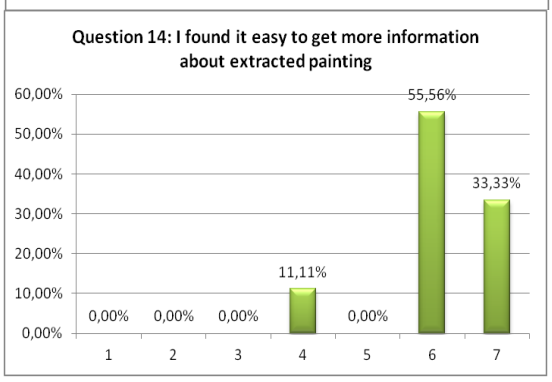
Information representation & extraction

Regarding the ways that information is represented and extracted users were in general very satisfied (~85% scored from 5 to 7 in all questions). Nevertheless there is a percentage of ~55% that are not fully satisfied in the way that information is browsed in general, thus implying that some improvement should be made. In this sense 33% scored 5 in the way that information is browsed using body tracking, ~44% scored 6 for the timeline while ~55% scored 6 in both the Digital Frame and the Art River. It is obvious that information representation within these three applications can be improved.









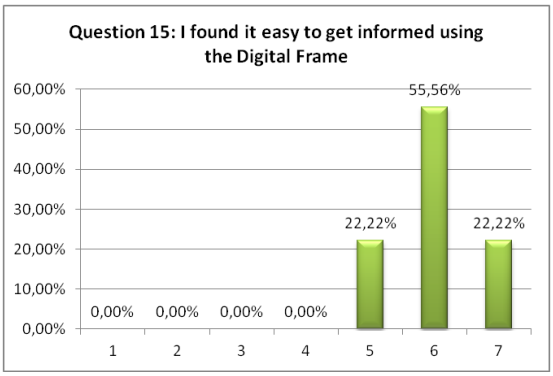


Figure 265: Questions about the quality of information retrieval mechanisms

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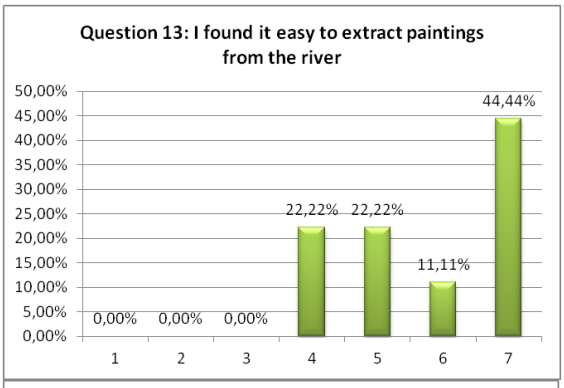
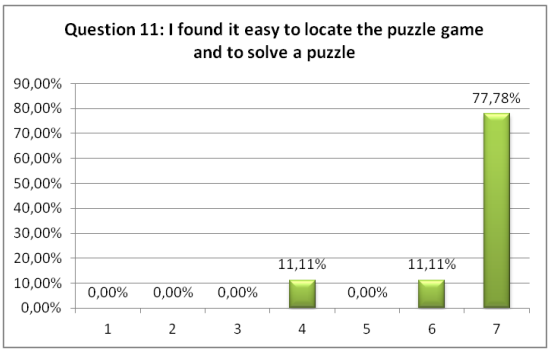
General System Use

Finally in questions that affect general system use the results pin point that within the Art River there is a ~44% scoring 4 and 5 to the way that paintings are extracted while on the digital frame ~33% scored 1 and 3 to the way that information is personalized through postures.





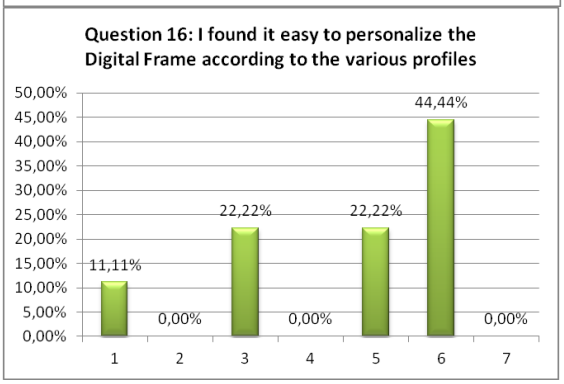


Figure 266: Questions about general usage of the system

10.2.1.1.4 Usability Errors Identified

Users were requested to also provide comments in each of the question of the questionnaire identifying potential issues or usability problems. These comments were analysed in conjunction to the recordings of user interactions in order to produce a list of usability problems that were resulted from the aforementioned evaluation. In this

sense the most important aspects that should be improved based on the user based evaluation where:

- **Sliding should be improved:** Sliding of the caption had increased failure rate mainly due to the fact that the next page had to be slided until the middle of the previous page in order for the slide to be completed. Furthermore acceleration should be taken into account in order to cope with users performing quick touch and slide gestures.
- **Caption zoom in zoom out functionality:** In the deep zoom component of the caption right click through continuous touch should be deactivated.
- **Hand tracking:** When hand tracking is employed users reported fatigue of their hand (users had their hand expanded for enough time during the task). This issue is related with the task itself because it requested a large number of selections within limited time period. Nevertheless it clearly shows that when hand tracking is employed users should not be required to have their hands expanded for a long time period. For example when browsing POIs using hand tracking the POI should be activated and stay this way if the user hand returns on the side of user's torso.
- **Magnetic hand issue:** Users reported problems with the hand being magnetised by controls (in this way users do not have to point in the exact location of the control but somewhere close to the control). This problem is occurring when passing on top of a collection of controls were the hand get constantly magnetised resulting into reduced user experience. A potential solution to this issue would be the disabling of magnetic function when the hand is moving quickly through the application.
- **Selecting among the list of artists:** The area of the screen where users should select among a list of artists is the place where the problem identified above occurs more often. In this area the users commented that the text size for artist names should be increased. This will result into making easier the success of the select artist task.
- **Hand bottom right border issue:** During the first day of the evaluation the hand was activated for selection only on its bottom right side. This was considered a crucial usability error that could result into failure of all of the hand selection tasks and thus the issue was solved prior to conducting the rest

of the evaluation sessions (three out of ten evaluation sessions were conducted before solving the issue).

- **Slow down scrolling speed:** In the exhibition browser and especially when scrolling through paintings users reported that the scrolling speed was too fast. The recording also show the same problem (the users had a late response when requested to locate the "burial of Count de Orgaz"). The scrolling speed should be therefore decreased in order for users to be able to keep up.
- **Brighter highlight for Points of Interest:** When users were using their body to locate information within a painting they could locate the information but occasionally missed to locate the highlighted area of the painting. Users commented that highlighted sections should become brighter. This problem was not identified on other applications employing the same metaphor (mainly through the conduction of user testing in brighter displays)
- **Timeline sliding issue:** Some users experienced flickering problems when scrolling the timeline (mainly due to fault multi-touch events). This issue can be solved by supporting only single touch for sliding the timeline.
- **Timeline rotation issue:** In some cases users made a rotate gesture (with their two fingers) to rotate the timeline. This gesture works on other components (e.g. the puzzle) but not on their timeline. Gestures should be consistent through the same application so the timeline should also support this gesture.
- **The information should appear quicker on the river:** Users in some cases reported that nothing was happening when placing rocks on the river (items start scrolling within the screen after three to four seconds). To overcome this issue items should appear within the screen concurrently with the placements of rocks.
- **Flipping painting on the river issue:** Users could not always identify that they should click on the flip button to rotate the painting so as to get more information. In most of the cases they double clicked the painting. Double click should therefore replace the flip button for performing this action.
- **Digital Frame gestures:** Users had increased failure rates when performing gestures in front of the Digital frame (not all users performed the next gesture in the same manner). These gestures should be made more flexible.

- **Digital Frame postures:** Small bodied users had issues performing postures in front of the Digital frame. This was consider a critical issue (encountered in the first day of the evaluation) and was fixed before proceeding to the next day (greater threshold has been introduced in the body tracking service to allow tracking irrelevant to skeleton size)

10.2.1.3 Usability evaluation for Art Creation

The demographic information of the users participating in the Usability evaluation for Art Creation is presented in Figure 267. Concerning the participants' gender, it came out that more male users participated in the evaluation, in percentage ~66%. Regarding the age of the participants 50% was between 20 and 29 years old, also having 50% within the age group of 30-39. All the participants turned out to be highly educated; all of them had at least completed a university degree, while ~66% of them had completed postgraduate studies as well.

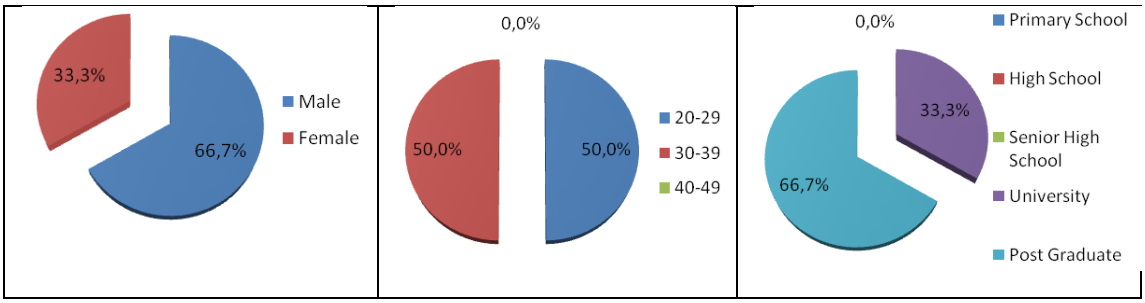


Figure 267: Demographic information of the users participating in the Usability evaluation for Art Creation

In this section the results of the usability evaluation for Art Creation are reported. In this context the scenarios that have been given to the participants contained eleven main tasks to be completed:

Task 1: Sit on the design space and locate the "Art Compare" application

1. Select "Art Styles" from the menu
2. Use the augmented beverage coasters to get more information about impressionism

Task 2: Sit on the design space and locate the "Art Compare" application

1. Select "Art Styles" from the menu
2. Use two of the augmented beverage coasters to compare impressionism and expressionism

Task 3: Sit on the design space and locate the "Design Space" application

1. From the search window open the "Art" collection
2. Locate one of the painting of El Greco
3. Drag the painting on the surface

4. Apply random filters to the painting

Task 4: Sit on the design space and locate the "3D Composition" application
1. Add two planes and select lights
2. Insert a yellow cube
3. Insert a red sphere
4. Arrange the cube and the sphere on the surface

Task 5: Locate the Augmented painting surface
1. Frame the composition
2. Transfer the composition for painting

Task 6: Locate the tablet pc on the augmented painting surface
1. Use the colour mixer to create colour mixtures
2. Transfer the mixture on the painting surface

Task 7: Locate the tablet pc on the augmented painting surface
1. Use the colour wheel to open the collection of reds
2. Select a red from the swatch to preview its relation to ideal reds

Task 8: Locate the Augmented painting surface
1. From the composition menu select the Thick Lines filter
2. Transfer the composition on the canvas
3. Clear the filter in order to reveal again the composition

Task 9: Locate the Augmented painting surface
1. From the canvas menu select colour palette
2. Create a mixture inline
3. Preview the mixture within the canvas

Task 10: Locate the Augmented painting surface
1. Use the painting framer to open the swatch of available colours
2. Select a colour from the list to preview it on the composition

10.2.1.3.1Results of the Pre-Test Questionnaire for Art Creation

The results of the pre-test questionnaire are presented in Table 56. As shown in this table ~12.5% of the users were educated artists while the rest of the target user population were users that had little or no experience in painting. Users with no experience where selected based on their positive attitude to painting and their desire to start practicing some form of painting. Users that had prior experience with painting were comfortable with creating their own compositions by also using reference material. At the same time this user population is using painting materials that are relevant to this research work. 25% of the users' exercise in some way its

painting skills while there is also 12.5% that uses some kind of optical media for painting (projector, tracing device).

Are you an Artist?	**Yes**	**No**		
	12,5%	87,5%		
Do you have any experience in painting	None	Little	Medium	Expert
	62,5%	25,0%	0,0%	12,5%
Are you preparing your compositions and if yes how?	Yes	No		
	25,0%	75,0%		
Do you paint using photos as reference materials and how?	Yes	No		
	25,0%	75,0%		
Do you exercise your skill and if yes how?	Yes	No		
	25,0%	75,0%		
Do you use any kind of optical media for painting and if yes what?	Yes	No		
	12,5%	87,5%		

Table 56. Results of the pre-test questionnaire for Art creation

The mini survey conducted with the pre-test questionnaire provided important information about the attitude of users in relation to this research work. More specifically while ~60% of the users enjoy some form of painting. 80% of the users believe that interactive technology for painting has great potential while thinking in their great majority that technology should not replace but assist the artistic creation. Users are divided into their view about whether traditional painting is more pleasant that digital painting. Finally users are positive about using technology for composition while also being positive about the potential benefits from using technology for art creation in general.

	1	2	3	4	5
a. I enjoy painting	20,0%	20,0%	40,0%	0,0%	20,0%
b. I think that interactive technology for painting has great potential	0,0%	20,0%	0,0%	60,0%	20,0%
c. I think that technology should not replace but assist painting	0,0%	0,0%	40,0%	40,0%	20,0%
d. I think that traditional painting is more pleasant than digital painting	0,0%	20,0%	60,0%	0,0%	20,0%
e. I think that technology should provide new means for painting	0,0%	0,0%	0,0%	60,0%	40,0%

f. I think that technology could facilitate the creation of compositions making this quite difficult task easier	0,0%	0,0%	0,0%	80,0%	20,0%
g. I think that optical media and technology could greatly benefit art creation	0,0%	0,0%	20,0%	60,0%	20,0%

Table 57. Results of the pre-test questionnaire survey for Art creation

10.2.1.3.2 Results of the Post-Test Questionnaire for Art Creation

The results gathered through the post-test questionnaire are used to calculate four factors. The OVERALL factor expresses the overall satisfaction of the users regarding the system (calculated by the average of all the answers' grades). The SYUSE factor measures the satisfaction of users when using the system, while the INFOQUAL measures the information quality provided by the system (calculated by the average of questions 2, 7, 11). Finally, INTERQUAL is a factor that captures user satisfaction regarding the interface provided by the system (3, 4, 5, 6, 8, 9, 10, and 11).

Figure 268 represents the OVERALL factor for each of the ten participants, clearly showing that the users were generally satisfied (~85% of the users are within the range 5 to 7 while 31.82% of the users provided a grade of 7 to all questions) by the overall usability of the system. However, there are ~8% of the users that state that were not satisfied.

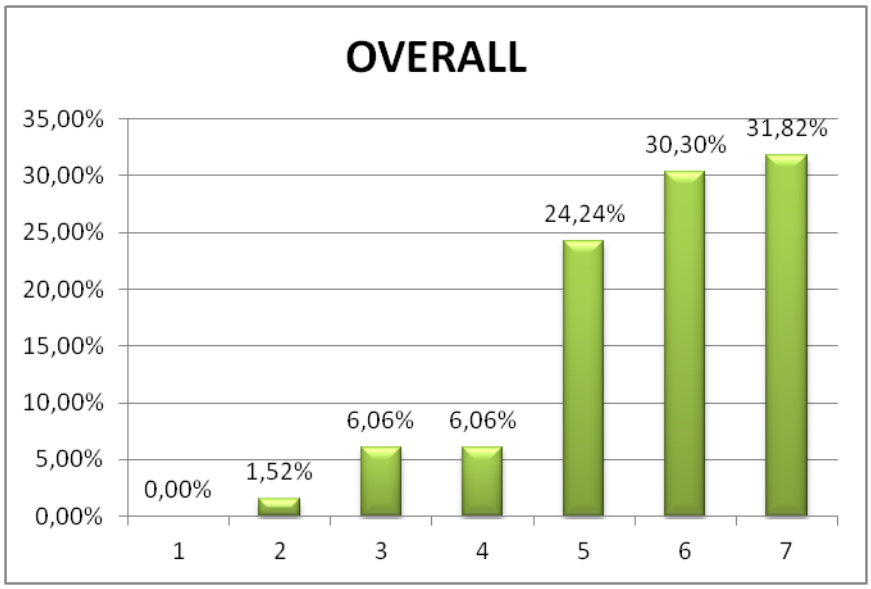


Figure 268: Factor OVERALL for Art Creation

Figure 269 represents the SYUSE factor, clearly showing that the users were generally satisfied (~85% of the users are within the range 5 to 7 while 37, 04% of the users provided a grade of 7 to all questions) by the overall satisfaction by using the system. However, there are ~14% of the users that state that were little to medium satisfied.

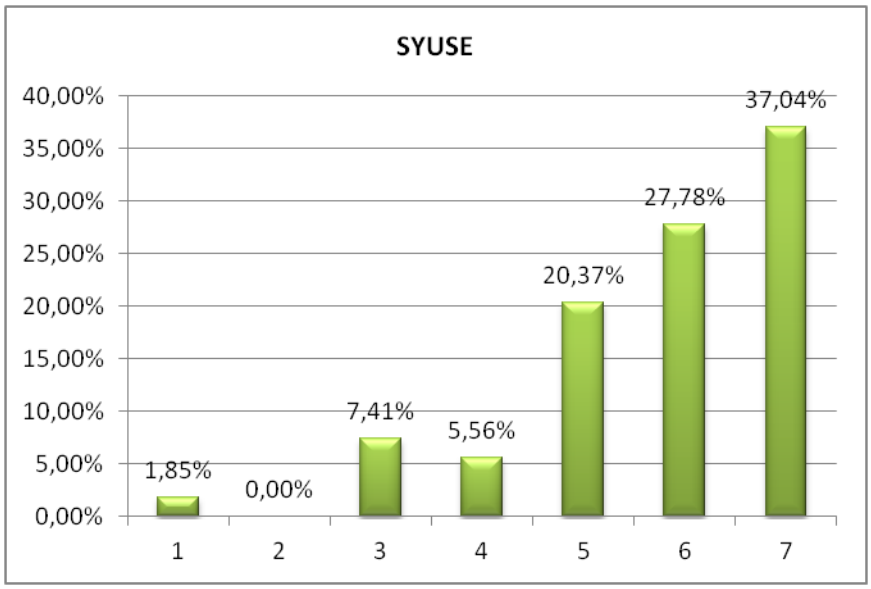


Figure 269: SYUSE factor for Museums and Smart Living Spaces

Regarding the quality of information Figure 270 clearly shows that the users were generally satisfied (~88% of the users are within the range 5 to 7 while ~33% of the users provided a grade of 7 to all questions). However, there are ~33% of the users that scored 5 which implies that are is a substantial amount of users that requires some form of improvement in the way that information is presented. To identify this more detailed analysis of questionnaire data is conducted in the following section.

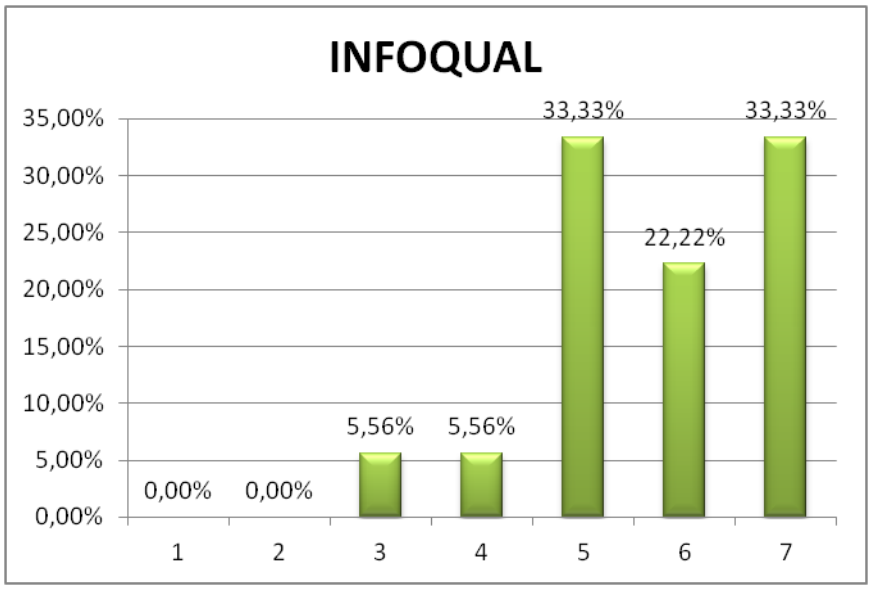


Figure 270: Factor INFOQUAL for Art Creation

Finally regarding the interaction quality Figure 271 shows that the users were generally satisfied (~82% of the users are within the range 5 to 7 while ~31% of the users provided a grade of 7 to all questions). However, there are ~19% of the users that scored 5 and ~33% that score 6 which implies that are is a substantial amount of users that requires some form of improvement in the interaction.

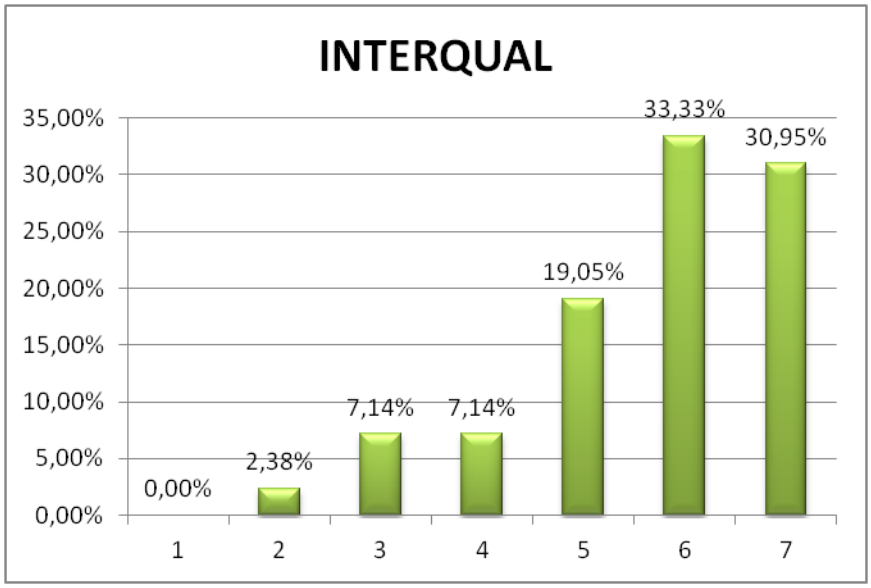


Figure 271: Factor INTERQUAL for Art Creation

10.2.1.3.3 Questionnaire analysis

General User Satisfaction

As shown in Figure 272 regarding the general user satisfaction ~66% of the users score 6 and 7 to this question but there is a ~33% scoring 5 which imply that some form of improvement is required.

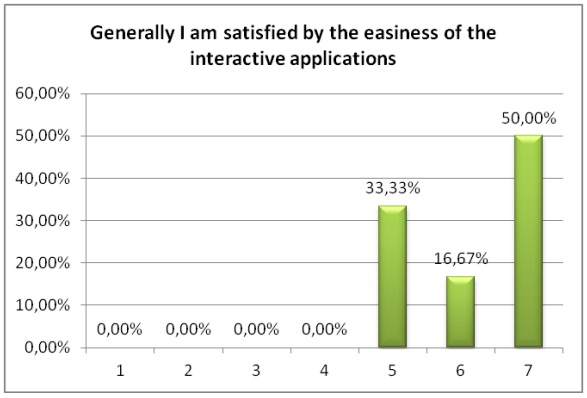


Figure 272: General user satisfaction

Augmented Objects for interaction

As long as augmented objects are used for interaction users were in general very satisfied (~33% of the users score 6 while ~66% of the users score 7).

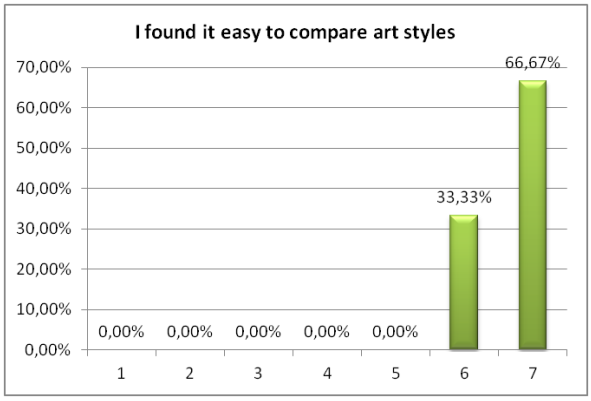
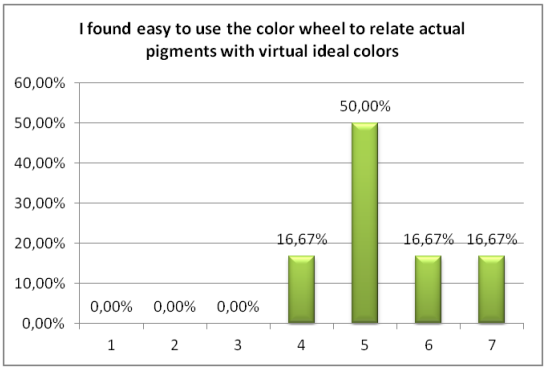


Figure 273: Acceptance of interactive objects as interaction metaphors

Information representation & extraction

Regarding the ways that information is represented and extracted users were in general very satisfied (~85% scored from 5 to 7 in all questions). Nevertheless there is a percentage of ~50% that are not fully satisfied in the way that information is presented in the colour wheel, thus implying that some improvement should be made. On the contrary users found it more efficient to locate information about art styles (~83% scored 6 and 7) while only ~16% scored 5. In general it is obvious that information representation within these applications can be improved.



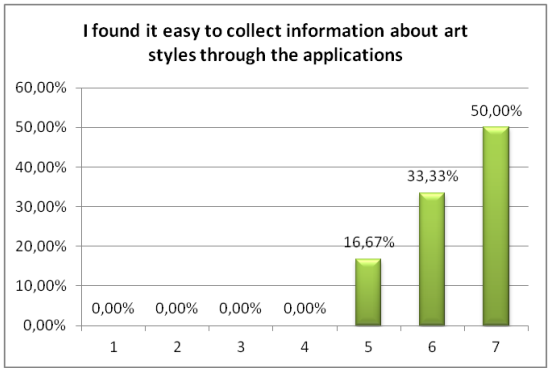
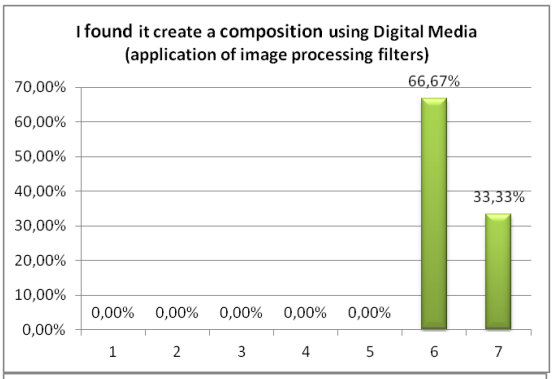


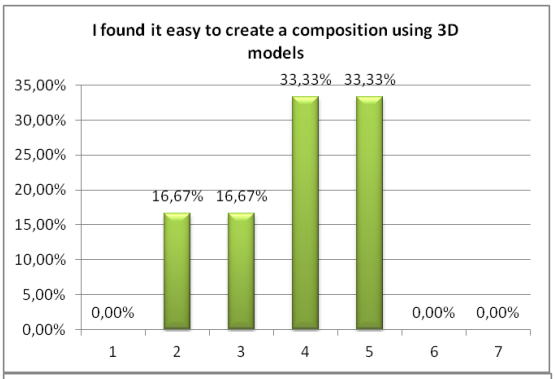
Figure 274: Questions regarding information representation and extraction

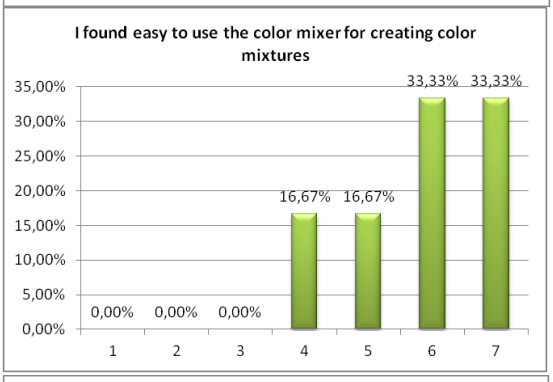
Interacting with & Using the System

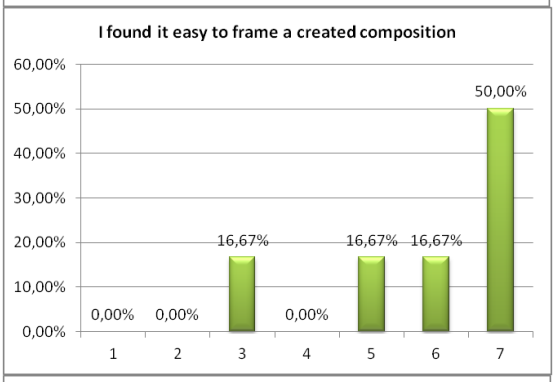
In this section the questions relevant to the critical tasks of the system are presented (critical in the sense that their completion is essential to painting). As shown in see Figure 275 all users scored 6 and 7 regarding the creation of composition using Digital media while the creation of compositions in 3D needs improvement (~33%

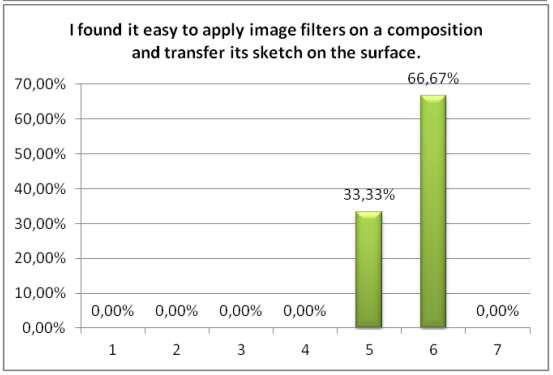
scored 4 and another ~33% scored 5 while there is ~30 of the users that were not satisfied by the application). In the same context colour mixer was very well received by users with only ~16% of the users declaring medium satisfied by its usage. Finally all the application running on the augmented painting surface had very good scores. More specifically 83% of the users found it easy to frame a created composition while the same percentage stands for selecting the most appropriate frame for a created painting (in both cases there is a ~16% that score 3 in these tasks). At the same time 100% of the users found it easy to apply image processing filters on a compositions but none scores 7 in this question leaving allot of space for improvement. Finally ~84% found it easy mixing and testing colours on the surface while ~16% scored 3 in this question. Overall in this section of the questionnaire users were very positive regarding the usage of the augmented painting surface while also stating that there are a number of issues that could be improved.

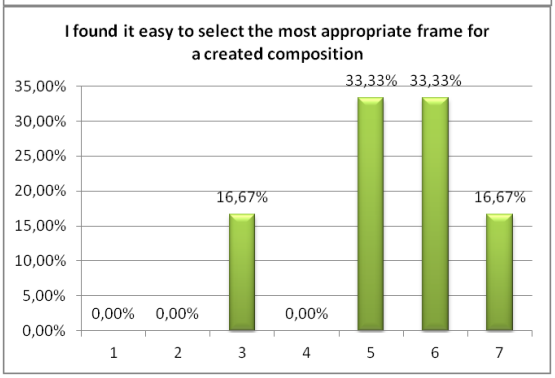












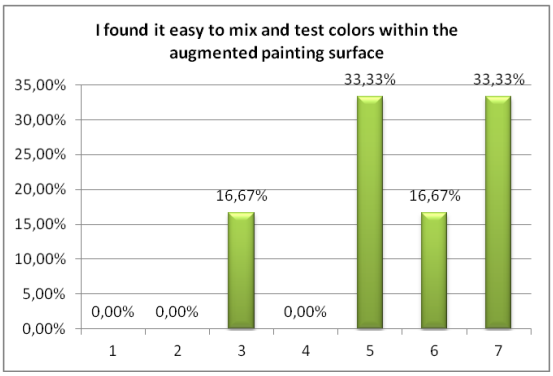


Figure 275: Questions regarding interaction with and usage of the system

10.2.1.3.4 Usability Errors Identified

Users were requested to also provide comments in each of the question of the questionnaire identifying potential issues or usability problems. These comments were analysed in conduction to the recordings of user interactions in order to produce a list of usability problems that were resulted from the aforementioned evaluation. In this sense the most important aspects that should be improved based on the user based evaluation where:

- **3D composition camera issue:** Most of the users encountered minor to major difficulties when manipulating the camera to control the view of the composition. Camera control should be scaled and its responsiveness should be improved.
- **3D composition object manipulation issue:** When manipulating objects within the composition users had increased failure rate (if user touches outside the manipulator it rotates the composition rather that manipulating the object). A potential solution to this issue is to disable manipulation of the composition with other ways rather than the camera manipulator and make available only the object manipulation function.
- **3D composition drag item request:** Some of the users tried to drag items within the composition rather than clicking on the composition and the manipulating the item. This behaviour is not consistent with the metaphors employed by all the other applications running on the design space (were dragging is employed). This issue should be solved in order to have consistency among the applications.
- **Drop issue (take snapshot):** On the design space users encountered a problem identifying the drop item function (most of them couldn't understand its

purpose. Most probably this should be replaced with a more expressive label such as “take snapshot”.

- **Close always on the right:** On the design space users expected the close button on painting to be on the right side of the container so as to be consistent with all other applications.
- **Mixing not sure how it worked:** Although users had no problems mixing colour on the colour mixer when mixing colours inline they encounter problems locating the appropriate functionality (mainly making the mixture then selecting test from the canvas and then previewing the mixture within the canvas)
- **Calibration on the surface:** Some of the users encountered issues when using the surface (on the first day the calibration of the surface was poor). This issue was solved on the second day of the evaluation (the surface was recalibrated) reducing radically the amount of comments received.
- **Responsiveness of the surface:** The majority of the users expressed the opinion that the responsiveness of touch within the surface should be improved.

11 Potential Impact

This research work aims at having a significant impact on four different key aspects of access and preservation of cultural heritage:

- The Cultural Heritage Sector: This chapter is going to highlight the potential of this research work in a number of directions such as: (a) affordability and widespread availability of tools and services for releasing the economic potential of cultural heritage in digital form and for adding value to cultural content in educational, scientific and leisure contexts, (b) wider range of users of cultural resources in diverse real and virtual contexts and considerably altered ways to experience culture in more personalised and adaptive interactive settings, (c) facilities that make the preservation of cultural heritage a part of artistic creation.
- Novel Means and Techniques for Art Creation: In this direction
- Art Education and Training
- Art and our everyday lives

11.1 The Cultural Heritage Sector

11.1.1 Releasing the economic potential of Cultural Heritage and adding value to cultural content

The EGMUS survey[11] provides statistics on European museums. Based on the available data, there are in Europe 19.274 museums, out of which 16,927 have been classified according to content type, and 44% of them (7538) are in the category of art, archaeology and history museums. According to EGMUS, 4097 museums in Europe makes use of computers, out of which 1375 (30%) for administration purposes, 684 (15%) for visitor's information purposes, e.g., interactive gallery system, 2231 (49%) have a database for electronic inventory, and 269 (6%) have Internet access. Although the collected data are not complete, these numbers clearly indicate the compelling need to widen the use of ICT technologies on the European Cultural Heritage scene.

According to the Research Agenda for the Applications of ICT to Cultural Heritage published by the EPOCH Network of Excellence [293], the current European market landscape in the CH domain is characterised by the wide adoption of audio guides, interactive installations based on touch or large project screens, web portals and forums, on-line shops and mobile services, whereas considerable limitations are observed in the adoption of mobile multimedia guides, location-based systems and augmented reality systems. Additionally, the capability for providing enhanced personalization and taking into account user contexts (e.g., location, user behaviours, needs and interests, etc.) is currently rather limited. Another serious limitation of current technologies which hinders their adoption in museums is the lack of multi-user support. In this respect, the Research Agenda identifies two main technology chasms in the CH domain [293]:

Chasm 1: *Transfer of 'near market' ICT prototypes to innovators and other early adopters in the CH sector. This transfer is hampered by: 1) limited number of research-driven companies that develop results of applied research into robust working solutions for the target market CH, 2) lack of incentives (competitive advantage) for CH sector, as well as capability for risk-taking that is required when adopting novel applications that have not so far proven their benefits.*

[11] http://www.egmus.eu/index.php?id=0&L=0&STIL=0

Chasm 2: *Adoption at a late stage by many institutions in the CH sector of a more mature application, a whole product with additional features and ancillary services. Most CH sector institutions are small organizations that lack technical staff and support and are not able to cover the total cost of ownership for ICT applications from their operational budget.*

In response to the above challenges, the outcomes of this research work have the potential to bring significant benefits to both ICT industry and the CH sector. With respect to ICT industry, this research work produced widely available and affordable components and tools to effectively satisfy the needs and requirements of CHIs in releasing the economic potential of digitised cultural heritage. The potential re-use of outcomes is one of the main goals set to ensure they are widely available. This work was based on a service oriented architecture that allows the interconnection of diverse software components (created in various platforms and having various roles in the overall architecture). This architecture is versatile enough to allow the maximum re-use of its building blocks. As a consequence, an important result is the potential for re-use of the generic software components, the Ontology Model and the application frameworks developed. This allows the maximum exploitation of results, offering several alternative exploitation paths, such as (a) using the sensing infrastructure to enable new systems to be built on the facilities offered by this research work for tracking users, gestures, etc. (b) using the image processing infrastructure, (c) using the knowledge model and tools to extend this research work, (d) using the adaptation architecture for advanced decision making in AmI environments, (e) using UI frameworks for the development of Ami applications, (f) using the application frameworks developed to develop applications and games with art content and knowledge, and (g) using this research work as a whole with content belonging to other application domains.

Costs of developing CH applications are minimised through (i) the service-oriented approach, (ii) the use of mainstream devices and sensors, (iii) compliance with knowledge representation standards of the target application domain. The above characteristics of the proposed framework have significant potential to lead to the development of applications which move beyond research prototypes towards integrated ***hardware / software solutions*** in the form of ***ready to use products***.

Finally, the main outcomes are ***open, scalable and flexible to address future technology evolution***. In this respect, this research work is anticipated to ***enhance the***

competitiveness of industry in addressing the CH market and ***provide flexible ways to invest*** in innovative interactive technologies.

According to [293] a number of factors affect the technology adoption in the CH sector, including the development of ICTs, the cost of technology, the acceptance of technology and the reliance on existing technological solutions. This work has the potential to raise the awareness of CHIs and the wider CH industry regarding the exploitation of modern technology for augmented interaction with art. At the same time this research work is providing **affordable high quality applications** embodying adaptive, personalised, multi-user and highly interactive ways of accessing art cultural heritage, opening new pathways for CIs in the provision of a variety of attractive services to visitors, targeted to be used both during and after a museum visit, thus helping the sector to ***release its economic potential*** in innovative ways, with a ***low technological investment*** and ***high potential for income***. These services include: (i) mobile applications and games, (ii) personalised tours, (iii) purchase of digital content and knowledge, (iv) personalised digital documentaries, etc. The services are easily adaptable to different hardware infrastructures and devices, and have the option to intelligently migrate to the visitors' homes after purchase. In this respect, this work is anticipated to provide a technological alternative and complement to traditional museum shops and web sites, while also contributing to wider access and understanding of art and its fruition in everyday life. Furthermore, games on art techniques and restoration may attract donations from visitors. Additionally, the proposed facilities support museums in near or dispersed geographical areas to share and jointly deploy (part of) their digitised content and raise the public's awareness of the richness of cultural heritage in specific areas or in relation to specific topics, so as to mutually increase visibility and attract the interest of higher numbers of visitors.

The monitoring facilities included in this research work, besides collecting run-information for adaptation and personalisation, will also offer to CIs suitable means to keep track of users' behaviour in order to ***continuously improve their offer***.

11.1.2 Widening and enhancing the art fruition experience for the Citizens

Technological investments in the CH sector are largely affected by considerations pertaining to marketing and the target audience, including enhancing the users' experience, widening the customers' base, and enhancing the educational impact of digitised content [293]. This research work has the potential to bring ***significant and measurable benefits to citizens*** regarding the wider and enhanced fruition of art cultural heritage. In this respect, this work is anticipated to ***extend the range of users of cultural resources***, and in particular art, by: (i) enhancing user experiences in museums, therefore extending the target user population of visitors, (ii) bringing art to everyday life environments and therefore raising the awareness about art; (iii) creating interactive games that bring art to the public and especially young people, and deepen the public's understanding of art, (iv) exploiting new media as a means of accessing Art, (v) extending the timeframe of museum visits by allowing knowledge to persist and by augmenting the knowledge gained from museum visits, and (vi) enhancing museum visits through modern technology and games. Additionally, ***the range of real and virtual contexts*** **in** which art content and knowledge can be experienced can be significantly extended through developing a number of enhanced interfaces to support the exploitation of digital content within everyday living environments, again minimising costs. These new contexts include ***virtual museums and exhibitions, private homes, working places, public spaces such as airports, train stations, city halls, tourist offices***, etc.

Finally, this research work has the potential to ***considerably alter ways to experience culture in more personalised and adaptive interactive settings*** *by* providing adaptation to: (i) the devices used for interaction (mobile device, tablet, interactive digital artefact, physical interactive artefact, interactive table, TV screen); (ii) the interaction styles supported by each device (touch, multi-touch, gestures, skeleton tracking, etc.), (iii) the context of use (e.g., user is in front of an interactive exhibit with a mobile device and a cardboard and decides to use the cardboard). At the same time personalisation is provided based on user parameters and interaction preferences through adapting the presented content and knowledge to: (i) the art expertise of the visitor through using anonymous profiles, (ii) personal understanding of art through users' annotations, (iii) the personal environment of the user, for entertainment,

information and learning purposes, (iv) collective intelligence acquired through socialisation groups.

11.2 Novel Means and Techniques for Art Creation

11.2.1 Augmented Art Creation process

This research work revolutionaries the way that Art is created by introducing the concept of Ami augmented creativity. This is done with respect to the process and techniques followed by the art masters and with the minimum technology intervention during the actual creation process. In this sense this research work creates a new form of Art creation that is as old as the frescos of Minoan Palaces and at the same time as modern as ambient intelligence.

11.2.2 Facilitating the preservation of cultural heritage

A large part of the research conducted to date in the cultural heritage sector is concerned with the identification of techniques, mediums, artistic styles and methods used by Art Masters of the past. Such research is based on the fact that such knowledge was a treasure that was carefully kept hidden by the masters themselves. This research work makes preservation of cultural heritage part of the artistic creation. Negotiations between Artists and Patrons, preparatory sketches and compositions, explored artistic concepts, colour preferences and mixtures, selected Art supplies, lighting schemes used etc. are collected by the system and connected with the Artistic outcome. Such information can be therefore used in a number of directions including (a) extracting information regarding an Artefact including the process of its creation, (b) determining the art style and methods of famous artists, (c) reconstructing the methods of Art Masters, (d) using knowledge for education and training etc.

11.3 Art Education and Training

This research work has conducted an analysis on the processes followed for educating artists in the past and also on identifying the major aspects of academic training in art (Bachelor and Master of Fine Arts). At the same time potential contributions has been provided by this research work regarding the implementation of facilities for enhancing creativity within artist's workshops. This analysis produced valuable feedback for identifying major goals of academic educations that could be facilitated by this research work. In this context the results of this work can be directly exploited in the context of academic education in Art. Further research is required, though in

order to measure the impact of these novel training methods in conjunction to the traditional ones.

11.4 Art and our everyday lives

11.4.1 Economic potential of Cultural Heritage within living environments

Another market sector which will have considerable benefits from the outcomes of this work is the ***Entertainment and Gaming industry***. New ways to exploit cultural resources in everyday life and for various purposes, including ***entertainment, education and learning***, with considerable exploitation potential will be developed. Especially for the educational games industry, a market study published by IDATE in June 2010 estimated around 1.5 billion EUR in revenue in the World at that time with an average annual growth rate of 47% between 2010 and 2015, thus leading to a sales forecast by 2015 of almost seven times what they were in 2010. This work opens new directions in further widening this market through exploiting knowledge stemming from museum visits in the context of various educational games.

11.4.2 Adding value to cultural content in educational, scientific and leisure contexts

This work contributes to ***adding value to cultural content in educational, scientific and leisure contexts*** through redefining the ways that existing digitised knowledge is used, enriching the meaning of artefacts and providing novel means of user engagement with cultural resources**.** In particular,: (i) elaborate knowledge for producing a number of gaming experiences in the context of augmented board games, memory games, art tutors and games for understanding art; (ii) allow end users to produce their own annotations about artefacts (based on their subjective understanding) and use them in the context of their personalised cultural experiences; (iii) allow users to be engaged with knowledge in the context of their socialisation activities and within popular social media; (iv) allow the offline exploitation of knowledge through the generation of documentaries based on museum visits, and the exploitation of this knowledge for enriching the knowledge collection used in games.

12 Conclusion

12.1 Summary

The work conducted in the context of this thesis addressed the creation and fruition of art in Ambient Intelligence environments. To this end, an in depth study of art itself has been conducted in order to acquire valuable insight about the way it evolved through ages. In the same context, the way art is created has been investigated. This knowledge was required for the generation of ontology meta-model for representing art. At the same time this meta-model was extended to address the needs of user based annotation of knowledge so as to be used in a number of diverse contexts and for multiple purposes. Having established the required infrastructure, three different directions of research have been identified, aiming at facilitating three different directions of art usage. In the context of an Ambient Workshop, the process of creating art is studied. On the other hand, the smart home aims at employing art for human enjoyment, education and entertainment. Finally, the ways to facilitate the traditional interaction with art were studied in the context of an Ambient Art Gallery. All these different directions were exploited in depth and during the design phase the requirements of the target user populations were identified. In this phase the smart environments facilitating these goals were designed both in the form of floor plans and in their 3D representation. During the design the hardware specification were also analysed and the hardware has been deployed in the virtual space. Following the design phase the system architecture was established in order to: (a) provide a multitude of mechanism for accessing knowledge, (b) offer user and context

awareness based on a device abstraction layer, (c) form a computer vision and media infrastructure in order to offer augmented interaction metaphors but also art related functionality, (d) form a communication protocol for applications, (e) establish the means for interaction and content adaptation - personalisation and (f) provide the means for a number of interactive applications to communicate, adapt to end users and personalise their content in the context of application scenarios. The development of the aforementioned infrastructure and applications was in turn conducted in parallel to the definition and setup of an actual Ami simulation space for their deployment. During the pre-production phase the implemented applications were analysed and tested to produce the final prototypes deployed within the simulation space. Within this unified environments four alternative scenarios were implemented focusing on the targeted by this research work activities. This deployment was initially tested in the context of expert based evaluation sessions with experts in order to get feedback regarding usability problems. These comments were in turn used to improve the deployed scenarios for allowing the conduction of wider user based evaluation. The results of these sessions provided valuable feedback and confirmed the value of the conducted research work.

12.2 Contributions of the thesis

As discussed at several points in this thesis, the scope of addressing the fruition of art in various context including its creation, presentation within CHIs and exploration in the context of daily activities is broad and complex, since it involves issues pertaining to techniques, processes and mediums of art creation, diverse user requirements, as well as the need of adaptation and personalisation. At the same time the interaction, cooperation and interconnection of several applications within diverse contexts and through supporting numerous interaction styles is also demanding and requires a well-defined architecture so as to achieve distribution within the environment, integration, usage and recording of knowledge and maximum reusability of components and services. This complexity arises from the numerous dimensions that are involved, and the multiplicity of aspects in each dimension.

The usage of Ambient Intelligence Technologies for art creation is novel research topic addressed by this research work. As no backgrounds in this subject exist, this research work is setting the foundations of creating a novel form of art creation with great respect to the processes, mediums and techniques of the Art Masters. In this

sense rather that creating a novel form of art (e.g. Digital Art) this research work empowers the artist with novel means and technology to achieve his goals.

In the context of museum experience research has focused on: (a) personalised Information in Museums, (b) interactive Exhibits, (c) Interactive Games Installations in Museum, (d) Museum Mobile Applications, (e) Museums presence on the Web and (f) Museum Social Applications. This research work builds on existing research to provide augmented digital and physical exhibits supporting simultaneous multi-user access using a number of alternative devices, extending the museum experience in unoccupied/empty spaces and exploiting the integration of interactive technology within museum leisure spaces. In this sense this research work addresses the fundamental issue of supporting concurrent personalised access to information through the provision of different levels of information via different applications and devices and exploring the potential of exploiting knowledge within various contexts and for various purposes. Finally this research work builds on the facilities provided by the Artist's workshop infrastructure to provide art enabled games for museum visitors.

In the context of smart living environments research has focused mainly on informative art. Informative Art is computer generated or augmented aesthetic objects that act also as information displays. In the same context ubiquitous computing has proposed the mixing of technology with physical media to develop interactive art. This work extends the state of the art in the context of informative art and moves forward into transferring the museum experience to smart living environments through the support of direct logging of museum exhibits using mobile devices and through the provision of knowledge aware souvenirs from museum visits. In both of these scenarios knowledge from museums is transferred and exploited in a number of directions including information, education, entertainment and aesthetics. The scope of information is exploited by extending the potential visualisations of informative art. Education and entertainment is facilitated through the automatic generation of interactive documentaries from museum visits and by providing a number of Art-enabled games including an educational table top quiz for the whole family and a painting application for children. Finally the Augmented Living Room painting alleviates the aesthetics of the living environment through the presentation of high quality art within the living room taking into account the personal preferences of family members.

12.2 Future work

Two main directions of further work are anticipated in a path towards supporting the fruition of in Ambient Intelligence Environments. The first direction concerns the improvement of developed infrastructure and applications and their evolution from an in-vitro prototype to a mature software product. Towards this end, a number of planned improvements of the application are stemming from the conducted evaluations. To this end there is a number of less critical usability errors identified using the expert based evaluation of the applications that should be addressed together with the results stemming from the user based evaluation. These results are important as mirroring issues of the end-users experience with the system. Additionally, the integration of the proposed architectural framework and applications in a more mature (currently equipped) simulation space within FORTH's AmI facility will pose several requirements in terms of integrating new sensors and automation mechanism to the system. This is going to generate new requirements both in terms of integrating new technology but also facilitating the input generated by this technology for creating smarter and more adaptive system behaviour. Furthermore the knowledge model's employed by this research work although trying to reuse existing standards in the domain of cultural heritage do not explore in full the possibilities today offered by these models. Potential effort should be made to further formalise the representation of knowledge. More specifically the museum experience should further employ the reference model so as to achieve compatibility with external sources of information regarding artefacts that could be either used to import knowledge to the model or for dynamically generating exhibits that extract knowledge from a remotely located endpoint. In the same context the annotation model created for the purposes of this research work could be enhanced to support recent research advancements and open standards [363]. These are some generic directions that should be addressed in the context of future activities but at the same a number of improvements should be made in each of the targeted application domains.

The Artist's workshop is in a very mature stage and has successfully used to conduct a number of feasibility studies. In this case one of the most important improvements is to invest further on the extraction of knowledge for art creation facilities. Currently all the generated events by applications are transmitted to the appropriate logging mechanism but a subset of this collection is recorded. At the same time due to limited resources of employed hardware it was not yet feasible to record the art creation

process while also recognizing touch on the surface (simultaneous processing reduced fps on touch recognition). Finally a number of facilities could also be included for supporting the generation of instructional material from painting session. As long as functionality provided to Artist a number of issues could be improved. The facilities that involve the decoration of a physical canvas with a digital one (in the case of painting and framing) could incorporate some form of image processing mechanism to dynamically identify the selected canvas so as to project the decorator window without the need of adjustments from the artist. At the same time the model's plane could also include controllable lights and cameras allowing the artist to make the appropriate adjustments from the Augmented Painting Canvas. Finally an important factor reducing the user experience on the art creation space is the responsiveness of touch within the surface (currently running in 15fps) that should further be improved so as to reduce input lag.

The museum experience as facilitated by this research work has succeeded in a number of directions including the augmentation of digital and physical exhibits, the provision of simultaneous multi user access to exhibits, the facilitation of various spaces within CHIs, the extension of the museum experience to leisure spaces within CHIs and the transferring of knowledge to modern living environments. In this sense potential improvements to the above facilities should be directed on providing improvements rather than new facilities. Important aspect towards this direction is the provision of some mechanism for exhibit and profile identification from mobile devices. In this sense NFC together with NFC tags, or dynamic exhibit recognition through image processing could be employed to allow mobile devices to identify exhibits. At the same time user profile should be further addressed. In this context the user could fill in an anonymous profile on the reception and receive some kind of printout identifying his profile to museum exhibits. This printout could in turn be identified by exhibits (using an embedded camera on the exhibit) to adapt the presented information. Finally in the case of using tablet PCs to access information via skeleton tracking a technology implemented by FORTH-ICS and deployed in the Archaeological museum of Thessaloniki could be also employed to project such information on inexpensive tablet size cardboards.

The smart home experience is not fully addressed by this research work. On the contrary this work has focused on providing potential directions of facilitating knowledge stemming from museum experience into our everyday lives. In this sense

in the context of smart living environments the integrated facilities could be employed by this research work to improve user experience in a number of directions. For example the recognition of users based on postures on the Augmented Living Room painting could be facilitated through a generic recipient recognition mechanism. This could be also be facilitated for extracting profile information to be used by a number of other applications such as the digital frame the interactive documentary etc. In either case this research work has provided the appropriate means to achieve these improvements through the provision of a versatile and adaptable architecture, mechanisms for end user profiling and knowledge personalization.

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Usability evaluation for Museums and Smart Living Spaces: questionnaires and use scenarios

Background Information Questionnaire

Evaluator: _____

Background Information Questionnaire

With the help of this questionnaire (which starts in the next page), we intend to gather information on the background of the users who will participate in the "Ambient Intelligence Technologies within Museums and Smart Living Spaces" usability evaluation. This is an anonymous questionnaire and the information that you will provide will be used for statistical reasons only, in order to help us create a profile of the evaluation participants and thus understand better their behaviour and performance. Usually it is best to respond with your first impression, without giving a question much thought. Your answers will remain confidential.

Thank you for your cooperation!

A. GENERAL INFORMATION

1. Age: Into what category does your age fall?

- ☐ 20 – 29
- ☐ 30 – 39
- ☐ 40 – 49
- ☐ 50 – 59
- ☐ 60+

2. Gender

- ☐ Male
- ☐ Female

3. Education: Please check the highest grade level achieved

- ☐ Primary School
- ☐ High School
- ☐ Senior High School
- ☐ University
- ☐ Post Graduate

4. Occupation: Please define your professional occupation

_____

B. Art Experiences

1. How often do you visit museums? Please check one of the following:

- ☐ Once a month
- ☐ More than once month
- ☐ Once a semester
- ☐ More than once a semester
- ☐ Once a year
- ☐ Other:

2. What is your interest in Art? Please check all that apply:

- ☐ Painting
- ☐ Sculpture
- ☐ Ancient Art
- ☐ Other:

3. Do you follow any art styles or trends? Please check one of the following:

- ☐ Yes
- ☐ No

If yes please specify the art styles or trends you follow

_____

_____

4. Have you ever been in a Museum or a location with some form of interactive exhibits? Please check one of the following:

- ☐ Yes
- ☐ No

If yes please what is your opinion about the usage of interactive technology within museum

_____

_____

_____

5. Are you satisfied with the amount of information you get about an artefact (mainly through museum captions)? Please check one of the following:

- ☐ Yes
- ☐ No

If no please specify why you think this information is inadequate

_____

_____

_____

6. Do you think that museum visits are boring because most of the times you don't have enough information about artefacts? Please check one of the following:

- ☐ Yes
- ☐ No

If yes what kind of information would you think useful?

_____

_____

_____

7. Have you ever hired a museum guide? Please check one of the following:

- ☐ Yes
- ☐ No

If yes do you think that this visit was more educative than if you were visiting alone?

_____

_____

_____

8. Have you ever used an audio guide? Please check one of the following:

- ☐ Yes
- ☐ No

If yes do you think that this visit was more educative than if you were visiting without one?

_____

_____

_____

9. Have you ever used alternative forms of interaction with applications? (Other than mouse, keyboard and touch)

- ☐ Yes
- ☐ No

If yes please describe what forms of interaction have you used?

_____

_____

10. Do you enjoy having art at home?

- ☐ Yes
- ☐ No

11. Do you have paintings at home for decoration?

- ☐ Yes
- ☐ No

For each one of the statements below, please check the number, which best shows how you feel. (1 = Strongly Disagree, 5 = Strongly Agree)

		1	2	3	4	5
a.	I enjoy visiting museums					
b.	I think that interactive technology enriches museum visits					
c.	I think that museum captions are inadequate					
d.	I think that using a guide is the only way to get educated from a museum visit					
e.	I think that using an audio guide is the only way to get educated from a museum visit					
f.	I think that museums have not done enough to enlighten visitors about exhibits					
g.	I think that a tour guide is the only way to get educated from a museum visit					
h.	I think that museums do no facilitate appropriately entrances, corridors and empty spaces					
i.	I would like to transfer my museum experience at home so as to study the exhibits more carefully					
j.	I would like to have games at home that are updated from my museum visits					
k.	I would like to have a smart painting that presents artefacts from my most liked artists					
l.	I would like my home to encode information within paintings					

Interaction scenarios

Task 1: Step in front of the *Exhibition Browser*

6. Select the "All Artists" option
7. Locate "El Greco" from the list of Artists
8. Locate the "burial of Count de Orgaz"
9. Read the provided information about the painting
10. Reproduce the video of the painting

Task 2: Step in front of the *Exhibition Browser*

5. Select the "All Artists" option
6. Locate "Picasso" from the list of Artists
7. Locate the "Guernica"
8. Browse points of interest within the painting

Task 3: Step in front of the *Augmented Digital Painting*:

2. Move along the painting so as to access information about points of interest

Task 4: Locate the caption of the painting

4. Browse for the video description of the painting
5. Start the reproduction of the video
6. Pause the reproduction of the video

Task 5: Locate the caption of the painting

3. Browse for the Deep Zoom representation of the painting
4. Scale in and out the painting

Task 6: Locate the "Art River" in the corridor

5. Take one of the available rocks
6. Place the rock on the river bank
7. Extract items from the river
8. Get more information about the extracted painting

Task 7: Locate the "Museum coffee table"

5. Take one of the beverage coasters and place it on the table
6. Access the list of paintings from the coaster
7. Drag one of the painting on the surface
8. Get more information about the painting

Task 8: Locate the "Museum coffee table"

4. Take one of the beverage coasters and place it on the table
5. Access the timeline of the artists from the coaster
6. Browse the timeline

Task 9: Locate the "Museum coffee table"

4. Take one of the beverage coasters and place it on the table
5. Access the puzzle
6. Select and solve a puzzle

Task 10: Locate the "Digital frame"

3. Change Views
4. Show and hide the stock market widget

Task 11: Locate the "Digital frame"

3. Change Views until the last one
4. Change the profile using one of the available gestures (child, father, mother, family)

Questionnaires

Usability evaluation questionnaire

Evaluator: _____

Usability evaluation questionnaire

With the help of this questionnaire (which starts in the next page), we intend to give you the opportunity to express in what degree you are satisfied by the system usability. Your answers will help us locate the parts of the system that were easy or difficult for the user. While answering the questions have in mind the tasks you carried out. These questions explicitly concern the applications used. Please read every claim and note the degree of your agreements by circling the grade of your choice. The grade scale is between 1 and 7 where 1 means you totally agree with the claim and 7 that you totally disagree. If you believe that a claim is not applicable to the system you evaluated circle the point N/A that means not applicable.

Thank you for your cooperation!

1. Generally I am satisfied by the easiness of the interactive applications.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

2. I found it easy to browse information through the applications.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

3. I found it easy to synchronise the movement of my hand with the mirrored hand within the application.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

4. I found it easy to navigate to content using my hand.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

5. I found it easy to locate the desired content using my hand.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

6. I found easy to browse information from a painting using the location of my body.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

7. I found easy to synchronise the movement of my body with the information presented.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

1. I found it easy to slide the different view of the caption to access information about a painting.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

2. I found it easy to use both the augmented beverage coasters and their menu for accessing information.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

3. I found it easy to browse information from the artist's timeline.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

4. I found it easy to locate the puzzle game and to solve a puzzle.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

5. I found it easy to use rocks on the river for importing paintings

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

6. I found it easy to extract paintings from the river

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

7. I found it easy to get more information about extracted painting (from the river)

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

8. I found it easy to get informed using the Digital Frame

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

9. I found it easy to personalise the Digital Frame according to the various profiles

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

Appendix II. Usability evaluation for Art Creation

Background Information Questionnaire

Evaluator: _____

Background Information Questionnaire

With the help of this questionnaire (which starts in the next page), we intend to gather information on the background of the users who will participate in the "Ambient Intelligence Technologies for Art Creation" usability evaluation. This is an anonymous questionnaire and the information that you will provide will be used for statistical reasons only, in order to help us create a profile of the evaluation participants and thus understand better their behaviour and performance. Usually it is best to respond with your first impression, without giving a question much thought. Your answers will remain confidential.

Thank you for your cooperation!

A. GENERAL INFORMATION

1. Age: Into what category does your age fall?

- ☐ 20 – 29
- ☐ 30 – 39
- ☐ 40 – 49
- ☐ 50 – 59
- ☐ 60+

2. Gender

- ☐ Male
- ☐ Female

3. Education: Please check the highest grade level achieved

- ☐ Primary School
- ☐ High School
- ☐ Senior High School
- ☐ University
- ☐ Post Graduate

4. Occupation: Please define your professional occupation

_____

B. Art Experiences

1. Are you an Artist? Please check one of the following:

- ☐ Yes
- ☐ No

2. If yes please specify your expertise

_____

3. Do you have any experience in painting? Please check all that apply:

- ☐ None
- ☐ Little
- ☐ Medium
- ☐ Expert

4. What painting techniques do you use? Please check one of the following:

_____

_____

5. What painting supplies do you use? Please check one of the following:

_____

_____

6. What painting mediums do you use? Please check one of the following:

_____

_____

7. Are you preparing your compositions and if yes how? Please check one of the following:

- ☐ Yes
- ☐ No

_____

_____

8. Do you paint using photos as reference materials and how? Please check one of the following:

- ☐ Yes
- ☐ No

_____

_____

9. Do you exercise your skill and if yes how? Please check one of the following:

- ☐ Yes
- ☐ No

_____

_____

10. Do you use any kind of optical media for painting and if yes what? Please check one of the following:

- ☐ Yes
- ☐ No

_____

_____

10. Do you use any kind of image processing software for painting and if yes what? Please check one of the following:

- ☐ Yes
- ☐ No

_____

_____

For each one of the statements below, please check the number, which best shows how you feel. (1 = Strongly Disagree, 5 = Strongly Agree)

		1	2	3	4	5
m.	**I enjoy painting**					
n.	**I think that interactive technology for painting has great potential**					
o.	**I think that technology should not replace but assist painting**					
p.	**I think that traditional painting is more pleasant than digital painting**					
q.	**I think that technology should provide new mean for painting**					
r.	**I think that technology could facilitate the creation of compositions making this quite difficult task easier**					
s.	**I think that optical media and technology could greatly benefit art creation**					

Interaction scenarios

Task 1: Sit on the design space and locate the "Art Compare" application

1. Select "Art Styles" from the menu
2. Use the augmented beverage coasters to get more information about impressionism

Task 2: Sit on the design space and locate the "Art Compare" application

1. Select "Art Styles" from the menu
2. Use two of the augmented beverage coasters to compare impressionism and expressionism

Task 3: Sit on the design space and locate the "Design Space" application

1. From the search window open the "Art" collection
2. Locate one of the painting of El Greco
3. Drag the painting on the surface
4. Apply random filters to the painting

Task 4: Sit on the design space and locate the "3D Composition" application

1. Add two planes and select lights
2. Insert a yellow cube
3. Insert a red sphere
4. Arrange the cube and the sphere on the surface

Task 5: Locate the Augmented painting surface

1. Frame the composition
2. Transfer the composition for painting

Task 6: Locate the tablet pc on the augmented painting surface

1. Use the colour mixer to create colour mixtures
2. Transfer the mixture on the painting surface

Task 7: Locate the tablet pc on the augmented painting surface

1. Use the colour wheel to open the collection of reds
2. Select a red from the swatch to preview its relation to ideal reds

Task 8: Locate the Augmented painting surface

1. From the composition menu select the Thick Lines filter
2. Transfer the composition on the canvas
3. Clear the filter in order to reveal again the composition

Task 9: Locate the Augmented painting surface

1. From the canvas menu select colour palette
2. Create a mixture inline
3. Preview the mixture within the canvas

Task 10: Locate the Augmented painting surface

1. Use the painting framer to open the swatch of available colours
2. Select a colour from the list to preview it on the composition

Questionnaires

Usability evaluation questionnaire

Evaluator: _____

Usability evaluation questionnaire

With the help of this questionnaire (which starts in the next page), we intend to give you the opportunity to express in what degree you are satisfied by the system usability. Your answers will help us locate the parts of the system that were easy or difficult for the user. While answering the questions have in mind the tasks you carried out. These questions explicitly concern the applications used. Please read every claim and note the degree of your agreements by circling the grade of your choice. The grade scale is between 1 and 7 where 1 means you totally agree with the claim and 7 that you totally disagree. If you believe that a claim is not applicable to the system you evaluated circle the point N/A that means not applicable.

Thank you for your cooperation!

1. Generally I am satisfied by the easiness of the interactive applications.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

2. I found it easy to collect information about art styles through the applications.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

3. I found it easy to compare art styles.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

4. I found it create a composition using Digital Media (application of image processing filters)

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

5. I found it easy to create a composition using 3D models

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

6. I found easy to use the colour mixer for creating colour mixtures.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

7. I found easy to use the colour wheel to relate actual pigments with virtual ideal colours.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

8. I found it easy to frame a created composition.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

9. I found it easy to apply image filters on a composition and transfer its sketch on the surface.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

10. I found it easy to select the most appropriate frame for a created composition.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____

11. I found it easy to mix and test colours within the augmented painting surface.

Strongly Disagree	1	2	3	4	5	6	7	N/A	**Strongly Agree**

Comments _____
_____
_____