King Pong: Design and Implementation of a Multimodal Pong Game

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Abstract

Today, computer games are considered to be an important source of entertainment for people of all ages, genders and socioeconomic backgrounds. However, the game development industry releases games which not only require but in some cases challenge human sensory and motor abilities. Therefore, the vast majority of these games are rendered inaccessible for disabled people, in particular for visually and motor impaired. King Pong is a universally accessible remake of the classic Pong game fostering the inclusion of people with disabilities to computer games entertainment. King Pong is targeted not only to disabled but also to able-bodied users and thus promotes collaboration and interaction between diverse user groups.

King Pong focuses on the cross-modal equivalence and multi-sensory perception around the concept of a multimodal game space - visual, auditory and haptic display. A key objective of this work is to combine and integrate all these modalities in order to significantly reduce the effect of certain user limitations on interaction and gaming. To this end, King Pong employs an innovative auditory environment and several haptic devices.

In particular, King Pong supports a spatially localized audio environment and force feedback (translating sound into haptic feedback). It may be played either by one player and the computer as opponent or by two players. In two-player mode, the opponents can share the same computer or alternatively play the game over the network. Moreover, the game has been designed to adapt to different levels of visual disability. King Pong also supports recording and playback of game play activities for offline analysis and evaluation.
King Pong: Σχεδίαση και Υλοποίηση ενός Πολυμορφικού Παιχνιδιού
Τύπου Pong

Απόστολος Στάμου

Μεταπτυχιακή Εργασία

Τμήμα Επιστήμης Υπολογιστών
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Περίληψη (GR)

Σήμερα, τα ηλεκτρονικά παιχνίδια θεωρούνται ως μία σημαντική πηγή διασκέδασης για όλους τους ανθρώπους ανεξάρτητα από την ηλικία τους, το γένος τους και το κοινωνικοοικονομικό τους επίπεδο. Όμως, η βιομηχανία ηλεκτρονικών παιχνιδιών προωθεί στην αγορά παιχνίδια τα οποία όχι μόνο απαιτούν αλλά και σε ορισμένες περιπτώσεις δοκιμάζουν τις αισθητήριες και μηχανικές ικανότητες των παικτών. Κατά συνέπεια, η συντριπτική πλειοψηφία αυτών των παιχνιδιών καθίσταται μη προσβάσιμα για άτομα με ειδικές ανάγκες και ειδικότητα για άτομα με προβλήματα όρασης και κινητικό δυσκολίες. Το παιχνίδι King Pong είναι μία καθολικά προσβάσιμη επανέκδοση του κλασικού παιχνιδιού PONG το οποίο προήχθη την συμπερίληψη των ατόμων με ειδικές ανάγκες στην διασκέδαση. Το King Pong απευθύνεται όχι μόνο στα άτομα με ειδικές ανάγκες αλλά και στους αρτιμελείς παικτές ενσχύοντας την συνεργασία και την αλληλεπίδραση μεταξύ χρηστών διαφορετικών κατηγοριών.

Το King Pong εστιάζει στην ισοδυναμία μεταξύ διαφορετικών μορφών παρουσίασης πληροφορίας και στην πολύ-αισθητηριακή αντίληψη γύρω από την ιδέα ενός πολυμορφικού χώρου παιχνιδιού – οπτική, ακουστική και αστική αναπαράσταση. Κύριος στόχος αυτής της εργασίας είναι να συνδυάσει και να ενσωματώσει όλες αυτές τις διαφορετικές αναπαραστάσεις έτσι ώστε να μειωθεί σημαντικά η επίδραση συγκεκριμένων περιορισμών των χρηστών στην αλληλεπίδραση με το παιχνίδι. Για αυτό τον σκοπό, το King Pong χρησιμοποιεί ένα πρωτοποριακό ακουστικό περιβάλλον καθώς και αρκετές αστικές συσκευές.

Πιο συγκεκριμένα, το King Pong υποστηρίζει δισδιάστατο χωρικό κατανεμημένο ήχο και αστική ανάδραση. Επίσης, προσφέρει την δυνατότητα διπλών παιχνιδιών είτε μοιραζόμενοι οι παίκτες τον ίδιο υπολογιστή είτε απομακρυσμένα μέσω δικτύου. Στα
διπλά παιχνίδια, οι αντίπαλοι μπορούν να μοιράζονται τον ίδιο υπολογιστή ή να παίζουν διαδικτυακά. Επιπρόσθετα, το King Pong έχει σχεδιαστεί έτσι ώστε να προσαρμοζόταν στα διάφορα επίπεδα οπτικής ικανότητας του παίκτη. Τέλος, το παιχνίδι προσφέρει την δυνατότητα εγγραφής και αναπαραγωγής η οποία διευκολύνει την διαδικασία της αξιολόγησης και ανάλυσης του παιχνιδιού.
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Introduction

1.1 Motivation

Undoubtedly, computer games play an important role in our culture and help add to our quality of life since they are on of the primary sources of entertainment among people of all ages, sexes and socioeconomic backgrounds. It is known that the sales of game titles surpass the sales of books while the annual budget of game industry can only be compared with those of Hollywood Box Office and music industry (Screendigest, 2004). In 2005, revenues for entertainment software and directly related products (gaming devices, etc.) were $10.5 billion only for the USA while the average rate of gaming software sales is expected to remain at 15% per year through 2010 without taking into account the game piracy which costs the game industry about $3 billion every year (Gamasutra, 2006). Additionally, the role of entertainment for pedagogical purposes, supporting or even complementing the learning process, is well known in the education domain, being universally acknowledged. Indicative is the fact that some university departments are gradually introducing computer games in their curricula to support alternative learning styles, attract student interest and help reinforcing learning objectives (Giguette, 2003). One key lesson many games teach children is the value of people working together and helping each other (Prensky, 2004). Games are also promoted as policy education, exploration and management tools (e.g., the Serious Games Initiative and the Global Management Challenge business game).

Nevertheless, the vast majority of existing computer games requires advanced motor and sensor skills, needed for interaction control, such as simultaneous keystrokes of two or more keys or concurrent use of two input devices (for instance, keyboard and mouse). This fact often renders these games inaccessible for disabled people and especially for visually and motor impaired. As a result, million people experience a kind of social racism as they are excluded from entertainment activities and socialization with their peers. The latter lies on the fact that disabled lack the ability to integrate with other members of society since collaboration among impaired and able-
bodied is difficult. In addition, disabled children do not have equal opportunities for education as they do not have access to games catered for training and learning, known as game-based learning (Prensky, 2000), in order to take advantage of the unparalleled motivation and engagement that computer games can offer to learners of this age.

Recent statistics show that there are about 180 million people worldwide who have a visual impairment and is estimated that 40 to 45 million of them are blind while it is expected that these numbers will further climb to reach 75 million blind and 220 million visually impaired by the year 2020 (World Health Organization, 2003). The situation is similar for motor impaired people since more than 25 million people only in the USA (12.1% of the population) suffer from a moderate or severe motor disability. Moreover, there are a variety of studies collected and compiled by the United Nations showing that between 10% and 20% of the people in any country can be considered to be disabled. Additionally, ageing is another factor that further aggravates the above numbers in the sense that it adversely affects vision as well as motor functions. As recent surveys indicate the worldwide population is ageing, since in 2000 there were about 600 million persons aged 60 years and over, a number that is estimated to double by the year 2025 and reach 2 billion by 2050 (WHO, 2004). At the same time, the number of elderly people who are fond of playing computer games also increases making a greater number of people unable to play mainstream computer games. In 2007, the 24% of gamers were over the age of 50, an increase from 9% in 1999 (ESA, 2007).

The number of people interested in gaming transcends age, gender, income and disability. Although specific needs vary from person to person, the common issue is the same: the need to address accessibility in gaming is imperative. Also, the disabled are often misunderstood and underestimated in terms of potential and participation. In this context and under a Universal Access and Design for All (Stephanidis, 2001) perspective, this thesis proposes the design and the development of a fully accessible version of Pong game, named King Pong, intended primarily for blind, visually and motor impaired people. This work has been conducted in the context of the EU funded project, MICOLE. The aim of this project is to develop a system that supports collaboration, data exploration, communication and creativity of visually impaired and sighted children. In addition, this system is anticipated to have social implications
through improved inclusion of the visually disabled in education, work and in society in general. In order to achieve these goals it is needed to conduct empirical research of collaborative and cross-modal haptic interfaces.

1.2 Objectives

King Pong supports a spatially localized audio environment, force feedback (translating sound into haptic feedback) and it may be played either by one player and the computer as opponent or by two human players. In two-player mode, the opponents can share the same computer or alternatively play the game over the network. The game has been designed to adapt to different levels of visual disability. To that end it offers a “high-contrast” and an “extra large” game space catering to people with moderate visual disabilities. It also supports recording (logging) and playback of game play activities with time stamps for off-line analysis and evaluation. The game is fully configurable, regarding the auditory grid, the behavior of the force feedback, the graphical appearance and various sound effects. In addition, King Pong emphasizes the need for e-learning systems for children with cognitive disabilities such as attention deficit disorder. In this context, it provides specific methods in order for children with learning difficulties to sharpen particular skills. These methods include the simulation of computer opponent in a non-trivial way and the triggering of effects when certain events happen. It is worth noticing that the game is designed to be enjoyable not only for the visually impaired people but for everyone.

One question that raises naturally is why Pong game is selected amongst other popular games. First of all, Pong is very simple to play and its rules and mechanics are mostly obvious to anyone. Additionally, the purpose of this work is to concentrate on a game with spatially-oriented attention, with an inherently simple game scene, enabling to investigate augmented auditory representations. Furthermore, it provides a suitable platform for cognitive disabled people to sharpen various kinesthetic and intellectual capabilities.

1.3 Contributions

The primary contributions of this thesis are the following:

- The provision of a fully accessible Pong game to the disabled community.
• The extraction of particular guidelines on the development and assessment of accessible games.

• Research in cross-modal interaction focusing on auditory and haptic modalities which replace the vision. The visual modality will still be used to allow partially sighted and sighted people to play the game in a more effective manner.

• Investigation of bimanual interfaces employing haptic devices, vibration gamepad and Braille display.

• The promotion of collaboration and the reinforcement of social cohesion (through two-player games) between disabled and non-disabled groups or between people with different disabilities.

• Raising the awareness of game industry on game accessibility issues.

• Description of the current status of game accessibility and review of the initiatives taken thus far.

1.4 Thesis outline

The rest of this thesis is organized as follows. Chapter 2 presents the history of Pong game and some of its most popular descendants. It also reviews the bibliography presenting background information regarding computer accessibility in general and introduces the notion of game accessibility. Furthermore, the most remarkable efforts at designing accessible games are mentioned and finally, King Pong is compared to a few other accessible Pong games stressing their differences as well as the reasons why King Pong outperforms them.

Chapter 3 describes in detail the design process of King Pong. Firstly, the Unified Design of Universally Accessible Games is presented which is an effective technical approach to achieve game accessibility coupled with high interaction quality. Moreover, this chapter shows how this approach applies to the design of King Pong and the benefits which are derived from this method. Subsequently, the concept of the triple game space is introduced which is committed to deliver an enhanced game play experience for both blind and sighted users. The backbone of the design is based on the notion of cross-modal interaction and equivalence which is extensively discussed afterwards. In this context, this chapter describes the auditory environment and how it is employed to facilitate players to locate the position and direction of game objects. In addition, a haptic interface is also used to act complementary to the auditory
environment and it is thoroughly examined. Furthermore, in this chapter two different bimanual interfaces are investigated to ascertain in what extent two-handed interaction affects the way players experience King Pong game. Apart from that, this chapter explores the capability of interacting with the game using only a single switch, in order to render the game accessible for motor impaired people. Moreover, as it is already mentioned, this thesis focuses on the collaboration between disabled and non-disabled people. To that end, it is explained how two-player games - locally or through network – may contribute to this aim. Lastly, the functions of recording and playback of game play are discussed which gave a significant boost to the assessment phase of King Pong.

Chapter 4 discusses the implementation details of King Pong. In particular, the software architecture of the game is outlined while the major components are described. Additionally, this chapter focuses on the method employed to implement the functions of recording and playback of game sessions as well as network games. Moreover, the algorithm for assigning each loudspeaker to the corresponding auditory cell is presented. It is worth noticing that this algorithm is independent of the number of sound cards installed in the system. Finally, this chapter describes the micro-language which is used to develop the configuration manager of the game and how King Pong is customized through configuration files.

Chapter 5 is dedicated to the evaluation process of King Pong. Firstly, the evaluation methods which are used to assess the game are presented. Briefly, the evaluation of King Pong combines expert based inspections as well as user-based tests. The former method is applied in the relatively early stages of development and is carried out by a handful of HCI experts in order to detect the clumsy design errors and real users not be frustrated by them. In contrast, user-based evaluations are conducted in the final phases of development. In this method, disabled and able-bodied players using screening techniques (for example, wearing blindfolds) interact with the game while the evaluators observe and take notes of the interaction. Lastly, this chapter presents and discusses the evaluation results.

Finally, Chapter 6 concludes the work by summarizing the main findings and draws direction for further research work while in the appendix is presented a concise manual of King Pong.
2 Background and Related Work

2.1 Pong History

Pong game is regarded as a milestone in the history of video games. Contrary to popular belief which considers Pong to be the world’s first video game, the earliest known interactive electronic game was “Tennis for Two” and was developed in 1958 by William Higinbotham on an oscilloscope which simulated a game of tennis or ping pong. Pong was created by Nolan Bushnell with the help of Al Alcorn and it was released in 1972 by their company. This company was ATARI which was founded the same year and that was to play a starring role in the evolution of computer games. It was a pioneer in arcade games and home video game consoles for over a decade until the mid of 1980’s when it ran into financial crisis after continuous unsuccessful product releases, such as Atari 5200 game console and the “E.T. the Extra-Terrestrial” game, and the fierce competition that faced from Nintendo.

Figure 2-1: Screenshot from an early remake of Pong game.

Pong created a new generation of games based on its simplicity. Since its creation, numerous remakes and variations of Pong game have been released. Pong not only recorded an immense commercial success by itself, but some of more than 20 video games which are influenced by its concept, including Arcanoid and Breakout followed Pong success.
2.2 Computer Accessibility

Computer accessibility refers to the usability of a computer system or application by people with disabilities or impairments. There are numerous types of disabilities that affect computer use. Although, there is not an official definition of when a person is considered disabled (mainly because disabilities may range from mild to severe) the major types of disability are roughly categorized as follows:

- Visual impairments: divided into three major types; complete or partial blindness, color blindness and low vision.

- Auditory disabilities: ranging from total deafness to partial hearing loss. Hearing impairment is considered to be the easiest disability to tackle with in terms of computer accessibility.

- Motor or dexterity impairments: including paralysis, neurological disorders and absence of upper limbs or fingers.

- Cognitive impairments and learning disabilities: come in many degrees of severity. This category covers a wide range of difficulties including but not limited to dyslexia, memory loss, autism and Attention Deficit Disorder.

- Speech impairments: are quiet rare and usually appear in conjunction with other types of disability, such as severe hearing disability.

- Illiteracy: despite the fact that this category can not be regarded as a physical disability, it places considerable obstacles to computer accessibility. Especially, poor communication and reading skills may contribute to the creation of a “two-tier” society of “haves” and “have-nots”.

- Age-related disabilities: stemming from ageing and usually fall within the above categories.

In the last decade, many efforts have been focused on accessibility issues and mainly on Web Accessibility. This can be attributed mostly to the fact that the Internet plays a key role in the Information Society and therefore disabled users have led the Web Accessibility movement demanding equal access to this resource of information. Apart from that, a significant boost to web accessibility has been provided by the initiatives of international organizations such as the W3C-WAI (Web Accessibility Initiative of the World Wide Web Consortium) which develop strategies and guidelines to help make the Web accessible to people with disabilities.

Apart from that, since 1998 many organizations have become familiar with the need to make their websites accessible. Some countries, including USA and many
European have made mandatory for all computer systems to be accessible, by introducing respective laws in their legislation. A typical example is the section 508 of the US Rehabilitation Act which was later strengthened by the US Congress in the Workforce Investment Act and requires access to any electronic and information technology developed, procured, maintained or used by Federal agencies. Additionally, in the UK, the Code of Practice: Rights of Access – Goods, Facilities, Services and Premises document published by the government’s Disability Rights Commission refers that websites must not discriminate against people with disabilities. At the same time, all Governments in Australia have policies and guidelines that require accessible public websites while in Ireland the Disability Act 2005 supplemented with the National Disability Authority’s Code of Practice on Accessible Public Services acts as a practical guide to help all Government Departments to comply with their obligations to provide services accessible to all citizens.

2.3 Game Accessibility

Video games, regardless of platform, are a natural branch of accessibility in a similar vein as other entertainment and even educational systems. Only the last few years, the need for developing universally accessible games has emerged. However, these efforts are rather independent, unorganized and are mostly initiated by a few associations of disabled people who strive to publicize their problem and the discrimination that they face. As it is evident, these efforts have a small, if not at all impact on the game industry which continues to invest in 3D games, with content conveyed entirely with 3D inaccessible artwork, while most game developers are still unaware of game accessibility and its importance. The audio part of these games is auxiliary, aiming to better set-up the overall game atmosphere. Moreover, these games do not even offer any alternative way of interaction control to accommodate players with upper limbs disabilities or disorders. While most games include subtitles for dialog, many do not caption the sound effects from weapons or enemies, and thus these games turn out to be inaccessible to deaf and hard of hearing players. Unfortunately, the vast majority of modern video games fails to meet the needs of players who function under limiting conditions which can be roughly categorized as blindness, deafness, cognitive and mobility disabilities. All these lead up to the fact
that the industry has intentionally ruled out a big part of society from playing the games which it releases. Although the potentially larger audience could act as a powerful financial incentive to companies to develop accessible games, there are some critical impediments to the adoption of Design for All principles. In particular, there is scepticism concerning not only the practicality but also the cost justification of universal design.

### 2.3.1 Initiatives and Efforts

In contrast to Web accessibility, up to now, relatively few efforts have been devoted to game accessibility. Just in 2004, the Game Accessibility Special Interest Group first introduced and defined the notion of game accessibility as “the ability to play a game even when functioning under limitations, or disabilities – such as blindness, deafness or mobility limitations”. However, it must be underlined that simple access do not suffice, but games should provide an elegant way of interaction in such a manner that disabled people do not have to make a special physical or mental effort in order to complete a task in comparison to non-disabled people. Currently, there are no related official guidelines or standards, nor any worldwide initiatives compared to W3C-WAI in the domain of game accessibility and evidently no related governmental or legislative action. Although this situation is not expected to change seriously in the near future, some initial steps towards bridging the accessibility gap in IT applications and particularly in games have been taken.

Firstly, in 2003 the prestigious International Game Developers Association (IGDA) formed the Game Accessibility Special Interest Group (GA-SIG) whose purpose is to provide support for creating games universally accessible to all gamers regardless of their disability. The most important action of that group was the release of a whitepaper (IGDA, 2004) describing the state of the accessibility within the game industry. Another important initiative has been launched by the Accessible Game Developers’ community whose aim is to provide a way to advance the state of accessible gaming (AGDev, 2005). AGDev has also set up a roadmap describing the short, medium and long-term goals of its activities. In the short term, AGDev wishes to spread the notion of game accessibility to developers and game industry so that everybody be aware of this issue, while its medium and long-term goals include the creation of a complete repository of knowledge and support for the development of
accessible games as well as to reinforce the collaboration between game developers. Additionally, in 2006 the Bartiméus Accessibility foundation initiated the Game Accessibility project, a research project which focuses on creating awareness and providing information for game developers, researchers and disabled players. It is also interested in gaining more knowledge on accessible game design. Part and outcome of the Game Accessibility project is the Audio Game Maker (currently in beta version; 2007), a free application which enables visually impaired people to make their own sound-based games. In particular, AGM offers a simple and accessible game building environment, where the game developer can place building blocks which emit different sounds in the game space arena. These building blocks may represent different types of game elements that can work together to form a scenario in the game. Finally, Gamasutra, a website intended to video game developers, has published several articles related to game accessibility (Andersen, 2002; Bierre, 2005; Grammenos, 2006; Folmer 2007).

Apart from these developers’ driven efforts of promoting game accessibility, some noteworthy initiatives have been taken by associations to support and encourage this objective. The Association for Computing Machinery (ACM) sponsors and organizes annually the prominent SIGACCESS conference committed to promote the interests of professionals working on research and development of computing and information technology to help persons with disabilities. Although this conference covers computer accessibility in general and not only game accessibility, it is considered highly influential and a point of reference for the research in this field. Moreover, in the context of the famous Game Developers Conference (San Jose, 2006; San Francisco, 2007) a session was devoted to game accessibility issues, where attendees had the chance to play a variety of games using special game controllers designed for gamers with disabilities. Furthermore, the International Conference on Universal Access in Human Computer Interaction, which is organized biennially hosted a session entitled “When Computer Games Meet Universal Access” (Las Vegas, 2005) and a tutorial entitled “Game Not Over: Why disabled Gamers Can’t Play Your Games and How to Fix It!” (Beijing, 2007), which were dedicated to the design and development of accessible games. The ICCHP 2006 (Linz, 2006) is another conference which contributed to the entertainment software accessibility in which accessible games and guidelines for the development of accessible computer games
were presented. Finally, the 9th ERCIM Workshop “User Interfaces for All” (Bonn, 2006) coped with game accessibility issues where part of this work was presented. It should be noticed that several other less influential conferences and workshops deal with entertainment software accessibility all over the world.

Lately, several academies and universities have promoted entertainment software accessibility by introducing in their curriculum student projects related to game accessibility. In 2003, the sound-based racing game Drive was a graduation assignment of the Utrecht School of the Arts (faculty Art, Media and Technology) in cooperation with the Bartiméus Accessibility foundation. The goal of this project was to create a non-visual computer game prototype that is as enjoyable and exciting as a visual one. Moreover, in 1997 Conor Cahill in the context of his Master of Science in Multimedia Systems at Trinity College Dublin, developed the Interactive Audio Game project, a game where the player navigates a virtual space using only sound, potentially on screenless handheld console. Furthermore, some research centers have focused on this field as well. The HCI laboratory of ICS-FORTH has proposed the concept of UA-Games, putting forward the objective of creating games that are concurrently accessible to people with diverse abilities. Currently, four games have been developed under this approach. In addition many research projects have been involved in accessible game development. The AGRIP project, started in 2003, was devoted to developing an accessible version of the mainstream games Quake and QuakeWorld. The outcomes of this project are the games AccessibleQuake and AudioQuake. The latter builds on the concept of the former and both aim at advancing the knowledge of techniques for developing accessible games. Another project which intends to facilitate the development process and reduce the development time of an audio game is the Klango project. Particularly, it aims at creating a flexible and user friendly programming environment for the developing and running of interactive audio-based games. From the user point of view, Klango will be offering a variety of audio games in one application in future releases, so a visually impaired player will have the chance to choose among various types of games such as board or strategy games. TIM project (stands for Tactile Interactive Multimedia), a research project funded by European Commission within the IST program, aims at providing visually impaired children, with or without additional disabilities, with multimedia computer games that can be accessed without the assistance of sighted person. Finally, part of
the work of MICOLE, an EU funded project, is to investigate and develop accessible gaming applications which are to be integrated into both disabled and non-disabled groups.

It is widely known, however, that game accessibility is predominantly a concern of organized groups of disabled people who lead a movement to increase public awareness which is currently fairly low. TAFN’s Accessible Game List is part of the Accessible Friends Network, a voluntary group set up to improve the quality of life by and for visually impaired via the Internet. The AudioGames.net website is dedicated to propagating audio based games for visually impaired players and also posts news, articles and various events regarding audio games. Additionally, since 1996 the Audyssey online gaming magazine discusses and presents games which are accessible to blind people. A respective website for players with hearing impairments is the DeafGamers which presents reviews of closed captioned games. Furthermore, Reid Kimball, a game designer who is hearing disabled, makes efforts to sensitize game developers to closed caption their games. In furtherance of this end, Kimball started the Game[CC] group whose purpose is to modify existing games to add closed captioning to them. Game[CC]’s first completed project is Doom3[CC] which was nominated for an award in the IGF Modding Competition in 2006. Robert Florio is a quadriplegic after an accident and he is currently working on making a universal accessible game. Mark Barlet, a disabled veteran, runs AbleGamers.com website whose mission is to help disabled to find a suitable game for them and to provide game industry with feedback to facilitate the development of accessible games. The OneSwitch website is a resource of games and news aimed at moderate to severely physically disabled people while it has also created a blog in which physically impaired can exchange their opinions. Lastly, SpecialEffect, a charitable organization, is dedicated to helping young people with disabilities to enjoy computer games. It investigates if and how each mainstream game can be played using access technology like switches, head pointers and adapted keyboards and it posts these results in its website.

Apart from that, the disabled community tries to draw attention to game accessibility issues by publishing related articles to respected and highly visited websites. Ouch! is an online magazine hosted by BBC where the vast majority of the editorial team has various types of disabilities. This website reflects the lives and experiences of
disabled people while it also hosts opinions of HCI experts. Although, this magazine covers a broad spectrum of computer accessibility, it emphasizes game accessibility as it recognizes its monumental importance and thus several noteworthy articles have been published related to this topic (O’Modhrain, 2004; Ellis, 2004). Moreover, other news portals, such as Guardian, have published articles about game accessibility (Williamson, 2003; D’Amico, 2001). Additionally, game accessibility, as a demand of disabled players has recently attracted radio and television coverage. People with physical and hearing impairments have been interviewed and described how difficult is for the disabled to play the mainstream games trying to persuade game developers that game accessibility is a matter of life quality for them. On top of that, ABC’s Main Menu Radio Show is ABC Radio’s regular look at technology from a blindness perspective, while it carries technology news, interviews, reviews and hints from blind people around the world.

Another means of spreading and bringing a light to the concept of game accessibility within game industry is through competitions. In 2006, the Retro Makers website organized a single-switch game programming competition where the games submitted had to be played through a single keyboard key and thus could potentially be accessible to motor impaired gamers. In addition, the same year, the DonationCoder.com website held a similar accessibility game coding contest appertaining to games for visually and motor impaired. Indicative is the fact that these competitions had a high level of participation and the vast majority of these games were of high quality. An important part of these contests are the prizes that were awarded to the winners, such as free of charge participation in the GDC conference sessions and game programming books which further motivate the participants to continue the research on game accessibility issues.

In the last years, several small-sized companies have been involved in the development and production of accessible games. The US government has passed the 8826 Tax Credit which helps and strongly encourages the small businesses to implement accessibility into their games, giving them financial aid (ADA, 2005). In particular, the companies which make use of this regulation can get back up to 50% of the total expense incurred by the implementation of accessibility. GamesForTheBlind.com website offers accessible game intended to visually impaired and blind users. This company has released the SV game series which includes eight
games. The initials SV stand for the term “Self Voicing” which indicates that these games have a built-in speech synthesizer (Eloquence) and there is no need for any additional software or hardware device. BSC Games, founded in 2002 as subdivision of blindsoftware.com LLC, also specializes in creating accessible games for the visually impaired. It has released a variety of games including arcade and educational such as puzzles and verbal games. Bavisoft and Pb soundscape offer a smaller number of audio games while GMA Games develops and sells a couple of adventure audio-based games. As far as single switch games are concerned, Arcess provides three single switch games, namely Alien Invasion, Brickout and Ruby Ridge, free of charge. Additionally, BrillSoft and RJ Cooper have a number of free games available for download, while MarbleSoft, Novita Tech and StarQuail sell commercial single switch games. However, all these companies share a common downside: they do not offer fully accessible games but are targeted to a specific group of impaired people.

2.3.2 Approaches to Achieve Game Accessibility
Currently, there are a variety of ways to implement accessibility in games with the use of assistive technologies, falling in two major categories: the hardware and software based (Bierre, 2005). The hardware based approach suggests the use of special devices to facilitate the interaction of disabled players with games. Some of the devices that can be employed for this aim are: head mouse whose functionality resembles a common mouse and it is controlled by head movements, on screen keyboard, data glove, any kind of switches including sip and puff switches, haptic devices such as Omni Phantom™, Omni Falcon™, VTPlayer etc. and some more futuristic controllers like biofeedback devices that measure muscle movement or brain waves to control a game. The drawback of this approach is that suffers from low quality interaction and limited accessibility (Stephanidis, 2001). Moreover, most of these devices require specialized software and due to this complexity may be incompatible with games. On the other side, the software based approach encompasses several methods including screen reader, screen magnifier and speech recognition. However, this approach entails that the games themselves provide some support to cooperate correctly with the above software. For instance, screen reader software often only works with text displayed using a specific set of programming interfaces.
In addition to the above, there is a tendency for development of special purpose games intended solely to people with disabilities like audio-based games for blind, caption closed games for deaf, switch-based games for motor impaired etc. Although this approach can be considered encouraging and promising, these games may contribute to the social exclusion, isolation and alienation of disabled community, since they segregate the impaired people from the able-bodied in entertainment activities. Furthermore, the cost of developing accessible games of high quality, cater only to disabled is disproportionally high compared to the size of the potential target group.

2.3.3 Accessible Games

In many cases, the aforementioned initiatives and efforts have born fruit throughout the last few years. Several successful accessible games have been developed and are currently played by the disabled people. In this section, some of the most prominent of them are described.

In 2004, Valve Software released **Half Life 2**, a first-person shooter game which was designed from the beginning to address the accessible issue. This game is a sequel to the popular game Half Life which faced sharp criticism from deaf gamers of not being accessible to them. In order to achieve this goal, Valve developed a closed captioning system while deaf gamers were consulting during the design process and were also part of the evaluation process.

**Terraformers**, released in 2003 by Pin Interactive, is a first person adventure game which can be played by blind gamers. Terraformers provides two playing modes, a graphics and a non-graphics one. The game can be played like a standard graphics based game so that sighted gamers can play the game. In the non-graphics mode, a sophisticated form of sonar is used by the player to locate and identify game objects. Moreover, the sonar provides the player with additional information, such as directional help (through the “sound compass” system). A personal digital assistant (PDA) is used to handle inventory as the player collects objects. Puzzles are sound based with the player using tones to determine what codes to enter to open a door. This game was the winner of the “Innovation in Audio” award at the 2003 Independent Games Festival.
Demor is a location based 3D audio shooting game designed to be enjoyable for both blind and sighted players. The main objective of this game is to foster the inclusion and integration of visually impaired in the society. In order to play the game, the player is equipped with a laptop in a backpack, headphones, a GPS receiver, a head tracker and a modified joystick. The playfield can be any large, empty outdoor space. Once the game starts, the player stands in the center of the 3D arena where he can move through the auditory surroundings and hear sounds. These sounds represent among other things the bad guys the surroundings and ammunition. The location based aspect of this game lies in the fact that the soundscape adjust itself in real time to the position of the player and the direction in which he moves his head.
Finally, **UA-Chess**, developed by the Human-Computer Interaction Laboratory of ICS-FORTH in 2004, is a universally accessible, fully-functional chess game which can concurrently be played by people with different abilities and preferences including people with disabilities. To this end, this game supports alternative input and output modalities and interaction techniques combined with customizable player profiles. UA-Chess was nominated for the final jury decision of the European Design for All Awards set by the European Commission, in the category “AT/Culture, Leisure and Sport”.

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**Figure 2-3: Demor’s architecture and apparatus.**
2.3.4 Accessible Pong Games

Numerous accessible Pong games have been already deployed, such as Win Pong 2, Showdown and Crazy Tennis. These games are quite similar to each other in design and the main disadvantage of them is that are designed exclusively for blind and therefore they do not make use of graphics (when these games are running, a white screen appears). For this reason, the evaluation phase of these games is a difficult task since evaluators can not see how players respond to auditory cues and in which direction move their paddle. In addition, they are not designed to be accessible for people with other types of disabilities, such as physically impaired or hard of hearing players. Furthermore, they only make use of the auditory modality and not the haptic as a result these games do not exploit this highly developed sense of visually impaired. Besides that, they completely lack configurability so that players are not able to customize the game to meet their special needs. Finally, these games do not offer two-player games neither by sharing the same computer nor over network as a result they do not foster collaboration between disabled people.
3 Game Design

3.1 Game Play

Regarding game play, King Pong resembles the classic Pong game. In this vein, King Pong simulates the table tennis (ping pong), where a small ball travels across the screen. Additionally, there are two paddles which controlled by one player each. The players control their respective paddle using keyboard or joystick and only in the vertical direction. When the ball hits the borders of the playing field or one of the paddles, it bounces and its vector velocity is changed according to the angle of the impact. The objective is to position the paddle so it hits the ball and returns it to the other side.

King Pong can be played either by a single player pitted against a computerized opponent or by two players each controlling a paddle. The two–player games are feasible not only by sharing the same computer but also over network.

3.2 Game Space

The design of the game was targeted in delivering an enhanced game-play experience for both blind and sighted users, primarily emphasizing accessibility and interaction quality. In this context, the game space was decided to be triple, providing a concurrent visual (graphical), auditory and haptic realization (Figure 3-1). To this end, following initial scenario-based conversations with blind users, it quickly came out that they were very much attracted with the idea of an auditory media space, providing spatially-localized audio, in comparison to the use of typical head-phones simulating 3D audio. Initial experiments were carried out with the use of typical 3D head-phones, but the results were less satisfactory than what was expected. Therefore, a multimodal game space was designed, comprising an auditory grid, on top of which the graphical game arena was to be projected in real-time. The design was based on the active synchronization of the auditory display with the graphical and haptic display as well. Clearly, this was far more than multiple views, as it reflected a type of view fusion, since the two alternative views were concurrently combined to provide an
enriched display experience; naturally, this additive benefit was evident only for sighted users, for which the graphical display seemed to have localized auditory capabilities. Initially, the potential topology of the spatial augmented displayed was investigated, leading to two alternative concept sketches, as shown in Figure 3-2. The haptic display acts complementary to the auditory display. The haptic modality employs two devices: the PHANTOM Omni haptic device and the Logitech gamepad which supports force feedback through two vibration motors. This modality partially represents the game space as it pertains only to the position and direction of the ball.

Figure 3-1: Overview of the KING PONG gaming environment: (1) graphical display; (2) auditory display; (3) haptic display; (4) potential input devices

Figure 3-2: Concept sketches of three alternative media space configurations, supporting view fusion, combining an auditory grid with graphical projection.
From the two alternatives, it was decided to start working on the “planar” prototype, mainly because it has been considered as easier to construct so as to quickly initiate the experiments; it is assumed that the results may be transferred to the other one in a straightforward manner.

The goal of this work is to design and evaluate some multimodal navigation tools for Pong game in order that people that face visual impairments, to be able to interact with it. To achieve this objective, 3D audio environment and haptic devices are used. Although ideally, impaired people should be able to experience the information as fluently as their unimpaired counterparts, it is beyond dispute that this is not entirely possible. Despite that, impaired people should be able to interact with the application without encountering obstacles and difficulties. In this context, it should be investigated some alternative methods to present information (concerning the position and the velocity of the ball, the position of paddles, etc.) for visually impaired players. For this purpose, an auditory and a haptic (force-feedback) interface are used. These two modalities have to be effectively combined and collaborate in such a way as to provide the players with a clear overview of the game space.

3.2.1 Visual Display

The graphical User Interface is a typical Pong style dynamic visualization, supporting configurability of all game-related bitmaps, such as paddle, background, score digits, ball, terrain split and direction indicators. Additionally, the split into auditory cells may be displayed, serving mainly evaluation and configuration purposes. The game scenery has been designed for projection on a large display, over the auditory grid, rather than to be played in front of a computer screen. This decision is aligned with our objective in delivering view fusion, where the visual display is augmented with localized audio. In this sense, some textual messages, such as those displayed by an automated computer opponent (a behavioral automaton actually), are displayed in small sized fonts (Figure 3-3), more appropriate for large projected display areas.
3.2.2 Auditory Display

In order to provide auditory navigational aids to players, an auditory planar media space structure is being constructed, approximately 2W x 1.5H meters, supporting spatially localized audio. The laboratory prototype version consists currently of a lattice of nine (9) loudspeakers, as a 3x3 grid, with distinct loudspeakers (Figure 3-5); the input devices for non-visual interaction, in particular a vibrating joystick and the Phantom™ device, are also shown. The eventual auditory display will encompass twenty four (24) auditory cells, arranged in four (4) rows, six (6) cells each, putting a loudspeaker per cell, thus resulting in an auditory media space with twenty four independent channels. The idea is that every distinct game object occupies at any point in time at least one primary auditory cell, associated with a distinct dynamic sound (Figure 3-4). The choice of the sound sample used to represent the pong ball is personalized, since it is to be heard continuously, requiring the user to concentrate on it to so as to effectively track the current ball position. Additionally, when the ball bounces on the terrain borders (top and bottom) a “wooden” sound is reproduced at the hit location, while, similarly, if the ball hits any of the two paddles, a “metallic” sound is reproduced. When the paddle reaches the upper or lower borders of the game area, a respective “collision” sound is reproduced, to indicate that the paddle cannot move more towards this direction. All such sounds are configurable via a configuration file according to individual user preferences.
3.2.2.1 Auditory Feedback Method

The default behavior is to activate three loudspeakers, each one with a different volume, to indicate the ball position and direction, following the technique illustrated in Figure 3-6.
More specifically, according to the current ball position the primary region is calculated as the one in which the ball entirely resides. Apart from the primary region, secondary regions are identified according to the ball direction vector. In this context, two secondary regions are distinguished: (a) $R_1$ is the one with which the $y$-component of the direction vector intersects; (b) $R_2$ is the cell which lies on the left or on the right of $R_1$ according to the direction of the ball. If the ball is directed to the right then $R_2$ lies on the right of $R_1$ and vice versa. The characterization of regions is adopted to identify the type of dynamic auditory feedback for the auditory cells close to the ball. The volume of each loudspeaker is proportional to the distance between the ball and the corresponding cell. As a result the volume of loudspeaker which corresponds to $R_1$ region is always greater than that of $R_2$ region.

### 3.3 Bimanual Interaction

Up to now, efforts were concentrated on the development of an accessible Pong game space exploiting merely spatial audio and vibration feedback effects. Although, several and sometimes severe design changes, concerning mainly the auditory environment, have been made so that visually impaired children to obtain a better mental image of the game, we can not ignore the fact that these players still encounter some difficulties in playing it effortlessly. This is probably because of the innovative setup, which is rather unusual to the vast majority of users and therefore it places some obstacles to them. Furthermore, it must be taken into consideration that we should study some additional methods in order to present the required information to users more efficiently.

The investigation of cross modal equivalence using two haptic devices is a many promising idea which may contribute to the achievement of our objective which is to
facilitate the interaction with the game for visually impaired children. However, little attention has been given in this topic and as a consequence the literature on this specific field is rather poor. For these reasons, the investigation ought to involve several steps and require sufficient answers to critical questions, otherwise it is likely to turn out to have more problems than it would have solved. Some of these research questions which will be fully explored in the later sections are: Which problems do we try to solve? Which pair of haptic devices should be chosen in order to cooperate complementary? Is it possible for a novice user to handle efficiently both devices? Do they raise any other problems? If so, how important are they and how can they be overcome? What role does each device play?

These devices should have discrete roles and serve two distinct purposes. It could be said that one device should have the primary role and the other an ancillary. In other words, the first one should provide more focused information about a specific element, such as a game object (paddle or ball) whilst the other one should present general information about the context of the game. An important issue is how a player can simultaneously manipulate and perceive information from two haptic devices. The most efficient approach seems to be the following: users handle the primary device with their dominant hand whereas the other device with their non-dominant hand. This implies that the game have to be evaluated against right-handed and left-handed users to ensure that both groups are able to interact equally with the specific haptic devices. In this context, two different interactions techniques are investigated in order to examine the impact of bimanual haptic interface upon blind or visually impaired players’ ability to interact with the game.

3.3.1 Previous Work

As it has already been said, only the last few years bimanual interaction techniques have extensively attracted the interest of the HCI community. It is indicative that the most interesting studies have been published the last three or four years. Most of the research efforts are focused on designing and implementing high quality scientific tools. CINCH (Akers, 2006) is a system for disentangle and analyze neural pathways estimated from magnetic resonance imaging data. This tool makes use of a pen (stylus) and a trackball allowing neuroscientists to navigate through 3D pathways efficiently. Moreover, DTLens (Forlines et al, 2005) is a tool for exploring large maps
and design diagrams on interactive tabletops which aims at mechanical engineers and geospatial experts. DTLens employs a multi-user and two-handed technique which enables group exploration of spatial data. Another example of bimanual interface is the symSpline tool (Latulipe et al, 2006). SymSpline introduces a technique for the manipulation of spline curves where two cursors (controlled by two mice) determine the positions of the ends of the tangent to an edit point. Peephole Displays (Yee, 2003) is another indicative investigation of bimanual interaction. Yee contributes to previous studies about spatially aware display (a position-tracked display which provides a window on a larger virtual space) and proposes a two-handed interaction technique combining pen input with spatially aware displays. This interaction technique is accommodated in handheld computers which have a reduced screen space for display and interaction. Several applications make use of this technique such as drawing program, map viewer and calendar.

Although there are several recent studies concerning bimanual interaction, it has not been thoroughly examined in the light of visually impaired users. In the context of a maze environment (Crossan et al, 2006), it is studied a bimanual interface which facilitates the navigation in the game space, exploiting a PHANTOM device and a VTPlayer tactile mouse.

### 3.3.2 Two-handed Interaction

This study’s aim is to ascertain in what extent two-handed interaction affects the way visually impaired experience the King Pong. We have investigated two different haptic interfaces: The first one includes a PHANTOM® Omni™ haptic device (from SensAble Technologies) and a force feedback controller (Logitech™ RumblePad 2), while the second one includes a Braille display and the above force feedback controller or the PHANTOM device. Evaluation conducted show that the players have a better experience of the game when using these interaction techniques. In particular, the assessment results of the first interface indicate a substantial improvement in the ability of players to locate the game objects successfully.

#### 3.3.2.1 First Bimanual Interface

The force feedback controller has been already used to provide hints about the position and the direction of user’s paddle. This was proved quite helpful to visually impaired players since they have an additional cue (apart from the auditory
environment) about the handling of the paddle. However, it would be pretty interesting to further extend this functionality to all game objects (practically to the ball) and investigate whether this has a major impact on the interaction of visually impaired players with the game. The rationale behind this idea is to guide visually impaired children through the game action and show how the game objects behave after certain events occur. This is a fundamental issue, especially for beginner players who are not familiarized with the game. In other words, it is a good way to introduce novice users to the game, demonstrating the rules of it. Moreover, it could act as a guide to the auditory environment and help players to be familiarized with it. For example, when the ball bounces against borders, a tactile effect and a sound reproduction occur simultaneously and in this way players can associate ball bounces with a specific sound from the auditory environment.

Figure 3-7: The Logitech controller (left) and the PHANTOM device (right) which are used for the first bimanual interface

This bimanual interface employs a PHANTOM device as well as a force feedback controller (see Figure 3-7). The latter is manipulated by the users’ dominant hand while the former by their non-dominant hand. The PHANTOM device which offers a high quality feedback, aims at indicating to players the orbit of the ball. This task is accomplished by rendering the trajectory of the ball in haptic information so that players have an additional cue about the position and the direction of the ball at any time. In addition, when the ball hits on the borders or paddles, a force feedback effect is produced to notify the user about this collision (see Figure 3-8). It should be mentioned that different types of effects are produced depending on the game object which collides with the ball so that users to be aware of the ball’s position. As far as the Logitech controller is concerned, it is used to provide hints about the ideal position of user’s paddle in order to hit the ball, about collisions of the user’s paddle with the borders of the game space and finally about successful hits of the ball by the user’s paddle. However, it must be noticed that the Logitech controller is designed to be handled with both hands and not with one as we are examining. This implies that
we have to investigate whether users face difficulties in handling the controller with only one hand (their dominant).

![Image](image.png)

**Figure 3-8: The haptic display**

Another thing that we have to study is if it is the same easy for right-handed and left-handed users to manipulate this bimanual interface. If a user is right-handed (as the majority of users are) then the paddle which handles should intuitively correspond to the right player of King Pong game. Otherwise, it would seem odd if a user manipulates the left player’s paddle with his right hand. Similarly, a left-handed user should handle the paddle which corresponds to the left player of King Pong game. So, it turns out that there must be a menu option from which a user can be able to select which his dominant hand is.

### 3.3.2.2 Second Bimanual Interface

Several speech messages are reproduced from the auditory environment to inform players about the progression of the game. These messages have an important role in the game and we cannot circumvent them easily. For instance, the announcement of score is necessary so that players can be able to follow the game flow. However, players are often seemed distracted by the use of those sounds and they often lose touch with the other hints provided by the auditory environment concerning mainly ball’s and paddle’s position. In the light of the above, we are examining an alternative way to provide players with all these messages, but not through the auditory environment which is already overloaded. The rationale behind this idea is to avoid “noise pollution” and minimizing as possible the players’ fatigue. It is a well-known
fact that the less sounds are used the easiest is for a player to concentrate on the game action and interact with it without encountering major obstacles (Cohen, 1991).

This bimanual interface employs a Braille display and a force feedback controller (Figure 3-9). Users handle the Braille display with their non-dominant hand whereas the force feedback controller with their dominant. All speech messages, including menu options, score announcements, computer opponent moods etc. are conveyed through the Braille display. In this way, the number of sounds which are reproduced by the auditory environment is substantially reduced and it is anticipated that the users will be benefited from this change. In addition, the first Braille cell of the display has a special purpose. It is used to guide visually impaired players to move their paddle to the correct direction (up / down) in order to hit the ball. There are three patterns indicating the direction to move in (Figure 3-10). Each pattern is represented by a group of raised pins. If the player should move his paddle upwards then the pattern illustrated in fig. 1(a) is displayed and similarly for the other direction. Once the paddle lies in the correct position then the third pattern is displayed (no raised pins).

The Logitech controller is used in the same way described in the previous section. Nevertheless, the PHANTOM can be used instead to provide cues for the manipulation of user’s paddle. This device appears to offer better feedback feeling than Logitech controller and for this reason it is preferred by users. Moreover, the
same rule about hand dominance applies also to this interface so the player must be able to choose if he is right or left-handed before the game starts. This does not affect the handling of Braille display, since visually impaired people do not seem to encounter difficulties in handling the Braille display with their non-dominant hand.

### 3.3.3 Evaluation

An evaluation was carried out to examine the performance of blind and low-vision users on the game after applying the above changes. This experiment was conducted in a quiet usability laboratory and nine (9) subjects who were all aged between 19 and 27 years old took part. Two of them were blind while the rest encountered severe visual impairments. Also, among the subjects was one left-handed user. Each subject was asked to play the game for five to ten minutes using varying settings (concerning speed of ball, volume of loudspeakers, etc.) that they considered better to suited to their needs. Moreover, the evaluation included two cases: one for each bimanual interface. It must be noticed that these participants had already tried to play King Pong so they were familiarized enough with it. The hypotheses which had been made before evaluation began are:

- Most of the subjects will manage to win the computerized opponent while the rest of them will be close to that achievement.
- Subjects will be able to determine the position and direction of all game objects at any time when they use the first bimanual interface. This will be tested by pausing the game action and asking the subjects.
- Subjects will experience a better performance of the auditory environment when they use the second bimanual interface. This will be determined by interviewing them at the end of the evaluation.
- Subjects will feel easy to interact with the bimanual interfaces.

Seven of the subjects succeeded in winning the opponent readily (in the first level of difficulty where the speed of the ball is low). Although, the other two did not achieve this goal they did not win for only two points. As a consequence it is allowed to say that the first hypothesis is supported. When the subjects were using the first bimanual interface, the evaluators frequently paused the game to ask them where they believe the game objects lie (at the bottom or at the top of game space, on the right or on the left of game space). The subjects answered correctly to almost all questions,
exploiting mainly the cues received from the PHANTOM. One thing that might have helped them is that all participants had tried the PHANTOM before and therefore they were familiarized with it. So it turns out that the second hypothesis is also supported. After evaluating the second bimanual interface, subjects were asked if they had noticed any improvement in the performance of the auditory environment. Three participants noticed substantial improvement; five participants commented that although this interface is helpful, they could manage to play the game without it; and one participant did not find this interface useful at all. Given that the majority of the subjects found this interface useful we can claim that the third hypothesis is also supported. Nevertheless, seven of the subjects complained about the handling of Logitech controller. As they explained they found quite difficult to handle the controller with only one hand. As a consequence the fourth hypothesis is rejected.

3.3.4 Discussion
This study has reported on the design of two bimanual interaction techniques which seem to have a quite positive impact on the players of King Pong game. In this context, we have investigated two two-handed interfaces which employ a PHANTOM device and a Logitech force feedback controller; and a Braille display and a Logitech controller respectively. Evaluation showed that users perceived a better mental image of the game and the interaction with it was facilitated. Particularly, the first bimanual interface helped users to better locate the game objects with the use of PHANTOM. However, the evaluation also revealed that users faced some difficulties in handling Logitech controller with only one hand so we have to rework a better solution which is to use a PHANTOM device instead. As a result, a further evaluation is needed in order to examine how effective this new concept is.

3.3.5 Guidelines
From this investigation, several guidelines can be drawn:

- Force feedback is suitable for providing supplementary cues through the non-dominant hand of users, when information is mainly conveyed by an auditory environment.

- The auditory environment should not be overloaded, since users appear to be distracted and confused. Information can be conveyed by other channels such as a Braille display.
• Visually impaired users do not seem to encounter difficulties in handling a Braille display with their non-dominant hand.

3.4 Additional Features

3.4.1 Low vision support
The rationale behind this design decision is that the game should adapt to users with different visual abilities. In particular, low vision players appear to benefit from enlarging game objects (i.e. ball and paddles) by a factor of 1.5. However, it is obvious that the game becomes less difficult, since it is easier for the player to hit the ball when his paddle occupies more space and for this reason the game may assume a tedious character. Furthermore, we have investigated the possibility to increase contrast between the background and the game objects in order to facilitate colour blind users to distinguish them. As it turns out after an evaluation, these two design decisions render Pong game more accessible to children with different levels of visual disability. Particularly, partially sighted children who participated in the evaluation played Pong game with the enlarged game objects. The results were quite encouraging as the subject could play the game without needing auditory or haptic cues while they familiarized themselves with the concept of the game much quicker compared to blind children. A more detailed description of this evaluation is reported in Chapter 5.

3.4.2 Motor-impaired support
King Pong is accessible to players suffering from mild or severe physical handicaps. Players can use two switches to control the paddle for up and down movement. Additionally, a player can play the game using only one switch in the following way. When he keeps the switch pressed the paddle is moving to the direction that the red arrow indicates (Figure 3-11). Once he releases the switch the paddle stops moving and the direction of the arrow is reversed. The next time he presses the switch the paddle will move in the opposite direction. It should be noted that a user can employ any kind of binary switch from the standard hand-controlled switch to sip/puff switches or switches controlled by thought alone.
3.4.3 Intelligent Opponent

When a user of King Pong plays against the computerized opponent, it should be determined how the opponent will behave. One trivial solution is to make him unbeatable, but this would be quite boring for players. An alternative solution is to add some elementary features of Artificial Intelligence to the computer opponent so as to make the simulation of the second player more realistic and the game play more spectacular. For this purpose, the computerized opponent may have one of the following moods: enthusiastic, bored, tired or angry. A FSM (Finite State Machine) controls the transition from one mood to another. The initial opponent’s mood (state) is “enthusiastic” and is altered according to the course of game play. Particularly, opponent is enthusiastic if the game is undecided, gets bored if he leads by greater than five points, feels tired when the game lasts a long time and gets angry if the other player leads by greater than three points.

Opponent’s mood affects the behavior of his paddle. For example, if the opponent is angry then he moves nervously his paddle and if he feels tired then the movements of his paddle are slightly delayed. As a result, the human player may influence the performance of the computerized opponent. When opponent’s mood is altered a respective speech message is reproduced to inform player about this change.

3.4.4 Two-player Game

The King Pong game allows for two-player games either by sharing the same computer locally or by competing remotely over network, as follows: (a) Local competition. The two players share the same computer, sitting in front of the grid (left
and right). Both players may use haptic interfaces, as far as there are two force feedback controllers available. (b) Remote competition. In this case, the input from one machine is transmitted to the other, while, due to the very low bandwidth and latency requirements, the game state is always identical during time.

3.4.5 Recording and Playback

The King Pong game is able to record and reproduce game sessions. When recording is enabled the characteristic sign flashes on and off indicating one of the two options is enabled a sign is appeared as illustrated in Figure 3-12.

![Figure 3-12: Recording and playback of game sessions as indicated by the respective signs in the upper right corner.](image)
4 Implementation

4.1 Implementation Details

King Pong has been fully implemented in C++ under Microsoft Visual Studio 2005 environment, using Microsoft DirectX technology, SDL (Simple Directmedia Layer) multimedia library and BASS audio library. SDL is a low-level, cross-platform, graphics and input library. It is used for rendering the graphics on the screen and getting data from the input devices supported by the game. BASS is a cross-platform 3D audio library and it is used for implementing the auditory interface. Additionally, Microsoft Speech API is used for synthesizing speech from the textual messages and objects that appear on the screen. Moreover, DirectInput (portion of DirectX) is used for controlling the force-feedback device. Currently, the game can be played only on a computer that runs Microsoft Windows. Finally, the 3D Touch™ SDK OpenHaptics™ toolkit is used to program the Omni PHANToM haptic device.

4.2 Recording and Playback

An essential part in the development cycle of an accessible game is the evaluation process. Evaluation may reveal significant interaction problems and in this case refinements and elaboration of the design is required. Additionally, evaluation should be conducted during the early stages of the development to detect any design imperfection, since in these stages modifications are relatively easy and inexpensive to make. Currently, the evaluation methods fall into two major categories: the empirical and the inspection methods. Empirical evaluation involves testing a game with real users whereas inspection evaluation requires that an expert tests the game and identifies potential problems.

Two innovative characteristics of King Pong, recording and playback of game play aim to facilitate the evaluation phase. Real users (visually impaired) play the game, while this is being recorded. Then, the game play is reproduced and evaluators can detect whether users faced difficulties playing King Pong. The weaknesses of the game, if any, should be reported to developers to make the appropriate changes in the
design. The contribution of this method to evaluation phase is that evaluators do not need to be present when the evaluation process takes place, but they can examine the results in a later time. More importantly, evaluators have the opportunity to determine how the visually impaired children respond to a different design of auditory and haptic interface and whether they obtain a better mental image of the game space. When King Pong operates in recording or playback mode, an indicative sign flashes in the right upper corner and a respective speech message is reproduced to inform player. It is worth noticing that an arbitrary number of game plays can be recorded and reproduced.

There are two main approaches to implementing these features. The first one is to capture absolute information (this means position, velocity, orientation, state, etc) about all game objects on a frame by frame basis. The reproduced sequence is then constructed by streaming this information back to the game engine. The second one is based on the observation that the same sequence of operations (player’s inputs) applied on the same set of data (game state), always produce the same result. This leads to the deduction that in order to reproduce a game play effectively, it is sufficient to store only the initial game state, along with the player’s inputs. At the playback phase, the game state can be restored and the sequence of saved player’s inputs applied to this game state. By this way, the replayed result is exactly the same as the original. Apparently, the second approach exhibits some advantages compared to the first one. Firstly, the size of the stored data is far smaller for the second method; secondly, from the development point of view, it is simpler to implement and maintain; and thirdly, this method appears to have some surprisingly interesting and beneficial side effects; these are a powerful tool for debugging and a basis for lightweight network support for the game.

Often, some bugs are occasional and it is quite difficult to be reproduced, as a consequence debugging is a really headache for the developers. For example, some bugs may occur under a specific sequence of player inputs, or after a certain amount of game play time. In this context, developers can exploit recording and playback operations for the debugging in the following manner. Testers should record the game play while testing the game and if they observe a bug (or an unexpected behaviour of the game), they will report it to developers. Developers, using the stored data can
easily reproduce the problem and fix it. The other side effect will be discussed in the following section.

4.3 Two-player Game

King Pong allows for two-player games either by sharing the same computer (locally) or over network (remotely).

4.3.1 Locally

Two-player game where the two players share the same computer is much like single-player game concerning the way of interactions. An important feature is that both players can make use of haptic interface, provided that there are available two force feedback controllers.

4.3.2 Remotely

Generally, it could be very hard to implement network support for a game. The straightforward solution is to run a local version of the game world on each machine and transmit locally generated data to other machine. The main difficulty is the latency of network which will result sooner or later in an event occurring in one machine that does not occur on another (well-known as de-synchronization effect). In order to address this problem, absolute game state data have to be transmitted from one machine to another at a fixed frequency. This implies a high cost of network resources, especially for a low bandwidth connection. As a consequence, a more lightweight solution which respects bandwidth capacity should be investigated.

As mentioned above, the record and playback operations give a foundation of a low bandwidth networking solution. Since it is obvious that the same sequence of inputs applied on the same game state, produces the same result then a more affordable solution is to transmit only players’ inputs from one machine to another. If two game engines start from the same game state and process the same flow of inputs, the game states will be identical during the time. Similar to recording, it does not need to transmit the absolute game state but only the players’ inputs. The advantages of this method are that it requires lower bandwidth; it is quite simple to be implemented and it reuses code (as game engine has already functions for processing network messages because of the similarity with the recording and playback operations).
4.4 Configurability

King Pong can be configured both by editing configuration files and through graphical menu. These two methods are complementary and are designed to be used in conjunction with users’ preferences and abilities.

4.4.1 Configuration Files

Amongst the configurable characteristics of the game are some that are considered advanced and for this reason it is expected to be modified only from expert users such as evaluators or tutors. In order to simplify and not burden the menu these characteristics can be modified only through configuration files. The most important advanced attributes are the sounds, the height and the width of the auditory grid and other related with recording and playback of game sessions. The statements in configuration files have the general form “attribute = value”, where attribute is the configurable characteristic and value can be either an arithmetic / boolean expression or a string. Evidently, modifications are relatively easy (for intermediate users) to be made because of this simple format. The configuration files have a “.conf” suffix and are located in the directory in which King Pong is installed.

4.4.2 Graphical Menu

Over the last decade, it has been made a great stride in providing accessibility in graphical user interface (GUI). One approach that has been proposed is to model the graphical interface in tree-structure which represents the graphical objects in the interface and the hierarchical relationships between those objects. Visually impaired people use this model to interact with the graphical menu of King Pong. This model works in the following manner: Users navigate the menu by changing their position in the interface structure tree using the selected input device (keyboard or joystick). Each movement (up, down, left right) positions the user at the corresponding object in the tree structure while he is informed about his current location through a speech cue.

Users have the capability to highly configure the game through the menu. Particularly, they can choose HRTF-based auditory interface instead of multi-channel, the difficulty level (concerning the speed of the ball), whether the game session will be recorded or not, the game type (circular pong instead of classic). In addition they can
select the playing mode (single-player, two-player locally or remotely and playback) and finally they can select different bitmap themes (aimed only at sighted users).
5 Evaluation

5.1 Summary

In this study, the usability and accessibility of King Pong is evaluated in a collaborative environment. The evaluation process encompasses two main phases. In the first phase, a group of HCI experts interacted with the game trying to detect common design flaws and proposed relative solutions in the context of a heuristic evaluation. This evaluation method is known as expert-based inspection and aim at eliminating the clumsy design errors in order not to frustrate the real subjects with them during user trials. In the second phase, four blind and partially sighted children invited to participate to a preliminary test. In addition, able-bodied children using screening techniques to simulate physical impairments collaborated with visually impaired to investigate whether the King Pong can effectively support game sessions between players with different disabilities.

5.2 Evaluation Strategy

The overall purpose of the evaluation was twofold: to evaluate the usability and accessibility of menus and to assess how effectively information is conveyed to disabled people comparing also the different bimanual interfaces. In particular, subjects were asked to navigate through menus following specific scenarios (or tasks). As far as the second goal is concerned, the thinking aloud (, 1993) approach was chosen as the most appropriate for evaluating a game. According to this approach, one evaluator was observing the players interacting with the game while he asked them for vocalization of their thoughts and feelings about the gameplay experience. This test revealed if players had obtained a correct mental image of the game space and how confident they had been about playing it effortlessly. More importantly, this method enabled designers to identify players’ major misconceptions.
5.2.1 Participants

One blind and three partially blind children took part in the evaluation while they were also separated into two groups. The age of the children was ranged between 12 and 14 year old while they had not any additional disability. Furthermore, all children were frequent computer users whereas they had limited experience in PHANTOM haptic device. The subjects’ characteristics are summarized in the following table.

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sight</td>
<td>Blind</td>
<td>Low vision</td>
</tr>
<tr>
<td>Age</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Gender</td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td>Relationship</td>
<td>Schoolmates</td>
<td>Schoolmates</td>
</tr>
<tr>
<td>Other disability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand dominance</td>
<td>Right-handed</td>
<td>Right-handed</td>
</tr>
<tr>
<td>Previous experience of Phantom device</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Computer use</td>
<td>frequently</td>
<td>frequently</td>
</tr>
</tbody>
</table>

Table 5-1: Subjects’ characteristics

5.2.2 Context

During the first two weeks of June 2007 (1 - 15) an experimental evaluation conducted by FORTH examining the usability and accessibility level of King Pong. The evaluation took place during the afternoon hours after school. The system installed at the usability evaluation laboratory of FORTH equipped with all necessary apparatus (computers, recording equipment, etc.). The King Pong set up comprised of a computer with keyboard and mouse, a 17” LCD display, the auditory grid, an Omni PHANTOM device and a vibration controller (Logitech gamepad). At the time of assessment only the evaluators and the subjects were present in the evaluation laboratory. Moreover, the partially sighted children wore blindfolds when a task required not to use their vision.

5.2.3 Procedure and Tasks

Firstly, HCI experts tried to create a friendly atmosphere so that children not to hesitate to ask any question or get embarrassed if they did not manage to complete a task. Subsequently, they gave a brief description of the Pong game and of its rules to children; although the children urged that they were already aware of them. After that,
the children were asked to fill in a questionnaire about their computer use in order that evaluators could determine children’s familiarization with computers and haptic or game devices. The results of this survey indicated that all subjects were frequent computer users, but novice computer game players. Furthermore, the survey also unveiled that the children had limited experience in game controllers and haptic devices. In particular, they stated that they had never used any kind of game controller like joystick, gamepad, etc. Additionally, the blind child reported that he had used the PHANTOM device only twice in the past while the other three did not have any experience at all. For that reason, the evaluators decided to introduce a training session before evaluation started so that children got familiarized with the gamepad and PHANTOM device. It was decided that the “Frictionless Sphere”, “Frictionless Plane” and “Hello Sphere” examples from Sensable were the most suitable demos to train children handling the PHANTOM device. This training session lasted about half an hour for all children while at the end they were pretty excited with the capabilities of this device as they stressed the quality of feedback they perceived. Afterwards, another training session followed which lasted only few minutes concerning the vibration game controller. In that session, evaluators explained how the gamepad works and how it should be held as well as they show some demonstrating the vibration of it.

The first phase of the evaluation was dedicated to the assessment of usability and accessibility of menus. To that end, the children were asked to complete the following tasks:

- Enlarge the size of game objects (ball and paddles) selecting the “X-Large” option through menu.
- Select a two-player game.
- Select your dominant hand.
- Quit game.

In the second phase of the evaluation, the objective was to assess how effectively information is perceived by disabled people testing also the different bimanual interfaces. The first bimanual interface consists of a PHANTOM device and a vibration controller while the second one includes a Braille Display and a vibration controller. These two interactions have been reported in section 3.3. In the beginning
of the evaluation in order that children got familiarized with the innovative set up, they were provided some hints about the direction that should move the paddle. These hints were conveyed through force feedback effects and speech messages. Once evaluators deemed that children were confident enough to play the game, the main evaluation began which comprised of two parts. In the first part, each child interacted with King Pong using the two bimanual interfaces. As reported in a previous section, the four children were separated into two groups. One group played the game using the first bimanual interface and the second one afterwards while the other group employed the interfaces in the reverse order. The rationale behind this arrangement is that evaluators wanted to investigate the impact of each interface without introducing bias. In the second part, children played two-player games as opposed to the first part in which they played against the computer opponent. In this part, evaluators assessed the ability of King Pong to offer enjoyable two-player sessions between people with different disabilities, as for instance between visually and motor impaired children. Additionally, the evaluators paused the game and asked the subjects frequently about the position (upper right, upper left, lower right, lower left) of game objects in order to assure that their mental model of game space matched the real one. Finally, after the end of evaluation, subjects were asked to fill in an overall satisfaction questionnaire.

5.2.4 Interviews
After the interaction with King Pong, evaluators interviewed children to determine their satisfaction from the game. The interview was based on as well as on the IBM Computer Usability Satisfaction Questionnaires. Two evaluators took part in the interview: the first one conducted the interview while the second one was taking notes of children’s answers and comments. Evaluators tried to conduct the interview in the context of a friendly discussion. The following questions were asked to the subjects:

- Did you find the game enjoyable? Do you want to play it again?
- What did you like most about the game?
- What did you like least about the game?
- Was there anything that you did not understand?
• Did you find difficult to use the haptic devices? Did they help you to interact with the game?

• Did you find the bimanual interaction helpful? Did you obtain a more clear mental image of the game?

• Did the auditory environment of King Pong help you to locate the position and direction of game objects?

• How much time did you need to familiarize yourself with the concept of the game?

• Did the reproducible game sessions help you to familiarize yourself with the auditory and haptic display of the game?

• Is there any feature that you would like to see in the game?

• Were the two-player games more enjoyable than the single-player?

• Did you manage to cooperate with your partner effectively?

5.2.5 Measurements

The overall evaluation process was recorded by the recording equipment of the evaluation laboratory. Additionally, one evaluator was responsible for taking photographs, trying not to distract the children.

The King Pong has a built-in functionality which allows for logging of game sessions and reproduction of them. All game sessions during the evaluation were logged so that evaluators could have the opportunity to analyze and investigate them at a later time.

5.3 Results

5.3.1 General Usability

The subjects did not experience any major difficulty during the evaluation, given that the concept of the interaction was totally new to them and especially the haptic devices and the auditory environment. In fact, they seemed to need some time in order to get used these novel features of the game. Nonetheless, the blind child faced greater difficulties in the beginning of the evaluation since he did not feel comfortable using the bimanual interfaces and appeared confused from the information he perceived. More importantly, he complained that he could not handle both devices
simultaneously. Similarly, the other children also pointed out that it was tired to manipulate both devices. After these comments, evaluators rearranged the equipment so that PHANTOM device was closer to children. In addition, the subjects complained that it is not comfortable to handle the vibration gamepad with only one hand. For this reason, evaluators placed the gamepad on a stand to facilitate players to interact with this device. Children responded positively to these two changes as they were much more confident of playing the King Pong after these modifications.

As reported in section 5.2.3, the children formed two groups to evaluate the two different bimanual interfaces. The test revealed that the bimanual interface consisting of the PHANTOM device and the vibration gamepad, provides players with more valuable information than the other bimanual interface. Particularly, the group of children which used this interface first appeared to be more effective in playing the game and locating the position of game objects. This is mostly attributed to the high quality of feedback that PHANTOM device delivers. In contrast, the group of players which used the interface comprised of a Braille display and the vibration gamepad, did not manage to complete the tasks as effectively as their peers of the first group. Moreover, the game was evaluated against the left-handed child to ensure that both right-handed and left-handed players are able to interact equally with the specific haptic devices.

The three partially sighted children found quite helpful the option “x-large” that the game offers. Using this option the game objects or sprites (ball and paddles) are displayed enlarged by a factor of 1.5. This game feature allowed children to use their partial vision to familiarize themselves with the game elements very quickly. Indicative is the fact that the partially sighted children were much more confident after several minutes of interacting with the game, as opposed to the blind child. Afterwards, these children were asked to play the game without using their partial vision so that evaluators could ascertain the impact of exploiting the visual modality. The results of this test indicated that children were able to play the game without facing problems. This implies that King Pong does require a short time for training.

An important aspect of King Pong is the recording and playback functions which were proved to be very helpful for children. These features allow for recording a game session and in a later time to precisely reproduce it. It must be noticed that during a reproduction of a game session the auditory environment and the haptic
devices are. The children were impressed when they could feel the movements of the paddle that they had done some minutes before. In particular, they understood the wrong decisions about that they move and this was a significant boost to the training phase of King Pong.

King Pong offers an intelligent computer opponent in order to arouse the interest of players for the game. The intelligent opponent changes its behavior according to the progress of the game and thus it acts as a stimulus for players to explore new characteristics of the computer opponent. The subjects asked about this feature since they had not understood this concept in the first place. Moreover, they became more and more excited about this feature and they attempted to make the computer opponent angry trying to win him a number of consecutive times.

As far as the stability of the game is concerned, users did not experience any unexpected event or crash.

5.3.2 Exploration and Navigation
The exploration of the game space of King Pong was quite well after an initial training session. During the assessment, the evaluators were pausing the game frequently to ask the subjects about the position and direction of the paddle and ball. As the children’s experience was getting longer, the wrong answers to these questions were lessening.

Moreover, the evaluation was also concentrated on the usability of menu options. In this task, the children managed to navigate through the menus without problems. More importantly, the partially sighted subjects were asked not to use their vision since evaluators deemed that this task was rather easy to be accomplished.

5.3.3 Learnability
The results of the evaluation indicated that the King Pong has a quite fast learning curve. This means that the children get familiarized with the game gradually. In the beginning, children experienced several difficulties in locating the position and direction of the ball and mainly the position of the paddle that they controlled. However, the majority of the children appeared to be confident of playing the game fairly quickly. This happened for mainly two reasons: First, due to sophisticated haptic devices that are used, it took children some time to get familiarized with them.
Nevertheless, once children got used to these device, they seemed to perceive a quite clear mental image of the game. Second, the inexperience of the children in computer games may account for these difficulties that children faced in the beginning.

5.3.4 Assistance
Evaluators were continuously helping the children during the experiment. The subjects were frequently asking for confirmation and reminding of the tasks that they had to complete. In particular, the blind child appeared to feel more the need to ask for help. Additionally, three children asked about the role of PHANTOM device and what kind of information they were supposed to perceive from this device. However, as the children were getting familiarized with the game, the number of questions was gradually reduced. More importantly, the children assist each other in two-player games. For instance, the first player in which direction should move the paddle.

5.3.5 Ability to Complete the Task
All children managed to complete all the tasks which were assigned to them. However, the blind children proved to have several difficulties at the beginning of the testing but after some minutes he understood the concept of the game.

5.3.6 Evaluation Issues of Co-operation
In the second part of the evaluation, the evaluators organized two-player game sessions. In this part, the visually impaired children played against each other while able-bodied players using screening techniques to simulate physical impairments and more specifically the absence of the upper limbs played against the partially sighted children. The aim of this test is to investigate if impaired users, even with different types of disabilities, can cooperate effectively and effortlessly in the context of a two-player King Pong game.

Having the experience of single-player games, all subjects did not face any noteworthy difficulty. Interesting was, though, the fact that visually impaired players were prompting each other to which direction to move the paddle that they controlled in order to hit the ball. Furthermore, the evaluators noticed that the children enjoyed more the game when played against each other rather than against the computer opponent. Finally, the visually impaired children played against subjects simulating
physical impairments. This test indicated that King Pong can potentially accommodate two-player games between motor impaired and visually impaired players.

5.4 Discussion and Conclusions

In this study, the King Pong game has been tested in a collaborative environment. The participants of the evaluation were four visually impaired children aged between 12 and 14 years old. The user-based evaluation included two main phases. In the first one the children played against the computerized opponent. This phase was considered to introduce the participants to the novel concept of King Pong game. The second phase emphasized the collaborative aspect of the game. For this reason the children were asked to form two groups and played two-player games so that evaluators were able to investigate the collaborative potential of the game.

In the beginning, the participants made several complaints about the ergonomics and faced some difficulties in understanding the set-up of the game and the information that they were supposed to perceive from the auditory display. This can be partially attributed to the fact that all children had limited experience in haptic devices. The evaluators responded to these notes by changing the arrangement of the devices while trying also to explain them the overall concept of the game. However, after this initial training session, the children were able to interact with the game having only minor difficulties. More importantly, in two-player games the evaluators observed that the children enjoyed the game and the collaboration between them was quite effective.

As it turns out, some further investigation should be conducted into facilitating the familiarization of novice players with the game. For instance, an effective way to boost this process would be to add a built-in training session intended to beginners in which novice users will familiarize themselves with the auditory environment and the haptic devices.
6 Conclusion

6.1 Summary

The main objective of this thesis has been the design and implementation of a novel accessible game exposing certain features dedicated to meet the needs of disabled people. The key design goal was to create an accessible game which fosters collaboration between diverse user groups. The King Pong is able to offer two-player games fulfilling this objective. It must be stressed that King Pong can be easily configured to allow users with different disabilities (such as blind and motor impaired) to play against each other. This feature is of paramount importance since disabled people often experience a sense of alienation and social exclusion. Using this option, disabled children have the opportunity to socialize and interact with their able-bodied peers. Moreover, due to the great significance of computer games in the sharpening of kinesthetic skills, King Pong may act as a platform for cultivating certain abilities of impaired children.

In particular, this work conducted a thorough review of the current status in the field of game accessibility which is still in a state of flux. The most important initiatives were presented while several typical examples of well-designed accessible games were described. Moreover, all accessible PONG games were listed, stressing their shortcomings and design flaws.

In this context, an innovative game space has been investigated aiming to deliver an enhanced game play experience to both disabled and able-bodied players. This is achieved by creating a pioneering triple game space comprising of a visual, an auditory and a haptic display. These different modalities have been carefully combined so that players not to feel overloaded from the information perceived from many sources. The auditory display consists of a grid of loudspeakers supporting spatially localized audio while the haptic display makes use of several haptic devices of high quality targeted mainly to visually impaired players. A lot of auxiliary features are incorporated into the core design of the game such as recording and playback functions, and an intelligent opponent. Moreover, a substantial effort was devoted to
the investigation of bimanual interaction techniques. Two bimanual interfaces were examined which employ a variety of haptic devices, while players seem to benefit from this type of interaction as the evaluation revealed.

In order to assess the usability and accessibility of King Pong, a formal evaluation session was organized in a collaborative environment in the usability laboratory of FORTH. The results were quite encouraging and promising since the subjects appeared confident of playing the game effortlessly. Nevertheless, the participants experience a lot of difficulties at the beginning of the testing and evaluators attributed this fact to the innovative characteristics of King Pong game space. It is indicative that the majority of the participants had never used before haptic devices. Furthermore, the evaluation indicated that the participants needed some time to familiarize themselves with the auditory environment. However, once they the players were able to interact with the game without facing difficulties. Finally, interesting was the fact that visually impaired enjoyed two-player games and the collaboration between them was very effective.

6.2 Future Work

Future work should target on the utilization and support of more haptic devices such the VTPlayer device. The VTPlayer is a tactile mouse equipped with two Braille cells. The idea is that King Pong should offer a variety of so that players have the opportunity to select the device that fits to their personal needs and preferences. Moreover, it is necessary to conduct a more thorough and rigorous evaluation in order to detect other design errors. In this evaluation, a greater number of visually impaired subjects should participate having also additional disabilities such as physical impairments.
Appendix A

7.1 Technical Requirements

The hardware requirements for the King Pong include:

- Processor: Pentium or higher
- RAM: 128 MB
- Video Card: DirectX 9 compatible;
- Sound Card: DirectSound compatible audio hardware
- Pair of headphones or 24 loudspeakers to form an auditory grid.
- Optionally: vibration controller, Omni PHANTOM device, Braille display, switches.

For the HRTF based audio, any DirectSound® compatible sound card is suitable. For the multi-channel version a 24 output channels sound card is required (or alternatively two or more sound cards installed, i.e. 3 x 8-channel sound cards).

7.2 Installation

To install the game in Microsoft Windows XP, launch the setup program (king-pong.exe) and follow its instructions. Note that the game does not require administrator privileges neither to install, nor to run. After the game is installed, it will create a new entry entitled “King Pong” in the windows Start menu and, optionally, a desktop icon. To run the game, either select it from the Windows Start menu, or double click on the desktop icon (if it was created).

7.3 Playing the Game

7.3.1 Selecting Mode

When King Pong starts, the Mode Selection Menu (see Figure 7-1) fades in from which you can select the mode for the current game session.
King Pong offers the following modes:

- **Basic**: a single-player game where the second paddle is controlled by the computer.

<table>
<thead>
<tr>
<th>Player</th>
<th>Move Up</th>
<th>Move Down</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UP ARROW</td>
<td>DOWN ARROW</td>
</tr>
</tbody>
</table>

- **Two Players**: a two-player game where the opponents share the same computer.

<table>
<thead>
<tr>
<th>Player 2</th>
<th>Move Up</th>
<th>Move Down</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>z</td>
</tr>
</tbody>
</table>

- **Network Game**: a two-player game where the opponents play through network.

- **Playback**: a reproduction of a previous recorded game session, suitable for conducting evaluation.

You can select a mode using anyone of the following methods:

- **Keyboard**: use the “UP/DOWN” arrow keys to browse the menu options and the “SPACE” key to select.
- **Joystick**: use the vertical axis (up/down) of the joystick to browse the menu options and the right trigger button to select.

### 7.3.2 Main Menu

After selecting a mode, the game’s Main Menu (Figure 7-2) appears. This menu can be used similarly to the Mode Selection Menu.

![Main Menu Image](image)

**Figure 7-2: Main Menu**

The Main Menu offers the following options:

- **New Game**: starts a new game using the currently active mode.

- **Options**: contains the following (see also section *Error! Reference source not found.*):
  
  - **Interface**: select the haptic interface with which the player will interact.
  
  - **Audio Environment**: select the available auditory environment.
  
  - **Visibility Selections**: select the appropriate display configuration.
  
  - **Dominant Hand**: select player’s dominant hand.
  
  - **Record Session**: record the following game session.
  
  - **Back**: return to the Main Menu.
  
  - **Select Mode**: go back to the Select Mode Menu (see also section 7.3.1).
  
  - **Quit**: exit *King Pong.*
7.3.3 Options Menu

After selecting “Options” from the Main Menu, the game’s Options Menu (Figure 7-3) appears. This menu can be used similarly to the Mode Selection Menu.

The Options Menu (as it is already mentioned above) offers the following options:

- **Interface**: the player can choose one of the following interfaces according to the available hardware:
  - **Basic**: this is the default interface and includes a keyboard or a joystick (with or without vibration).
  - **PHANTOM**: this is a bimanual interface where FF aims at providing hints about the ideal position of user’s paddle in order to hit the ball and PHANTOM aims at indicating to player the course of the ball.
  - **Braille Display**: this is another bimanual interface where Braille display is used to convey all speech messages, including menu options, score announcements etc. The FF controller is used in the same way as in the previous interface.
  - **Single Switch**: this interface encompasses only one switch (indented to motor-impaired players).

- **Audio Environment**: the player can choose one of the following auditory interfaces according to the available hardware:
  - **Spatial**: a 24-loudspeaker auditory grid is used.
- **HRTF**: a pair of headphones is used.

- **Visibility Selections**: the player can choose one of the following display configurations.
  - **Default**: Use of normal-sized sprites.
  - **High Contrast**: Use of high contrast sprites on low contrast background.
  - **X-Large**: Use of enlarged sprites to facilitate partially sighted people.

- **Dominant Hand**: the player can select which his dominant hand is. This affects which paddle the player controls (a right-handed should control the right paddle and vice versa)
  - **Right-Handed**: the player will control the right paddle.
  - **Left-Handed**: the player will control the left paddle.

- **Record Session**: select whether the game session will be recorded or not. This function is used in conjunction with the playback operation in the Select Mode Menu. Note that *King Pong* supports an arbitrary number of recorded sessions.

### 7.3.4 In-game Menu

While playing, you can activate the In-game Menu (Figure 7-4) through which you can do the following:

- **Continue**: return to the game and continue playing.
• **Restart:** restart the current game.

• **Abort:** end the current game and return to the Main Menu.

The In-game Menu can be activated by pressing the “Esc” key.

### 7.3.5 Other Configuration Settings

<table>
<thead>
<tr>
<th>Key Functions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set invisible sprites</td>
<td>‘v’</td>
</tr>
<tr>
<td>Toggle fullscreen/window mode</td>
<td>F11</td>
</tr>
<tr>
<td>Increase ball speed</td>
<td>‘.’ (dot)</td>
</tr>
<tr>
<td>Decrease ball speed</td>
<td>‘,’ (comma)</td>
</tr>
</tbody>
</table>
8 References


- Game Accessibility, http://www.game-accessibility.com/


