

**INTERGENERATIONAL PHYSICAL AND
CULTURAL PLAY SYSTEMS**

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B.Eng.(Hons), NUS

A THESIS SUBMITTED

FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

**DEPARTMENT OF ELECTRICAL AND COMPUTER
ENGINEERING**

NATIONAL UNIVERSITY OF SINGAPORE

2011

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This thesis is dedicated in loving memory to my late brother, Eng How.
His kind words gave me strength and calmness to overcome the challenges
in life.

“Just try your best, things will turn out fine.”

Acknowledgements

It is a pleasure to thank many people who made this thesis possible. I express appreciation to them all, even if not individually named below. I owe the most gratitude to my thesis supervisor, Dr. Adrian David Cheok, whom I respect as a wonderful mentor. I would like to thank him for never failed to believe that I could complete this journey. I started this research journey with limited knowledge about human computer interaction. He has opened my mind to remarkable scholarship and inspired me with his deep wisdom, insight and vision in this domain. I admire his highly driven personality and never say die spirit. Under his mentorship, I have learnt to tackle challenging problems and keep striving for the best. Dr. Cheok consistently gives his full support for my research, from technical advice and evaluation of this research, financial and resources allocation, to his patient assistance with editing and proofreading my thesis. Once, there was some delay in the administrative procedure for purchases pertaining to building my research prototype. Without hesitance, he offered and made the hefty

upfront payment using his personal money in order to expedite the ordering process, which helped me to complete my prototype sooner. Again, I would like to thank Dr. Cheok for the continuous support and encouragement, without which I would not have been able to complete this PhD thesis.

I am grateful to my PhD thesis committee members, Dr. Ryohei Nakatsu and Dr. Henry Been-Lirn Duh. They have provided timely guidance and insight for my research. Despite busy schedule, they took time to review my progress and provide critical feedback, which greatly improved the quality of my research. Their willingness to share in-depth experience in research has allowed me to learn many concepts and knowledge quickly.

I would like to acknowledge the collaborators for this research. I am grateful to Shang Ping Lee and Charith Fernando for their contribution in the initial stage of the prototype development for physical play system. I am in debt to all the collaborators for the cultural play research. They are Courtney Rong Fu from NUS East Asian Institute, Assoc. Prof. Yuet Keung Lo from NUS Department of Chinese Studies, and the other graduate and undergraduate students which they have recommended. I would also like to thank Xuan Wang and Jun Wei for their participation to improve the Confucius Chat prototype. I wish to thank the former undergraduate students that I have worked with, Yingdan You, Qing Long, Xiaoming Hu, Aung Aung Kyaw, Wei Min Teo, Vira Saksen, Mervyn Weiwen Lian, Kelvin Soon Keat Yeo, Yu Zhou and Ginn Shyong Toh for their contribution. I

would like to especially thank Yingdan You for her help in the formatting of this thesis.

It is my pleasure to thank Asst. Prof. Natalie Pang from Nanyang Technological University, for her advice and invaluable feedback on various aspects of the user studies in this thesis. Thank you for your encouragement and belief in my work. I would also like to extend my gratitude to Tim Merritt, Chengyi Liu, and Sharon Chu for their discussions in the design of user studies. I would like to show my gratitude to all the facilitators of the studies. I am also grateful to the individuals and families who have participated in the user studies in this thesis.

I would like to thank my parents and brothers for their endless love, patience, laughter and warmth, which have given me enormous strength to overcome the challenges in order to complete this journey. Last but not least, I could not express more gratitude toward the most important person, my wife, Xi Min, who has completed this journey with me. Her beautiful smiles ease the most frustrating and difficult period. Thank you for your faithful companionship in this winding journey.

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Summary

Due to global aging population, issues of family intergenerational communication are becoming increasingly important. Play has many proven benefits for intergenerational communication. However, prior literature and our own initial survey with Singaporean grandparents, parents and children reviewed that there are currently limited digital play and entertainment systems that are designed for their simultaneous consumption, despite their eagerness to participate in those activities together. While children are brought up with new technologies for communication and entertainment, grandparent, parent and children interaction is often limited to traditional media. This research aims to design and engineer novel interactive play systems that would facilitate intergenerational communication. Multiple-case study methodology is adopted. Two cases of intergenerational play, physical play and cultural play were designed and studied in this dissertation. Design-oriented research approach was employed in this research, to develop the research prototypes, while involving the intergenerational users through-

out the design process. The research prototypes were carefully engineered to meet the requirements of the users. In depth user studies and experiments were carried out to identify and validate usability and interaction issues and to uncover possible design principles. There are three research contributions in this dissertation: novel design and engineering of a physical play system, which allows grandparents, parents and children to simultaneously engage in games using their full body movements, and through a virtual game world; novel design and engineering of a cultural play system which allows parents and children to explore cultural values through a virtual chat agent, modeled after Confucius knowledge and teachings; uncover design principles from user studies of the two systems developed, to inform future researchers interested in designing better media experiences for an intergenerational audience.

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Chapter 1

Introduction

This chapter outlined the exploratory domain and the problem statement for this dissertation. The contributions to knowledge in this research is then elaborated. Subsequently, the motivation to design intergenerational physical and cultural play systems to promote communication between grandparents, parents and children is presented.

1.1 The exploratory domain and problem statement

Due to a global aging population, issues of family intergenerational communication are becoming increasingly relevant [32]. Communication can be defined as “a symbolic, transactional process, or to put it more simply, as the process of creating and sharing meanings” [28]. The symbols in communication can come in a variety of forms such as verbal behavior, or words, and nonverbal behavior through facial expressions, eye contact, gesture,

movement, body posture, appearance, and spatial distance [28]. In this dissertation, intergenerational communication is viewed as an activity that enables interaction or exchange of verbal and nonverbal symbols between any two generations, involving sharing of skills, knowledge or experience between the grandparents or parents, and children.

Play has many proven benefits for intergenerational communication, evident in prior studies. However, there is limited research which examines play between grandparents, parents and children, let alone interactive play systems that facilitate intergenerational communication. Prior literature and our own initial survey with Singaporean grandparents, parents and children reviewed that there are currently limited digital play and entertainment systems which are designed for their simultaneous consumption, despite their eagerness to participate in those activities together.

The research question of this dissertation is, “How do we design novel interactive physical and cultural play systems that facilitate intergenerational communication”. This research adopts a multiple-case study methodology to investigate the research question. Two cases of intergenerational play: physical play and cultural play were explored in this dissertation. Physical play is defined as engaging in a play activity which involves motor skills, while cultural play is defined as engaging in a play activity which allows the user to experience the core aspects of his or her culture. Design-oriented Research approach was employed in this research, to develop the research

prototypes, while involving the intergenerational users throughout the design process. The research prototypes were carefully engineered to meet the requirements of the users. In depths user studies and experiment were carried out to identify and validate usability and interaction issues. In the process of answering the research question, we aim to uncover possible design principles to adhere to for future researchers interested in designing better media experiences for an intergenerational audience.

1.2 Research Contribution

This dissertation has three contributions to knowledge.

I. Novel design and engineering of physical play system

A novel floor based physical play system that could be used simultaneously by the grandparents or parents and children, who have varied levels of familiarity in utilizing technology and varied level of physical abilities, was designed and engineered to meet the requirement of the users. The system allows users to use their full body movements to play the games. The design and engineering process of the physical play system would provide insights for engineering and human computer interaction researchers interested in intergenerational play.

II. Novel design and engineering of cultural play system

A novel cultural play system that could be used simultaneously by the

grandparents or parents and children, who have varied levels of familiarity in utilizing technology and varied level of understanding of cultural values, was designed and engineered to meet the requirement of the users. The system allows users to engage in cultural exploration through an interactive social network chat with a virtual chat agent, modeled after an Eastern historical figure. The design and engineering process of the cultural play system would provide insights for engineering and human computer interaction researchers interested in intergenerational play.

III. Design principles to design better media experience for intergenerational users

This research adopts a multi-case study approach to explore the research domain and uses the grounded theory to analyse the data. In the physical play case, an additional experiment design was carried out to further enhance the results. From the user studies, design principles to adhere to for future researchers interested in designing better media experiences for intergenerational users, were uncovered.

1.3 Motivation

Due to global aging population, issues of family intergenerational communication are becoming increasingly relevant [32]. Family is important in developing one's self-concept and its influence endures for a lifetime [112]. Grand-

parents play a vital role in a family, and the emotional attachments between grandparents and grandchildren are unique [53]. Furthermore, people with more positive grandparent-grandchild relationships tend to have more positive attitudes toward older people [87] [89]. In addition, in Singapore context, most of the elderly stay under one roof with their grandchildren [72], which provide plenty of opportunity for intergenerational communication.

There is great deal known about children's play [37] [100]. However there is limited research which examines play between grandparents, parents and children, let alone interactive systems that facilitate intergenerational communication. While grandchildren are brought up with new technologies for communication and entertainment [115], grandparent-grandchild interaction frequently occurs through traditional media [43]. According to the recent survey results in Japan, there is a high percentage of elderly who own and play electronic or computer games, but rarely do they play the games with their children or grandchildren [111]. For example, the Brain Age games on Nintendo DS have gained huge popularity among older Japanese people [26]. The older players believe that such games can sharpen their thinking and they enjoy playing the games. However, the games are mostly designed to be played individually, which limits social interaction. In our own research with Singapore's elderly and children, we observed that there is a significant gap between the two age groups in the way they use electronic games. The children are the active users of electronic games, while the el-

derly has limited or no participation at all. However, the elderly mentioned that they are eager to engage in computer-related games which are designed for them to use together with their grandchildren, if they are available.

Prior studies have revealed that intergenerational-interactions are mostly positive in nature and they are beneficial for the parties involved [54] [70]. In Newman and Ward's [70] study of interactions between young children and older adults with dementia, they found that the adults consistently displayed many positive behaviours (extending hands, touching and holding hands) when the children were present which they did not tend to display when the children were not present. In Kuehne's [54] study of intergenerational interactions over 9 weeks, he recorded 462 instances of positive intergenerational interactions versus 14 instances of negative intergenerational interactions. Bulks of the positive interactions observed are giving affection, complimenting and playing behavior.

Recent research on intergenerational communication across cultures has indicated that people in Asian nations construed older family and non-family members as less accommodating than did people in Western nations [31]. It is possible that the lack of understanding of the grandparents' culture, for example the ethic of filial piety, makes salient age-group identities and, thereby, triggers intergroup processes [11]. In support of this argument, studies have also shown that strong traditional Confucian norms, such as filial piety and elders' contribution to family harmony, have

resulted in youths having more positive images of old age, closer psychological proximity and thus more respectful communication with older adults in the East [30] [57] [71].

Furthermore, findings from scientific research studies show that playing video games can lead to changes in an individual's pleasure, arousal, dominance, and/or affiliative behavior [14] [61] [109]. Research has also shown that older people enjoy computer gaming experiences [110]. Furthermore, in *Digital Games for the Elderly*, IJsselsteijn et al. [47] argue that besides being used for therapeutic means, digital games also offer the benefit of connecting different age groups while playing, especially grandparents and grandchildren. Similarly, Tarling [97] claims that being able to play with grandchildren is an important incentive for seniors to play a computer game.

Play is an established area of research with many different established theories of play [40] [62] [105]. These various theories of play have identified many ways in which play may advance the cognitive, social and emotional development of children. Based on his observations of the types of play which animals engage in as well as the assumption that play is unique to childhood, Groos [40] argued that play develops children's physical and mental capacities that will serve them as adults. Lazarus [100] argued that play is used to restore energy that we use in work, while engaging our interest at the same time. Mead [62] viewed children's role play as a way for them to develop their sense of self as well as allow them a way to explore

roles and rules of functioning in adult society. From a sociocultural perspective, Vygotsky [105] deemed play as important because it helps to create a broad zone of proximal development for cognitive and socio-emotional development.

However, there is limited research that takes advantage of opportunities for fun and leisure as a mean to facilitate intergenerational communication. Vetere et al [102] observed that intergeneration play is highly phatic in nature. Phatic exchanges are interactions do not specifically aim to exchange facts or information, but act to strengthen their social bonds [29]. The shared activity was an opportunity to pass time together and build rapport. Similarly, IJsselsteijn et al [47] feels that there are significant design opportunities in the area of gaming as a social activity for elderly users. They feel that games can provide topics of conversation and/or be a common activity that can serve as a way of decreasing social distance. They also feel that digital games may also be able to bring grandparents and grandchildren together. Furthermore, there have been encouraging results on the use of modern communication technology in bridging intergenerational gap, such as the use of video blogs for the old people to communicate with the young people [38]. Therefore, it motivates us to design novel interactive media that could mediate intergenerational communication through physical and cultural play. We are motivated to design physical play system that allows the intergenerational users to simultaneously engage in a

fun and leisure activity which is currently not supported by most games or entertainment devices. On the other hand, eastern cultural values and teachings are traditionally communicated orally in family and are available in the traditional printed media, for example books. However, children today possess high level of digital literacy and are more inclined to explore new knowledge using digital media. This motivates us to design new form of cultural play system, where users can explore cultural values and teachings through digital media.

Chapter 2

Literature Review

This chapter presents the definitions for the two forms of intergenerational play, physical play and cultural play, explored in this dissertation. A detailed literature review of physical and cultural play systems then follows. The contribution of our research in this domain is elaborated and comparison is made to highlight the similarities and differences of our research and those in the literature review. Literature review on user play experience and variables that would influence the user's experience are presented. Finally, the theoretical framework for studying the user experience, which is based upon Game Experience Questionnaire, is reviewed.

2.1 Definition of Intergenerational Play

2.1.1 What is Play?

Ever since the publication of *Homo Ludens: a study of the play element in culture* [46], many researchers have tried their hand at defining the concept of play. While there are significant similarities in the ways that play has been defined, there are gray areas, points of contention or even contradictions among their definitions.

Arguably the first attempt at providing an exhaustive definition of play can be credited to Johan Huizinga who wrote in *Homo Ludens* [46]:

“Summing up the formal characteristic of play, we might call it a free activity standing quite consciously outside ‘ordinary’ life as being ‘not serious’ but at the same time absorbing the player intensely and utterly. It is an activity connected with no material interest, and no profit can be gained by it. It proceeds within its own proper boundaries of time and space according to fixed rules and in an orderly manner.”

In this dissertation, we define play based on few of the key ideas in Huizinga’s definition above while extending few of them, with the support of definitions from other researchers. The main features of play adopted in this dissertation are discussed as follow.

1. No distinct boundaries from real life

Huizinga viewed play as distinct from real life and refers to play as “standing quite consciously outside ‘ordinary’ life as being ‘not serious’”. However, this point has been contested by researchers who consider that there is no strict boundary between play and everyday practices [83]. Play can serve functions of real life, for example learning and play could happen simultaneously in edutainment [88].

In Asian culture, work and play are well integrated. Hence we view play as an activity that is not distinct from real life. Play should integrate well into real life activities to facilitate intergenerational communication.

2. Intrinsically motivated and pleasurable

Huizinga states that play “is an activity connected with no material interest, and no profit can be gained by it.” The lack of external rewards suggests that Huizinga views play as an intrinsically motivated activity. This aspect of play is reaffirmed by various other researchers who stressed the importance of play as an intrinsically motivated activity. In the words of Rubin et al [84], “play is not governed by appetitive drives, compliance with social demands, or by inducements external to the behavior itself; instead play is intrinsically motivated.” Because play is intrinsically motivated, this also implies that it is done with the goal of attaining pleasure. Rieber [82] stated that play is “intrinsically motivating, that is, it is pleasurable for its own sake and is not dependent on external rewards.”

3. Absorbing and engaging

Huizinga stated that the activity of play “(absorbs) the player intensely and utterly”. The word “intensely” suggests a certain degree of effort on the part of the user and Rubin et al [84] makes this explicit by stating that play is active, “Play involves active engagement. This distinguishes play from daydreaming, lounging, and aimless loafing.” The features of play as an intrinsically motivated activity which brings about pleasure and is extremely absorbing for the participant lead to Flow theory, described by Csikszentmihalyi [17].

4. Either structured or unstructured

Huizinga views play as a structured activity which proceeds “according to fixed rules and in an orderly manner”. However, this point has been consistently contested by researchers over the years. Responses range from defining play as an open-ended, unstructured activity to defining play as laying somewhere between the continuum of structured and unstructured activity. In this dissertation, play is viewed as an activity which can be either unstructured, i.e. free from externally imposed rules, or structured, i.e. games with rules. Thus play is viewed as being inclusive but not limited to games which are defined by Salen and Zimmerman as a ‘system in which players engage in an artificial conflict defined by rules that results in a quantifiable outcome’ [86].

2.1.2 Forms of Play

In Karl Groos' book *Play of Man* [40], he proposed many different types of play such as:

- Physical play where we learn about world around us through motor movements
- Exploratory play which combines curiosity with playfulness in order to learn more about the world which we inhabit
- Constructive play in which we learn through building things
- Social play in which we play with others and as a result acquire essential social skills
- Fantasy play which allows us to build our imagination and creativity allows us to think outside of the box and find unexpected answers

Thus, play can take many forms and can serve many different functions. Two forms of play, physical play and cultural play, which could facilitate intergenerational communication, are invested in this dissertation. Physical play is defined as engaging in a play activity which involves motor skills, while cultural play is defined as engaging in a play activity which allows the user to experience the core aspects of his or her culture.

2.2 Physical Play System

Physical activity is an important component of intergenerational play. Based on Vetere et al's [102] observational studies of three intergenerational play-groups, they found that grandparents would often sit down, physically placing themselves at the same level as the child, playing in a childlike manner, dancing, and singing. A separate research also reported that children favor games that are rich in physical activity, in their observations and interviews regarding what make outdoor play fun [101].

Physical play may offer potential health benefits, in developing strong bodies and improving motor coordination [40]. In a study to investigate the possibility that slow-down in performance of the elderly could be reversed through practice on videogames, Pac Man and Donkey Kong which require a measured response selection and have been regarded by elderly as challenging were chosen. The results showed that the weekly high scores on Pac Man nearly tripled over the seven-week period, and Donkey Kong improved almost fivefold for the group of elderly being surveyed [15]. Participation in physical activity helps elderly to feel better and healthier, as they recognize their ability to move and create something, which is important to produce a sense of health [60]. According to a recent report, moderate, regular exercise may be just as helpful in combating serious depression in older people as antidepressant medication [4].

Commercial arcades and gaming consoles have recently seen a growing trend in games that require human physical movement as part of the interaction. As an example, the game console Nintendo Wii has gained tremendous popularity and has sold over 75 million consoles by 30th September 2010 [16]. To play the games, for example the Wii Sports, the player physically swings and moves the Wii remote, which goes beyond the micro movements of just pressing buttons. Sony Move [58] and Xbox Kinect [63] have follow suit by offering similar physical interfaces. Despite the differences in their implementations, (Wii uses accelerometers and gyroscope for detecting the handheld controller's movements, Move uses computer vision to detect the handheld controller's movements, and Kinect uses computer vision to detect the player's body as the controller), these game consoles offer the players to make use of their enactive knowledge to play the game. Enactive knowledge, a term first coined by psychologist Bruner [12], is "knowledge stored in the form of motor responses and acquired by the act of doing." Enactive interaction allows the users to borrow their previous experience of motor actions in real life (for example swinging a racquet), rather than having to learn and memorize complex mappings between in-game actions and specific button presses.

However, these interfaces still require the user to face the television screen and understand that he is controlling a virtual avatar in the game. For example, if two people are playing a tennis game using Nintendo Wii,

they are playing with each other via the screen, which limits the social interaction between the two players. In addition, the player's body movements are more or less limited on the same spot. Instead, we would like to explore physical play system that transforms and integrates the physical space into the game space, where the users become the game characters. The players can have full body movements over a big space and enjoy richer natural interaction with other players in the physical and game space. Furthermore, these existing systems do not recognize unique users, which is important in balancing the game play between the intergenerational users with varying physical abilities. In the later sections of this dissertation, we have shown the design of our system that makes use of the unique identification of the users to create a more balanced game, and the effect on the players' game experience.

Researchers have also experimented with combining play and exercise as Exergame [9]. In Muller et al's [66] study of exertion interfaces, they have designed, developed, and evaluated an exertion interface that allows people who are miles apart to play a physically exhausting ball game together. Players interact through a life-size video-conference screen using a regular soccer ball as an input device. The exertion interface users said that they got to know the other player better, had more fun, became better friends, and were happier with the transmitted audio and video quality, in comparison to those who played the same game using a non-exertion keyboard

interface. These results suggest that an Exertion Interface, as compared to a traditional interface, offers increased opportunities for connecting people socially. While our research is similar to exertion interfaces which combine exercise and playing, our focus is to promote physical interaction between elderly and children players when they are playing together in a physical space.

Similarly, in the Human Pac-man mixed reality game [13], the players reported enjoying high level of enjoyment in the context of social and physical interaction. In the game, the players wear a head mounted display with location sensor which transforms them into Pacman characters, so that they can play the Pac-man [6] game in a real world setting. The player competes and collaborates with other players in the game in the real world. We are inspired by the physical and social features of Human Pac-man game. However, considering that elderly users have limited familiarity with technology, in designing intergenerational play system, we would like to explore interfaces that do not require the users to wear complicated equipment.

Curball [18] is a prototype of a distributed bowling game for older people, to be played with grandchildren over the internet. It is a cooperative intergenerational game using tangible objects as input devices. The game consists of a game field, obstacles and a ball. The goal of the game is to let a virtual ball roll from the starting to the finish area without touching any of the obstacles. However, the two players view and control different things.

The senior player sees the game field, the obstacles and the ball on his screen, but he cannot move the objects. The junior player has only the game field with the obstacles and does not see the ball. He is reliant on the other's commands, which tell him the obstacle he has to move so that the ball does not touch it, but the obstacles have to stay on the field. We are inspired by this research which helped facilitates intergenerational communication and social interaction. However, given that most of the Singaporean elderly and children are staying under one roof or in close proximity, we would like take advantage of this situation, to focus on intergenerational play in a physical space.

Previous entertainment systems address the differences of elderly and children by designing different roles for them. For example in the Curball system, the elderly takes a role with less physical exertion, as compared to the children. Our research explores the potential for symmetrical interaction between elderly and children, by putting them on the level playing field. Real time adjustable game parameters were employed to address the ability gap between these two groups of players. The system uniquely detects each player's position of the floor game board and allows them to use full body movements to play the game. Furthermore, the system affords rich verbal and non-verbal communication between the elderly and children players in the physical game space, without constraining them to a LCD monitor or TV screen in typical gaming systems. In addition, the system also offers the

possibility of real and virtual game play, where parents can join the game remotely through the Internet.

2.3 Cultural Play System

Children today possess high level of digital literacy and are more inclined to explore new knowledge using digital media. It is important for us to design a new form of cultural play system, where users can explore cultural values and teachings through digital media. We share Tosa et al's [99] view on cultural computing:

“Human communication is originally something cultivated in an environment comprising localities, national customs and language. Therefore, the fruits of these cultures have strong roots in their unique histories. [...] Now, as the computer society covers the earth, the task that computers must take on is the clear and accurate intercommunication between local and global cultures. Toward that end, it is first necessary for those involved with computer technology to bring to life local characteristics.”

There is an emerging trend in entertainment research known as cultural computing, which allows the user to experience an interaction that is closely related to the core aspects of his or her culture [85]. Similarly, Tosa et al [99]

think of cultural computing as a method for cultural translation that uses scientific methods to represent the essential aspects of a culture

For example in *Zenetic Computer* [98], the user inputs the elements that he/she wants in his/her *sansui* painting. Based on the user input, the system then tries to infer the user's internal consciousness and generates a story that the user can 'enter' via the computer display. The user can respond to objects presented by the interactive system by manipulating input media, such as a virtual calligraphy brush or rake of a Zen rock garden, on-screen images, or simply by clapping hands. By exerting effort to link the fragmentary stories, the user interactions help to decrease the gap between daily self and hidden self. The system aims to allow users experience a virtual unification of their daily self and their unconscious self into a recreated conscious self through this dialogue with the system.

In another research project, *ALICE* [85], Salem et al took inspiration from *Alice in Wonderland* project [75] and created an augmented reality (AR) narrative with intelligent agents acting as characters who lead the user through virtual and real locations, moral choices and emotional states. *ALICE* is designed to provoke self-reflection on unconscious cultural issues such as logic and reasoning, self and ego, selfishness and selflessness. This is achieved by giving users the opportunity to occupy and experience any of these mental and emotional positions as they move along the plot of *Alice in Wonderland*.

Zenetic Computer and ALICE projects used interactive storytelling and compelling visual to bring users through specific cultural content. On the other hand, we would like to take a more open ended approach, to allow the parents and children the flexibility to ask a wide range of questions, and the system would reply with the most relevant answer from the knowledge database, hence presenting the cultural content directly to the user. Our cultural play system employs natural language processing methods to analyse the user's input sentence, for example the keywords, the sense of the keywords, and their corresponding topics. At the same time, the system models Confucian knowledge and teachings, by engaging Confucius scholars to provide data set for classifying each of the Confucius database entries. The system will then retrieve the most relevant entry from the database based on the proximity of the input sentence and the scholars' classification of the entry. In addition, k-nearest neighbor training algorithm, a text classification method is used to improve the accuracy of the system retrieval.

2.4 Virtual Chat Agent

Table 2.1: Performance comparison of various chat agents

	Disadvantages	Advantages
ELIZA	<ol style="list-style-type: none"> 1.Rely on pattern matching. 2.Contain fixed number of input/output rules. 3.Any variations of an input sentence need to be pre-defined manually. 4.When encounter unknown input, cannot make use of any existing knowledge base to derive the answer. 	<ol style="list-style-type: none"> 1.When the set of carefully prepared reply rules are large enough, ELIZA can sound intelligent on a wide range of topics.
Hex	<ol style="list-style-type: none"> 1.Introduce a new subject with a certain probability. 2.When encounter unknown input, Hex cannot make use of any existing knowledge base to derive the answer. 	<ol style="list-style-type: none"> 1.Give a humorous response if user is silent, so that conversation can carry on. 2.Make longer replies so that it seemed more human-like.
Jabberwacky	<ol style="list-style-type: none"> 1.Jabberwacky relies entirely on previous interaction on the internet and does not verify the inputs. Thus the system is susceptible to vicious user inputs. 2.The learning mechanism may make user feels that she is teaching the system rather than chatting. 	<ol style="list-style-type: none"> 1.Jabberwacky learns from all previous interaction and builds its database entirely based on previous conversations. 2.Jabberwacky provides the “correct me” mode, so that user can teach the system when it generates incorrect answer.
Confucius Chat	<ol style="list-style-type: none"> 1.The metaphors used in Analects may be difficult to be understood by user. 	<ol style="list-style-type: none"> 1.The information being used to construct the reply is dynamically retrieved from a rich Confucius content library. 2.Uses pattern matching and semantic relatedness. 3.Make use of Confucius scholars’ training data to improve retrieval relevance.

Confucius Chat offers an alternative approach to existing virtual chat agents, for example ELIZA, Hex and Jabberwacky. Existing chat agents use simple pattern matching approaches and employ tricks to cover-up the

failure of understanding the user input, for example frequently switching topics, or rephrasing the input by replacing the first person's pronouns to second person's pronouns and vice versa. These approaches fail to help users gain further understanding on the topic of discussion, thus offer minimal benefits to the interaction. Table 2.1 summarized the performance comparison between Confucius Chat and other popular chat agents.

2.5 User Play Experience

Zillmann Bryant [116] identifies entertainment as a process rather than a product. In a similar vein, Vorderer [103] identifies entertainment as the experience one goes through while being exposed to the media. With these in mind, in designing intergenerational play systems, our objective is to identify the design parameters which would promote a more positive experience of the interaction process. Variables that would influence the intergenerational user play experience: social competition and balancing game difficulty, are reviewed. The theoretical framework for measuring the user experience based upon Game Experience Questionnaire, which is used in our user study, is also reviewed.

2.5.1 Social Competition

In addition, one of the key factors why people play is due to the people factor, since players use games as mechanisms for social experiences [56].

Players in groups emote more frequently and with more intensity than those who play on their own.

In this dissertation, social competition is defined as social play in competition games. Social play is defined by Isbister as “active engagement with a game (through use of its controls or through observation and attention to ongoing game play) by more than one person at once” [8]. Isbister claims that adding people to a play session changes the end experience.

Certain social interactions are made possible with the addition of another human player. For instance, players may model their game-play behaviour after their opponent. This will in turn impact player’s learning curve and mastery of a game.

The importance of social competition has been extensively studied in desktop graphical interfaces, i.e. computer games or video games. Users have shown preference for competing against other people to playing against the computer: “It’s the interaction with other people and there’s a buzz playing against other people and if you’re really competitive and you beat the other person, you feel good about it.” Users cited a variety of reasons for this preference including enjoyment derived from competition with others, the unpredictability of human players, and social interaction with friends [106]. Mandryk et al. [59] demonstrated that playing a computer game against another person leads to higher physiological arousal than playing against the computer. This is in agreement with Weibel et al’s

study [108] which showed that people who played against a human-controlled opponent reported more experiences of presence, flow and enjoyment than those who played against computer opponent. Other studies revealed that playing against a human avatar leads to a higher amount of spatial presence [81] and enjoyment, due to social competition [104]. However, current literatures are focused on desktop graphical interfaces and did not study elderly and children gaming interaction in specific, which are the focus of this dissertation.

2.5.2 Balancing Game Parameters

IJsselsteijn et al feels that digital games may also be able to bring grandparents and grandchildren together. However, they cautioned that such games need to meet requirements of multiple user groups at the same time [47].

There are physiological differences between senior and children players. Senior players may suffer a decline in memory, visual functions or motor ability [3]. Furthermore, there are also psychological barriers for elderly to overcome. Weisman attributed some seniors' refusal to play computer games to fear of exposing their deficits [109]. In addition, senior and children may have large differences in their familiarity with digital technology and games. Therefore, when designing intergenerational games, the challenges given to the senior and children players have to be balanced carefully to account for the differences highlighted above.

The most successful games are those which can be programmed so that the participants can start at a level that can easily be mastered and which progress in small increments to more advanced skill levels as the participant improves [109]. According to flow theory [17] [95], the challenge in a game should match the player's skill to experience flow, a mental state of operation in which a person is fully immersed in what he or she is doing. The state is so satisfying that individuals are intrinsically motivated to repeat the activity continually. If the challenge is too hard for the player, the game experience will be frustrating. On the other hand, if the challenge is too easy, the game experience will be boring. When designing intergenerational games, attention has to be paid to balancing the game difficulty to account for the difference between players' ability and skills. Imagine that two players of different ability are playing a game, competing against each other. The player with stronger ability will keep winning. According to the Flow Theory, he will feel bored, as there is a lack of challenge. On the other hand, his opponent, the player with weaker ability will feel very frustrated, as the challenge is too hard. This is based on the assumption that the game rules are the same for both players. However if the rules can be augmented to be different for each of them, the challenge given to each player would better match their skills.

Balancing a game can be done implicitly or explicitly. In an explicitly balanced game, the players are informed and aware of the balancing mecha-

nism, while in the implicitly balanced game they are not. Balancing mechanisms can also be either static, i.e. predetermined prior to the game and remains the same or dynamic, i.e. changes during the game. In the Age Invaders game, dynamic balancing parameters were introduced and controlled by the parents, who are the virtual players. In the Tap Tap Hearts game, the computer automatically controls the balancing parameters, based on the performance of the players during the game.

The concept of balancing game difficulty has been well studied in the general context of design, for example Cybernetic feedback which is elaborated in the book *Rules of Play* [86]. The existing literature is based on mathematical simulation and design assumptions. However, there is currently no literature that is based upon real intergenerational user study results. This motivates us to study the effect and implication of balancing on their game experience.

2.5.3 Measuring User Experience

Many researchers tried to break down media experience and most of them have identified similar positive characteristics such as pleasure, enjoyment, and even delight [10] [116]. Many communication researchers have used the term enjoyment to describe and explain such positive reactions toward the media and its contents [79] [96]. By focusing on making an activity enjoyable, it is possible to motivate users to do the activity for no other reason

than the pleasure gained from doing it, as described by Flow Theory [17].

However, media experience extends beyond pleasure or flow. In the case of interactive entertainment such as computer games, a certain sense of achievement, control, and self-efficacy [7] [39] [50] is associated with playing computer games. Poels et al [76] conducted a focus group in order to unravel the different dimensions of game experience and they came up with additional dimensions such as negative affect, suspense and social presence. Game Experience Questionnaire [48] was chosen for our experimental design because it is one of the most widely used questionnaire by academics that measure player experience in digital gaming. The questionnaire has already been validated in several European countries (the alpha value of all components, which corresponds to the reliability of the questionnaire, are $>.7$; most of them $>.8$ and some even $>.9$). The questionnaire has been validated in the European project FUGA. To date, 53 studies have included the GEQ, conducted at several other universities (Singapore, Germany, England, Finland, France, USA, Canada etc.). Some of them have already published their papers [27] [69] [55].

The seven dimensions of GEQ are competence, sensory and imaginative immersion, flow, tension, challenge, negative affect and positive affect. Flow, as defined by Csikszentmihalyi [17], is an experience “so gratifying that people are willing to do it for its own sake, with little concern for what they will get out of it, even when it is difficult or dangerous”. It is affected

by the match between the person's skills and the challenges associated with the task, with both being over a certain level [95].

As Poels [76] further broke down the dimension of flow into challenge and competence, competence can be related to one's skills which refer to how well games support player skill development and mastery whereas challenge refers to whether the difficulty level of the game is sufficiently challenging and matches the players skills [95].

Tension is considered as it is often related to annoyance and frustration which arises when the progress a user is making towards achieving a given goal is impeded. It is a negative emotion and is monitored for can be used to indicate when a user is in need of assistance [33].

According to Murray [67], immersion can be defined as "the sensation of being surrounded by a completely other reality [...] that takes over all of our attention, our whole perceptual apparatus". Ermi and Mayra further breaks down the dimension of immersion [68]. Sensory immersion refers to "the multi-sensory properties of game - the extent to which the surface features of a games have a perceptual impact on the user" whereas imaginative immersion refers to "the immersion within the imaginary fantasy world created through the game, and depends on the richness of the narrative structure of the game."

The two dimensions of positive and negative affect explain users' emotional experience while they are playing the game. Positive affect is gen-

erally associated with gaming achievement as participants felt gratified by their accomplishments, which in turn, leads to increased enthusiasm, drive, alertness, interest, and joy [51], described as the “momentary subjective experience” [80] and enhanced their self-efficacy for future game play. On the other hand, negative affect comprises a compilation of negative feelings such as boredom, regret, lack of focus and shame [76].

Chapter 3

Method

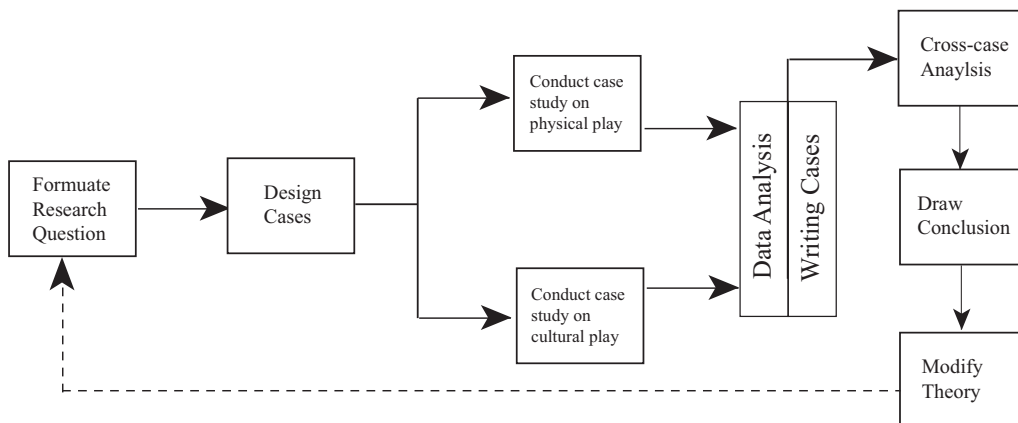


Figure 3.1: Overview of multiple-case study approach

In this chapter, the multiple-case study approach used in this research is presented. The overview of workflow in adopting a multiple-case study approach can be seen in Figure 3.1. To begin the research, the research question was set as “How do we design novel interactive physical and cultural play systems that facilitate intergenerational communication”. This in turn guided the design of physical play and culture play cases. The en-

gineering details of the cases and the system descriptions are presented. Subsequently, the methods for carrying out user studies for the two cases are elaborated.

3.1 Multiple Case Study Research Strategy

Yin [113] defined a case study as ‘an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when boundaries between the phenomenon and context are not clearly evident’. Case studies allow in depth exploration of an issue, rather than in general, and can make use of a variety of data, from both qualitative and quantitative sources. Stake [91] also proposed that case study designs are especially appropriate to explore and understand complexities of phenomena.

The aim of this research was to investigate how to design play systems that can facilitate interactions between users who belong to different generations as well as to uncover possible design principles to adhere to for future researchers interested in designing better experiences for an inter-generational audience. As the area of intergenerational play is an emerging area of research, there are few, if any, variables of interest identified by the research community. Furthermore, the need to control variables in play is undesirable since we would like to explore and understand the complex interaction that develops between the players and with the newly designed

systems. In view of the exploratory nature of our research, case study approach was adopted, with the objective of identifying relevant design principles for intergenerational play systems.

Yin [113] said that the purpose of case study is to ‘expand and generalise theories and not to enumerate frequencies’. Eisenhardt and Graebner [22] agreed with his point and had argued for the potential of multiple case studies to contribute to theory building research.

Evidence from multiple cases is often considered more compelling which would make the overall study regarded as more robust [44]. Yin [113] warned against using sampling logic for the selection or design of cases. Instead, every case should serve a specific purpose within the overall scope of the inquiry and therefore, Yin proposed that cases should be designed or selected for replication purposes. Cases in this dissertation are designed so that it predicts similar results (literal replication). Different play systems were studied to see if the same design principles can be applied across different types of play system to bring about similar effect in the user experience of the systems.

Yin [113] made a distinction between holistic and embedded case studies. A holistic case study analyses the subject of interest as a whole whereas in embedded case studies, attention is also given to a sub-unit or sub-units. In this research, the user experience is the main unity of analysis. However, as user experience is a multi-faceted construct, there is a need to incorporate

sub-units of analyses within each case. Individual user's interactions with the system as well as interactions between the users were identified to be the sub-units of analysis. According to Yin [113], the sub-units add significant opportunities for extensive analysis, enhancing the insights into the case.

3.1.1 Designing Cases and Engineering of Systems

In the design of systems, there can be a focus on various aspects, which can result in a system which meets the expectations of the various stakeholders at differing levels of success. In a traditional model of software development known as the Waterfall Model, the requirements of the system are defined in the beginning and the development continues, following this with the design goal as the most critical issue. In interaction design, it is more widely accepted to involve the users of a system throughout the design process in the hopes that the completed system will efficiently and accurately address the needs of the users. There are various models which follow the user centered approach and involve an iterative design process. Prototypes with few features are built for purposes of validating assumptions about the user needs and reducing the time delays and costs associated with building and rebuilding complete systems with full functionality.

Our approach is "Design-oriented Research," where our efforts are primarily research focused and aimed to find an appropriate use of media to understand and address a perceived human problem [23]. In design-oriented

research, the bringing forth of the research prototype is a vital part of the research process. Daniel Fallman argues that “the knowledge that comes from studying the designed artefact in use or from the process of bringing the product into being is the contribution, while the resulting artefact is considered more a means than an end.” Similarly, in this research, the development of the two different play systems were a means to test and uncover underlying design principles that would be useful in designing play systems meant for intergenerational use. With this in mind, we must also consider that our field of research is not focused on the human alone, but also the role of the machine in mediating communication and providing new situations and contexts of use. The driving force is in improving human issues in the world and understanding how technology can be crafted to be a tool and facilitator of communication.

Our problem statement focuses on intergenerational users with very different levels of acceptance of technology and tolerance for usability problems. In the design of the system, we had to make a system, which was easy enough for the parents or grandparents to participate and to hold their confidence in the technology and motivation, yet also challenging and fast paced for the younger players who are technology experts and who are easily bored when faced with simple interactions. We set out to design the system, which is not a simple productivity application, but a system that is an open platform encouraging interaction and promoting fun social

play. We followed a User-Centered Design approach in defining the steps for our research prototype development. These steps borrow from existing models [42], yet does not call for in-depth risk analysis as in business application development. This allowed the researchers to more quickly design the interactive system and provide workable prototype iterations.

The design steps we followed include the following: problem identification (described in Chapter 1 of this dissertation), problem exploration, setting the design goals, design requirements of prototype, research user needs, research context of use, design idea generation, prototype creation, and usability studies. Each iteration returned to the beginning and followed a subset of the design cycle in attempts to understand the user better or to overcome a technical challenge. In creating the prototypes, various technologies, their cost, availability, feasibility, implementation and performance are evaluated carefully. The objective is to discover novel use of technology to create new interaction experience. For example, low frequency RFID tag is typically as identity card for detection of a person. In our physical play system, we made use of the RFID detection capability by putting an array of tags on the floor while the user wears the RFID reader on his or her foot. By integrating the tracking with a large display on the floor, we designed a new gaming system that would allow players to use full body movements to play games, while the system detects unique player's position in real time and displays the game graphics on the floor

display. On the other hand, in our cultural play system, natural language processing and text classification methods are used to analyse user's input sentence and model Confucius knowledge, to enable interactive chat with a virtual Confucius. The creation of prototypes involved both hardware and software engineering development. In the hardware development process, prototype printed circuit boards (PCBs) are designed and evaluated to meet the user interaction needs. In the software development process, applications and graphical user interfaces are designed and evaluated to meet the user interaction needs. The development of the prototypes is presented in section 3.2.5 and the prototypes are elaborated in section 3.4. Technical evaluation of the systems are presented in section 4.1.1.

3.1.2 Validation of the Findings

In the context of multiple case studies, Yin [113] strongly advocates the use of triangulation as a way to ensure greater credibility and accuracy. According to Flick [24]:

Triangulation includes researchers taking different perspectives on an issue under study or more generally in answering research questions. These perspectives can be substantiated by using several methods and/or in several theoretical approaches. Both are or should be linked. Furthermore, it refers to combining different sorts of data against the background of the theoretical per-

spectives that are applied to the data. As far as possible, these perspectives should be treated and applied on an equal footing and in an equally consequent way. At the same time, triangulation (of different methods or data sorts) should allow a principal surplus of knowledge. For example, triangulation should produce knowledge at different levels, which means they go beyond the knowledge made possible by one approach and thus contribute to promoting quality in research.

3.1.3 Data Triangulation

‘Data triangulation’ refers to the use of various sources of data and should be distinguished from using different methods to produce data [20]. This can be differentiated in a number of ways; such as studying the same issues and phenomenon at different times, in different locations, and with different persons. In the context of this research, the data sources for both physical and cultural play comes from the users using the system, design team, facilitators and as well as from the system which keeps a log of how people use it. We also administer pre-test and post-test questionnaire to our users.

Another form of triangulating data is via the use of multiple data types. This is particular valuable in the context of this research as interaction is multifaceted and involves many senses. Therefore, this research makes use of textual type of data, visual data (e.g. photographs) as well as audiovisual

data (e.g. video) for both physical and cultural play.

A third form of data triangulation lies in the way multiple case studies are selected. In this research, two different types of play systems were designed. One is a physical play whereas the other focuses more on cultural aspects and is more cognitive in nature. This form of data triangulation ensured that data collected is able to reflect a fuller range of play systems.

3.1.4 Methods Triangulation

As opposed to data triangulation, methods triangulation:

involves a complex process of playing each method off against the other so as to maximise the validity of field efforts. Assessment cannot be solely derived from principles given in research manuals – it is an emergent process, contingent on the investigator, his research setting, and his theoretical perspective [20].

Denzin [20] suggested that methodological triangulation can be achieved by using different methods to investigate the same issues. In this research this has been achieved through the between-methods triangulation, that is, the use of different methods in multiple case studies such as interviews, surveys and experiments as shown in Table 3.1.

Focus group discussion and semi-structured interviews were conducted at the user requirement gathering phase. Before and after each user studies,

Table 3.1: Overview of methods used for each system

System	Methods
Age In- vaders	Semi-structured Interview, Focus Group, Questionnaire, Experiment
Confucius	Questionnaire, Semi-structured Interview, Content Analysis

data were collected in the form of questionnaire. Interviews and focus group discussion were also conducted after the user studies. In the case of physical play, a controlled experiment is carried out to add to the depths of findings from the emerging themes from earlier data. In the case of cultural play, content analysis was carried out to study the content of communication between the users and the system.

3.2 Designing Physical Play

3.2.1 Problem Exploration

We carried out a preliminary user study to understand the users better, in particular, the grandparents and children in the context of Singapore. The results of the study are presented below. Singapore has many senior citizen focused community centers, each located among the clusters of high-rise residential apartment buildings. These community centers offer a common place for older people who are living in the vicinity to socialize and partici-

pate in activities. The facilities commonly offered include televisions, tables and chairs, exercise equipment, etc. The older people normally gather at these centers during the daytime. We have carried out initial observation-based studies at one of the community centers, “Peace Connect,” which serves as a general model. We did the studies twice over a period of one month. We observed that there were many older people sitting around the tables. Some were watching TV and playing board games but most of them were idle.

There was little social interaction among the older people there and they exhibited little motivation to exercise or move around, even though there were treadmills and other exercise equipment provided. They looked tired and most of the time they rested in their seats. This was explained to us by the support staff, as being normal.

We conducted verbal surveys with ten older people in a focus group session during our second visit and realised that all the older people were illiterate or have very limited command of written English or Mandarin Chinese. They communicated verbally in the Mandarin and Chinese dialects of Hokkien or Cantonese.

In a similar process, we carried out a focus group study with 10 school children ages 10–12, from a neighborhood primary school. Eighty percent of them indicated that they play electronic games, ranging from personal computer games to console games such as Microsoft X-box and Sony Play

Station for more than 10 hours a week. On the contrary, 100% of the 10 older people ages 60–80 in our focus group study reported that they have never played any form of electronic games although they were aware of them.

From the initial study we observed the following trends:

(1) Many of the older people in Singapore live under the same roof with their children and grandchildren. There is strong bonding between the three generations.

(2) Besides the student who does not have grandparents in the family (only one out of the 10 students), the students reported spending, on average, 10 to 20 hours weekly with their grandparents with common activities including board games, card games and swimming.

(3) Eighty percent of the children indicated that they play electronic games ranging from computer games to console games more than 10 hours each week.

(4) Older people do not play games and do not have computer related experience.

(5) Older people are supportive of the grandchildren playing the games, although they have no understanding of the content of the games, nor do they understand how to participate.

(6) All of the 10 older people did not attempt to understand the games played by their grandchildren, primarily because they are apprehensive

about using computer interfaces like the LCD screen, keyboard and mouse, and do not understand the language used in the game.

(7) The older people are interested in playing games similar to Dance Dance Revolution (DDR) which promote their body movements as a form of exercise. The students that had played DDR enjoyed playing it.

(8) Older people are hesitant to try DDR because of the fast paced nature of the dancing game, which is perceived as too demanding for their physical ability. Hundred percent of the older people expressed that an entertainment platform that could allow them to play with children must have an adjustable game speed so that the game pace can be calibrated to suit both parties.

(9) Parents are busy at work and often not around at home. They only return home late at night.

From the above observations, in the middle class Singaporean context, older people and children spend substantial time together as a family. A majority of the students play and enjoy computer gaming experiences. Their familiarity with electronic games and their skill level is much superior to the older generations. There is no widely used electronic entertainment platform, which allows children and older people to play together.

3.2.2 Design Goals

Based on the observations above, we established the design goals for the physical play system as listed below:

(1) Intergenerational family entertainment: We wanted to create an entertainment system that would enable different generations, the grandparents, parents and children to participate in meaningful game play that could possibly strengthen family bonding.

(2) Physical and tangible interaction: Based on the above study, we have identified that the barrier for older users to participate in computer games is attributed to computer interfaces like keyboard and mouse, which seem difficult to use, and a lack of understanding of the language used in games. We propose to use body movements as the interface to the game, replacing the need for a keyboard or joystick to participate in the game. Besides being intuitive, it should also double as a form of exercise and the game controllers should be easy to use tangible interfaces with big buttons that are easy to manipulate.

(3) Social interaction: Although there is an emergence of multiplayer games, the interface to the games still remain largely in the form of individual two dimensional screens to facilitate user interaction. In some cases this is a portable screen, such as with personal game consoles. In either case, it forces the user to use the media to facilitate the interaction which

can cause for a loss of richness in sharing of meaning and emotions. Furthermore, from our initial study, all the older users felt uncomfortable interacting with computer screen interface. Hence, we envisioned a system that would allow players to interact with each other in close physical proximity, while augmenting the experience with the logic of the digital game.

(4) Remote interaction: Parents in modern society often have mobile and digital life styles. They may be busy at work and go frequently on business trips; hence, it is not always possible to physically interact with their family. To further enhance family interaction and bridge the physical distance between family members, we included a virtual world interface so that parents can join in the game in real time, remotely through the Internet with the players at home.

(5) Adjustable game parameters: The older people in the study expressed apprehension to participate in entertainment games because of their incompetence with the technology and the pace of such activities which are perceived as too fast for them, such as the DDR game. Hence, by having adjustable game parameters that could be tailored for users of different levels of physical fitness and competency with the game, we could potentially balance the game play between the older and young players.

3.2.3 Design Requirements

In this step, we identified the design requirements for the prototype. This phase takes into consideration a negotiation of the factors including: user needs, context of use, available resources and time constraints.

3.2.3.1 Resources and time constraints

The research lab takes into account the number of resources and skills available to develop the project. Because the funding of the lab is based on various sources, the tentative dates for the subsequent prototypes were established, but the features to be included remained undefined until the findings from each prototype were released.

3.2.3.2 User needs

As older people are hesitant to engage in computer related activities, the system should support our interaction design goals by not intimidating older people with traditional interfaces, such as keyboard, mouse, and monitor. To support physical interaction, the player's body should become the interface to the system. Instead of fiddling with a keyboard, the players should move their bodies to manipulate the digital elements in the game or entertainment system. Dedicated controllers that are intuitive and simple to use should be introduced. To support both physical and social interaction between players, movement over a big space is recommended. In respect to

that, tracking of the players in that space is required. However we do not want to overwhelm the players with heavy equipment. Thus the tracking should be invisible to the players and the accessories of the system should be wireless in order to limit the hindrance on physical movement in the game space. From the preliminary user study, we have identified adjustable game parameters as being an important factor in sustaining the players' interest. The older players emphasized that the game should not be too fast such that it would be tiring or too slow so that it would become boring.

3.2.3.3 Context of use

The system is envisioned as being installed in the home setting. Given this constraint, the system dimensions should be reconfigurable according to the room size. We envisioned the floor platform to be constructed from blocks of square tiles to facilitate this. For example, in houses with more space available, we could construct a larger floor platform consisting of more tiles and fewer tiles for rooms with less space available. Standard walking width as specified by a common standards handbook is best at 38 cm [1], so the 42 cm square is more than adequate to allow for this. It should be noted that these guidelines use a full sized adult man as a reference and we understand that this size specification does not apply to all people. Another point to note is that the physical player in our game uses only one of her feet to register the position on the board, so if the player is not able to or feels

more comfortable occupying more space, it is quite simple and comfortable to do so. For parents to play the game remotely from their workspace, the game server is connected to the internet so that virtual clients can join the game in real time.

3.2.4 Design Idea Generation

In this step, we carried out brainstorming sessions. We explored popular card games, board games and puzzle games that are popular in Singapore such as Mah Jong, memory card games, and Rush Hour. We also looked into music and dance games such as DDR. We also explored popular arcade games such as Pacman and Space Invaders. We were inspired by Human Pacman, in which the players were transformed into characters of the game. We decided to bring Space Invaders out of its original arcade form, transforming grandparents and grandchildren into human space invaders characters, and enabling them to play the game harmoniously at home. Parents at work can also join in the game's virtual world remotely through the internet browser, thus allowing all three generations to play together. The game is named Age Invaders.

3.2.5 Prototype Iterations

In this section, we provide an overview of the prototype iterations from the first prototype which addressed more technical issues, through the more

recently tested prototype, which allows for more complex game experiences.

We now describe the features of the prototype, the user involvement in the design, what design issue each prototype was attempting to answer, the user testing after the realization of the prototype, and the lessons learned which were carried to the subsequent iterations of the design cycle. The prototype iterations are shown in Tables 3.2 - 3.5.

Prototype 1 was a simple proof of concept system, which consisted of five floor blocks with LED display and built in RFID readers for tracking of player's movements. The prototype confirmed that the players were comfortable moving on the platform and that their position could be registered by the system. The players also tried launching lasers using a Bluetooth controller in the shape of a space gun. This prototype aimed to verify that the system was usable and enjoyable to all the players. Two main issues were identified in this prototype. First, implementing the RFID readers on each blocks of the floor display would be very expensive when the system platform is expanded to a bigger room-sized grid. Second, the Bluetooth controller shape was not suitable for family interaction due to the implicit violence and were too large in size and too bulky to carry around during game sessions.

In prototype 2, we redesigned the RFID reader to be in a pouch strapped on the player's leg and the antenna placed inside the shoe. The RFID tags were placed on the floor grid. RFID tags were significantly cheaper than

Table 3.2: Physical Play Prototype Iteration 1

Design requirements	
- Features to be tested	Physical user registration and interaction with a virtual world. Validate size and shape for future prototypes.
User needs	
- Human factors issues	Sizing of the game squares. 38 cm is a guideline for a walkway, US Government standards. This was validated by taping squares and having users walk in the squares. The most comfortable size was 42 cm. Confirmation from the user that their actions are registered by the system.
Context of user	
- Player composition	Ages 5 - 71 years, lab members, university employees and student volunteers.
- Location	Laboratory setting.
- Game scenario	Walk around, basic user interaction, no scoring system.
Idea generation	
- Drawing/sketches	Artist/engineers drafted designs of the physical space and ideas of technical challenges.
- Meetings with users	Meeting with the designers from the previous game Human Pacman were engaged.
- Meetings with designers	
Prototype creation	
- Brief specs	Five squares of 42 cm each arranged in a straight line. RFID tag embedded RFID reader to track the players. LEDs on the game square indicate player registration. Simple virtual game space with view only, no virtual player. Bluetooth controller in the shape of a space gun.
- Features introduced	
Usability studies	
- Test requirements	Walking back and forth on the squares. User position registration is calculated to be less than 100ms.
- User profile	Users were also asked to use the Bluetooth controller to send lasers to other player.
- Test description	
Lessons learned	
- What works well?	System was usable and enjoyable to all players.
- What is lacking?	An RFID reader in each square is very costly.
- Future improvements?	The delay in user position registration was reported by users as perfect. Size of the floor squares is just right. The Bluetooth controller was not appropriate for family interaction.

the reader; hence, we could save huge costs using this new design. We also redesigned the Bluetooth controller to be a simple rectangular shaped handheld controller approximately the size of a mobile phone with a simple button to activate the laser beams. We have developed the online virtual player interface and most game functions were implemented. The virtual players can play with real players simultaneously over the Internet. In this prototype we have implemented two games; the Age Invaders and the Rush Hour puzzle game. Age Invaders was much more favored over the

Table 3.3: Physical Play Prototype Iteration 2

Design requirements	
- Features to be tested	Larger game space to enable interesting interactions. Redesign of the tracking system due to high cost. Redesign of handheld controller. Addition of simple sound.
User needs	
- Human factors issues	Visibility of the game space when expanded. Sound is able to be heard and associated with events in the game.
Context of user	
- Player composition	Ages 5–71 years, lab members, university employees and student volunteers.
- Location	Laboratory setting and HCI conferences.
- Game scenario	Walk around, basic user interaction, simple puzzle game implemented. Sending lasers to the opponents.
Idea generation	
- Drawing/sketches	Meeting with designers and review of sketches.
- Meetings with users	Various configurations of the game space were reviewed.
- Meetings with designers	Sketches of the handheld controller were reviewed. Design strapped on pouch with antenna to put into the player's shoe.
Prototype creation	
- Brief specs	Game space increased to 9 x 5 squares, two games can be played. RFID reader is placed in the user's shoe. Handheld controller redesigned to be a more general input device. Virtual game space fully developed. Virtual player can place barriers and energy on the virtual interface, which will appear on the physical game space simultaneously. Virtual player can also adjust game parameters for example the laser speed and the speed of dance step patterns for players to follow.
- Features introduced	
Usability studies	
- Test requirements	General playability of the 2 games. Validation of the size and shape of the game space.
- User profile	Tested in the lab setting with 10 users ages 45–60 (older people), 16–20 (young) and demonstrated at many conferences and exhibitions.
- Test description	Usability of the system for virtual and physical players. Informal test which involves hundreds of users.
Lessons learned	
- What works well?	Screen is more for audience than for players. Performance aspect seems to be a large factor in the enjoyment. Virtual player experience is not as much fun as physical players. Stepping action was enjoyable. Having antenna in the shoe is cumbersome. Game strategies developed. Puzzle game was not as popular as the real time action based game.
- What is lacking?	
- Future improvements?	

puzzle game, due to the physical nature of the game and fast tempo of the interaction.

In prototype 3, we redesigned the floor platform to be rearrangeable and flexible in the number of squares. We have also redesigned the smart slippers to have an embedded RFID antenna, so that the player has only to wear the slippers in order to start playing. This prototype is fully functional

Table 3.4: Physical Play Prototype Iteration 3

Design Requirements	
- Time frame	System should be easily taken apart and easily transport and setup.
- Features to be tested	New smart slipper for tracking. New handheld controller with added LED display.
User Needs	
- Human Factors issues	Slipper should not detract from player movements.
Context of User	
- Player composition	Ages 4-80 years, lab members, student volunteers and public.
- Location	Facilitated game play sessions.
- Game scenario	Structured game play: Age Invaders.
Idea Generation	
- Drawing/sketches	Game scenario ideas amongst lab members.
- Meetings with users	Feedback from demos at conferences gave input to the types of interactions that users enjoy.
- Meetings with designers	
Prototype Creation	
- Brief specs	RFID reader embedded into slipper.
- Features introduced	Physical game squares can be added/removed. Game play is more developed for the Age Invaders game scenario.
Usability Studies	
- Test requirements	General playability & usability tested. Video recordings from platform demonstrations at conferences. Observation of 49 players in a structured format, questionnaires involving closed & open-ended questions. 3 focus group discussions, 1 before game play, another immediately after the game play and the last one with the older people 5 weeks after the game play. 4 semi-structured interviews with the design team and game play facilitators.
- User profile	
- Test description	
Lessons Learned	
- What works well?	Older people want the display of game statistic in an easy to read screen. Indication of start & end of game has to be clear. Slippers need to fit more securely. Stepping action & avoiding moving obstacles is fun for all users. Older people are less likely to know ahead of time what types of interactions are fun, but their willingness to try the system is strong.
- What is lacking?	
- Future improvements?	

with the inclusion of sound in the game. We have carried out most of the in depth user studies on this version of the system.

In the fourth prototype, we developed a graphical programming toolkit to allow rapid prototyping and reprogrammability of the system, providing game designers with the ability to develop many games in any configuration. In this prototype, the slipper is embedded with new pressure sensor which can detect foot actions like jumping and tapping. In this way, the user can select an item by double-tapping on the square, rather than pressing the

Table 3.5: Physical Play Prototype Iteration 4

Design Requirements	
- Features to be tested	Redesign of the user tracking slipper. Clear indication of player status and score. Development toolkit to allow rapid game prototyping. Improve the virtual player experience.
User Needs	
- Human Factors issues	Spatial sound system and matching it to the physical player actions. Usability of the physical players tracking device (slipper).
Context of User	
- Player composition - Location - Game scenario	This remains unchanged from the previous iteration.
Idea Generation	
- Drawing/sketches - Meetings with users - Meetings with designers	Game ideas workshop with designers for game content. Design meetings regarding sound and physical configuration of squares.
Prototype Creation	
- Brief specs - Features introduced	Squares are reconfigurable in various arrangements. Development of new games. Graphical & programming toolkit developed in MAX/MSP environment. Spatial sound for the physical game space using 7.1 speakers. Vibration feedback for game events.
Usability Studies	
- Test requirements - User profile - Test description	General playability testing of game ideas. Effectiveness tests for the spatial sound when squares are in various configurations. Virtual user testing in a remote setting.
Lessons Learned	
- What works well? - What is lacking? - Future improvements?	Spatial sound is intuitive. Use of the system for facilitating non-game activities such as dance, music, and other cultural entertainment.

wireless handheld controller. A flexible strap is placed on the slipper to allow better fit for different foot sizes. Based on the emerging themes from grounded theory, a controlled experiment is designed to further study the effect of two identified variables on the players' experience when using the system. A new game, Tap Tap Hearts, is designed such that it only requires the users to wear a pair of slippers to play the game, without the need for handheld controller.

3.3 Physical Play Description

The two games designed for the physical play system are now described.

3.3.1 Age Invaders

The concept of the Age Invaders game is shown in Figure 3.2, two children are playing with two grandparents in the interactive physical space while up to two parents can join into the game via the internet as virtual players, thus increasing the intergenerational interaction. Figure 3.3 and Figure 3.4 show the elderly and children playing Age Invaders game. The grandchildren form a team and the grandparents form another. The parents' role is to balance the game between the two teams. In the situation that not all family members are at home, it is possible to play the game with only two players (one in each team). Our study results suggest that users prefer four-player games because the games were more exciting by having a team member to engage in cooperative competition.

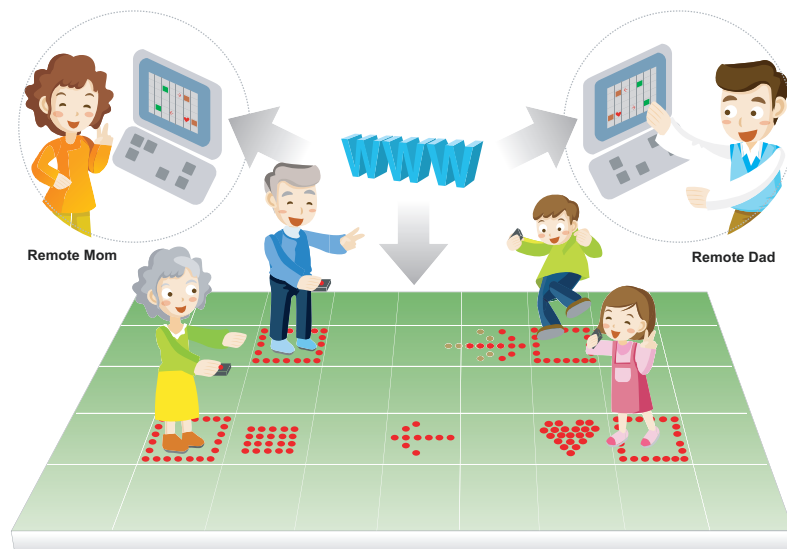


Figure 3.2: Age Invaders game



Figure 3.3: Elderly and children playing Age Invaders game



Figure 3.4: Elderly and children playing Age Invaders game

Grandparents and grandchildren wear lanyard-style Bluetooth LED displays for the purpose of displaying game events including loss of energy of their virtual avatar. The players wear special slippers with RFID tracking and a Bluetooth enabled handheld controller device. Each game session lasts for up to 2 minutes. The players gain points by picking up bonus items

and avoiding laser beams. Each player starts off with five energy levels. The player is out of the game when his or her energy level drops to zero. The game ends prematurely if the energy level of both players of the same team became zero. Otherwise, at the end of 2 minutes, the team with the highest score wins.



Figure 3.5: Player pressed Bluetooth controller to launch a laser

During the game play, as the player presses a button on the Bluetooth controller as shown in Figure 3.5, a laser image is displayed on the game board (Figure 3.6) and heads towards the opponent.



Figure 3.6: A laser image displayed on the game board

If the opponent is hit by the laser beam, he or she will lose one energy level and the Bluetooth display will light up as shown in Figure 3.7. The opponent can avoid the approaching laser beam by hopping over it or simply moving to the adjacent squares.

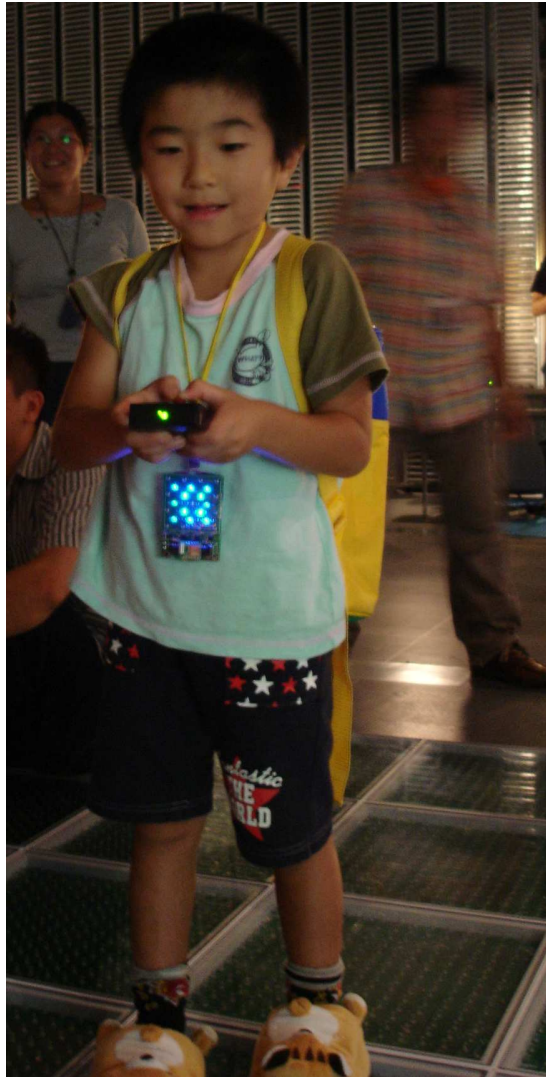


Figure 3.7: Bluetooth display lights up when hit by laser

Figure 3.8 shows an elderly player avoided an approaching laser by moving to the adjacent square. If the grandparent launches the laser, its speed is fast so that the grandchild has to react quickly. On the other hand, the grandparent has more time to react to the much slower laser beams launched by the grandchild. This balances the game difficulty between the ages.



Figure 3.8: Elderly player avoided an approaching laser

In order to make the difficulty of the game balanced between the young and older people, Age Invaders imposes additional challenges in an innovative way for the invader players (the young and more dextrous). The invader footprint is one of these challenges. In the game, the invaders are presented with two squares that are adjacent to their current position to which they can move, as shown in Figure 3.9. Each invader player need to follow his or her own footprint pattern, either a 'X' or 'O'. The footprint could also appear behind the player (Figure 3.10, hence making it more challenging for them to concentrate on the game while following the footprint.

There is a timer which requires the advancement of steps each period of time, after which an energy level is deducted. This period is determined by the invader footprint speed which can also be adjusted by the virtual players at any time. To be fair to these players, they are rewarded with one bonus energy level by following the footprints correctly ten times in a row.



Figure 3.9: Two invader players' footprint

The parents as virtual players, can drag-and-drop barriers or energy



Figure 3.10: Invader footprint behind the player

power ups in the shape of hearts on the virtual player interface, and appear almost immediately on the physical game board rendered in patterns of lights. The physical players can pick up the energy power ups to gain extra energy. The barriers will block laser beams. Parents can also adjust the game parameters as mentioned previously including the laser speed and the speed of the dance step patterns for the young players to follow. All the actions in the virtual environment are translated to the physical game board in real time. This provides a seamless game interaction between the real world players and the parents in the virtual world.

When a player steps on a puzzle, the game enters a “hyperspace” mode (Figure 3.11), where it is specially designed to enhance collaboration between the players. One of the “grandchildren” will be physically moving

on the game board to solve the puzzle while the “grandparents” who have more experience can exercise their mental ability and give hints at the side. The “hyperspace” mode encourages physical-mental collaboration between the “grandchildren” and “grandparents”. It promotes elderly to use their superior mental experience, in combination with the youngsters physical agility in a cooperative play.

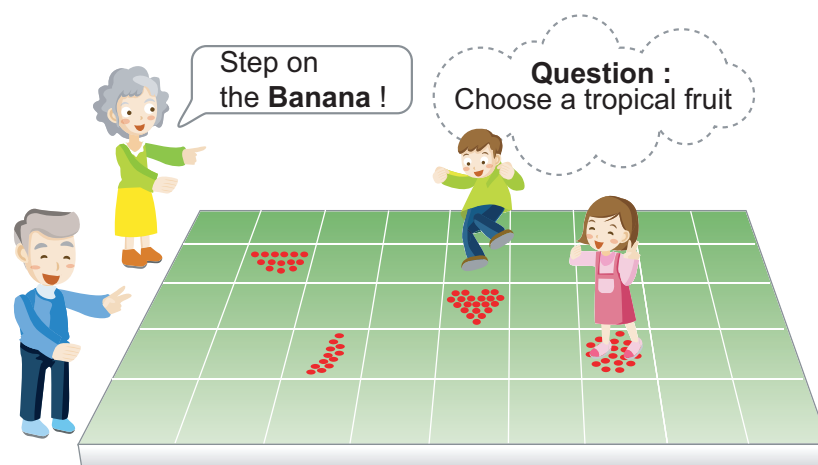


Figure 3.11: Age Invaders Game Hyperspace Mode

The game play challenges and aids are summarized below:

Young Player

- Must follow the dance steps as they appear
- Speed of laser beam is slower
- More difficult to collect power-ups unless intended for the player due to being restricted to their indicated squares

Older Player

- Can move freely on the game board
- Speed of laser beam is faster
- Power-up hearts can be collected easily

Virtual Player

- Placing power ups and barriers
- Balancing the play experience by adjusting the step speed and laser speed

3.3.2 Tap Tap Hearts

For the experiment, it is important that the game is simple and something that both seniors and children can relate to. Therefore the game design draws inspiration from traditional games like hopscotch and chasing games.

We named the game Tap Tap Hearts. There are two players in this game. Each player has to stand on a fixed square, behind the starting line, to start the game. Each player is required to collect a number of items from the floor. The number is shown on the floor in front of the player at the start of the game. To collect an item, the player is required to move to the square where the item resides and uses the active slipper (the one with RFID reader) to tap on the square twice. The corresponding item will change to the player's symbol (Player 1 - X; Player 2 - O). The first players who finish collecting the required items win the match.

To ensure fairness, items are equally distributed over the floor along horizontal and vertical grids and the players start from the same horizontal line. This configuration offers most direct form of competition as players have to race each others for items as they move down the alley. In addition, the total number of items on the floor is always one less than the total combined number of items that both players are required to collect in order to win. For example, if each player has to collect 4 items, there will only be 7 items on the game floor. This forces players to compete for the very last item.

Each game consists of five matches. One match is completed when a player managed to collect the number of items required, which earns him/her 100 points. Both players are required to walk back to the starting position in order to start the next match. They can take their own time and only return to the square when they are ready. There is a LCD scoreboard back facing the players, where they will see the score when they are walking back to the starting position as shown. The player with a higher score after five matches, wins the game.

Four game scenarios (A, B, C and D) as shown in the Figure 3.12 were designed. In game scenarios A and B, the computer opponent will reproduce the average speed of the human opponent recoded during the trial game played before the actual experiment.

For explicit-dynamic balancing game scenarios B and D, each player has

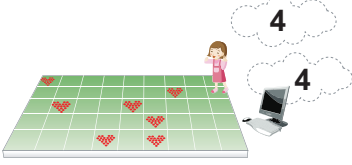
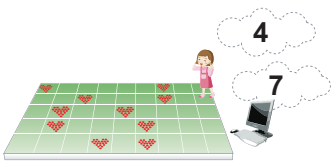
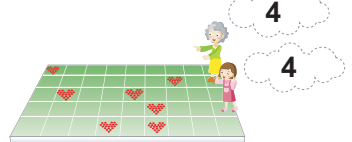
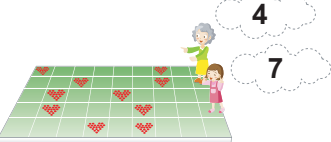
	Unbalanced	Balanced
Computer Opponent	 <p>A: Computer, Unbalanced</p>	 <p>B: Computer, Balanced</p>
Human Opponent	 <p>C: Human, Unbalanced</p>	 <p>D: Human, Balanced</p>

Figure 3.12: Four game scenarios of Tap Tap Hearts

to collect four items for the first match. The player who wins the previous match will have to collect additional n items, hence making the game more challenging for him/her. Various n numbers were experimented, and the increment of one item, $n = 1$ worked the best, in the sense that it increased the challenge of the game by a reasonable amount.

As the number of items required to win the game changes for B and D, the number of items required to win the game should change as well for game scenario A and C. In scenario A and C, the number of items that both players need to collect is increased by one per two matches. Thus, each player has to collect 4, 4, 5, 5, 6 items for first to fifth matches respectively.

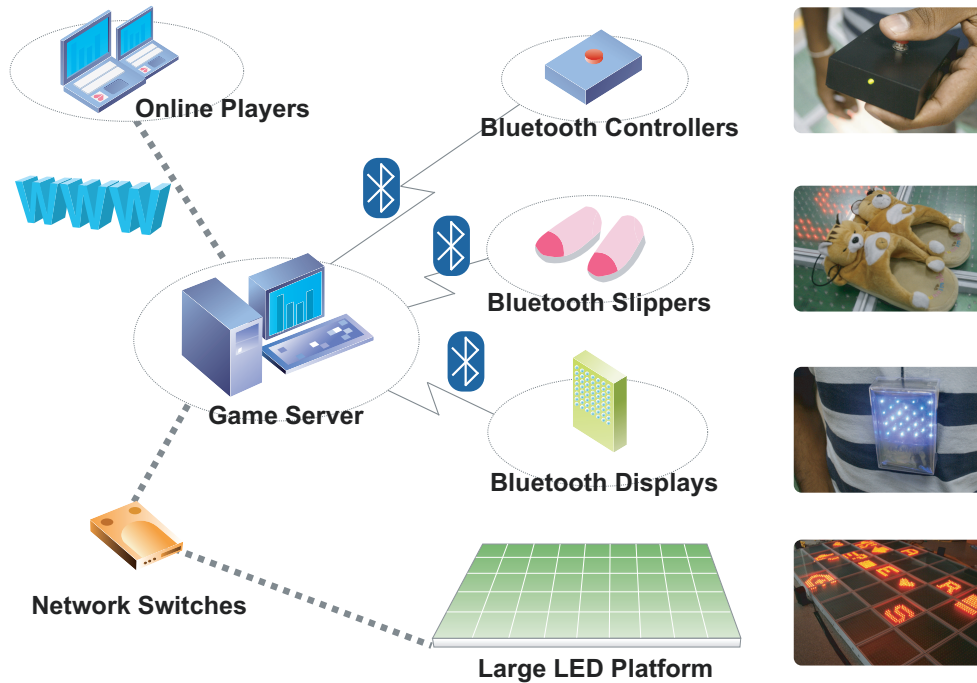


Figure 3.13: Physical play system architecture

3.4 Physical Play System Description

The physical play system architecture and block diagram are shown in Figure 3.13 and Figure 3.14 respectively. The components of the system are presented in this section.

The heart of the physical play system is a game server, which is responsible for handling inputs and outputs of the system in real time. The game logic resides in the server. The game server is connected to the Internet to synchronize the game play between the home system and the online player virtual clients. Inputs of the system include Bluetooth Controllers for trig-

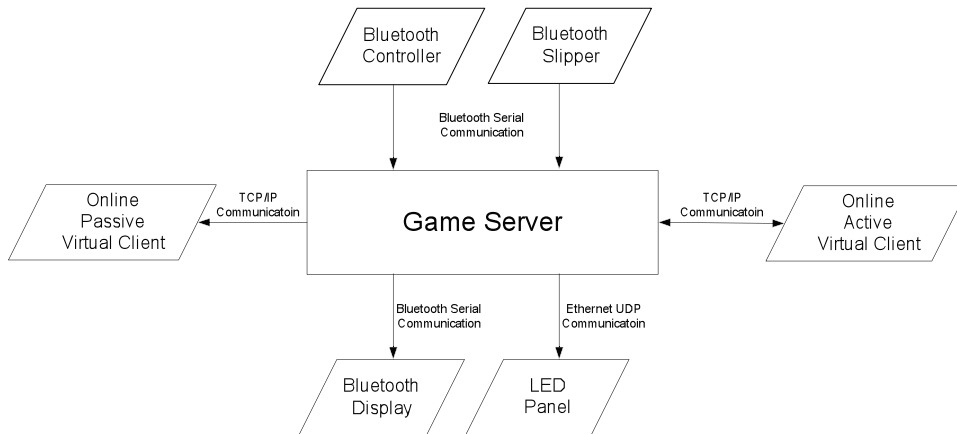


Figure 3.14: Physical play system block diagram

gering events in the game, Bluetooth Slippers with embedded RFID readers for tracking the position of the players, and control parameters from the online player virtual clients. Outputs of the system include 45 LED panels on the floor, each having 256 Ultra Bright LEDs, for displaying the objects and events of the game, lanyard style Bluetooth Displays for displaying individual player’s events, and a 3D online player virtual client for displaying the virtual world of the game. As the players move on the floor platform, their coordinates are tracked and translated to the virtual world in real time, creating a seamless link between physical and virtual worlds.

Figure 3.15 and 3.16 show the 45 LED platform displaying different light patterns.

Figure 3.17 shows the basic unit of the LED floor module, consisting three LED panels. This modular design allows us to build platforms of

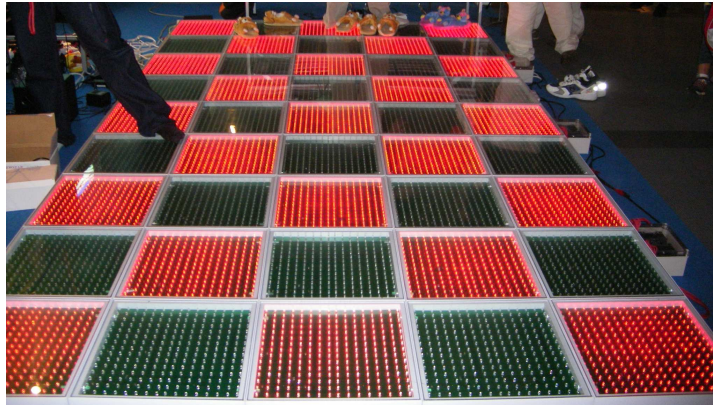


Figure 3.15: LED platform showing square patterns

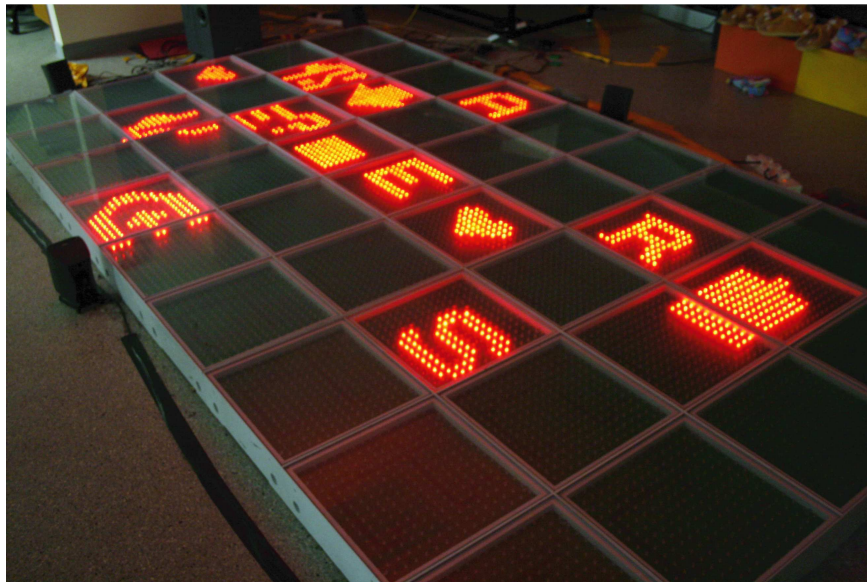


Figure 3.16: LED platform showing different patterns

varying sizes. The Ethernet UDP communication employed is also very scalable to address large number of LED panels. Figure 3.18 shows the 15 basic modules connected together to form the LED platform. Figure 3.19 shows lab members installing LED panels into the platform.

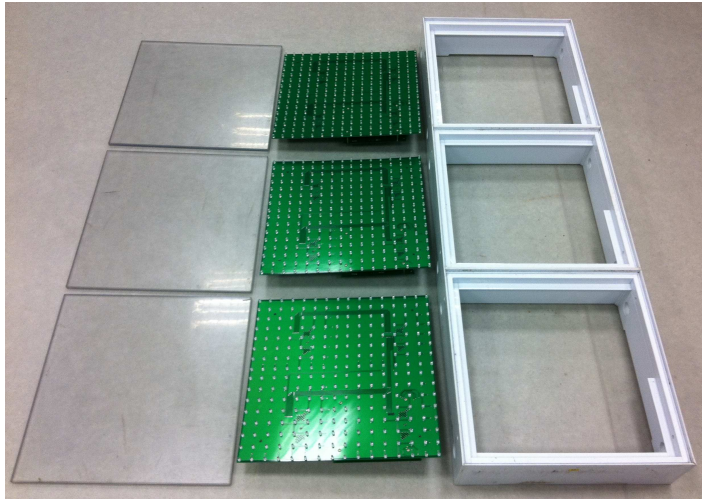


Figure 3.17: Basic unit of three LED panels module

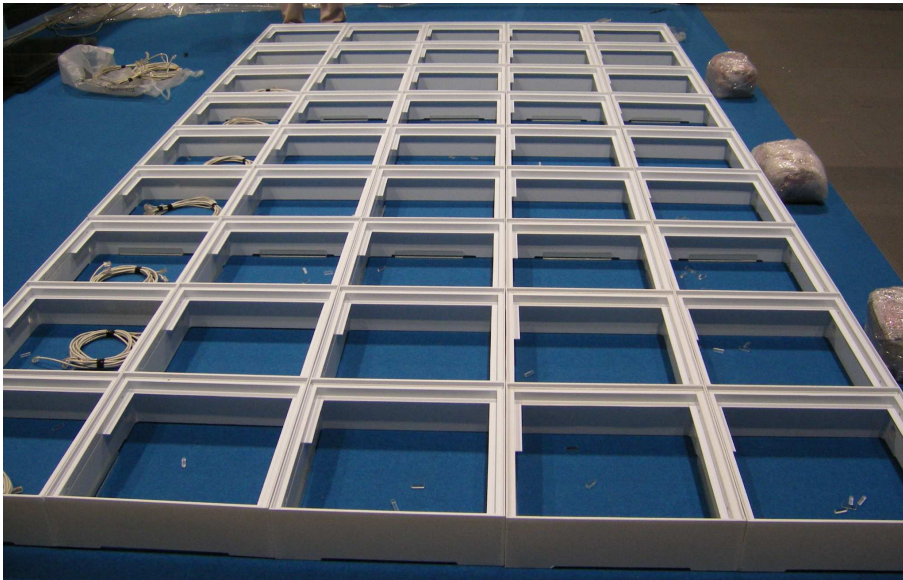


Figure 3.18: LED platform frame

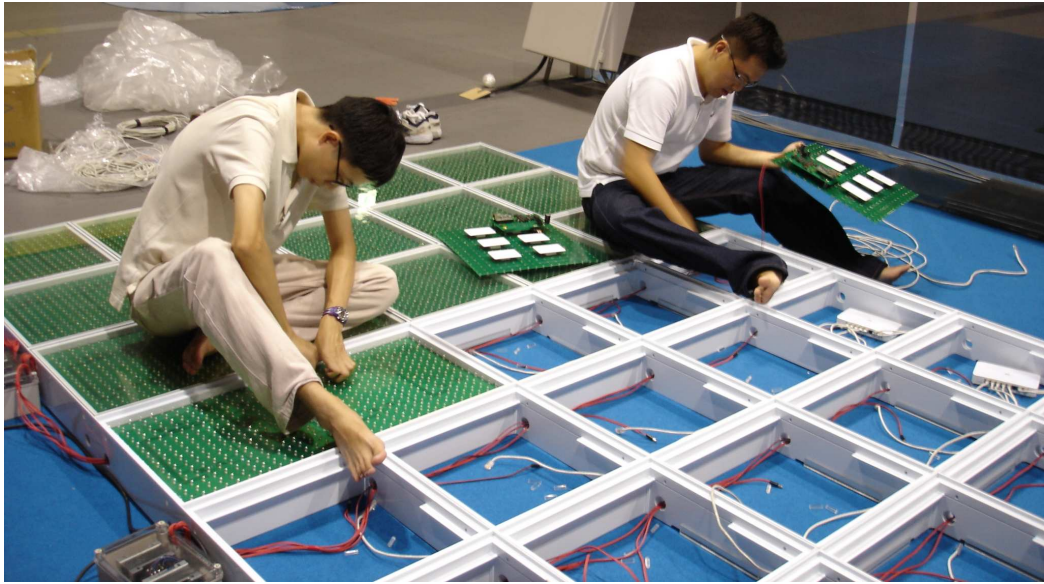


Figure 3.19: Lab members installing LED platform

Each LED Panel has one embedded Ethernet module, an EEPROM (8 Kbytes) and a LED driver microcontroller and a network microcontroller. The LED driver microcontroller is responsible for manipulation of images upon receiving the commands from the network microcontroller which is communicating with the embedded Ethernet module. Each embedded Ethernet module establishes a UDP data communication with the game server via network switches.

Each player has his own accessories Bluetooth Displays, Bluetooth Slippers and Bluetooth Controllers, which are connected to the game server through Bluetooth communication. As shown in Figure 3.20, for Bluetooth communication we are using Promi ESD02 device by Initium. This device can directly communicate with a microcontroller using UART port, but has to be first initialized and controlled using AT commands. We are using PIC 16F76 microcontroller to communicate with the Promi ESD02 device. In all the Bluetooth Controllers, Bluetooth Displays and the Bluetooth Slippers, we are using the same module to establish the Bluetooth communication.

3.4.1 LED Panel

Each LED panel has two printed circuit boards, the LED controller board and LED display board. The LED controller board has two main functions, the data communication with the game server and the manipulation of the LED images. The first function is described in the embedded Ethernet

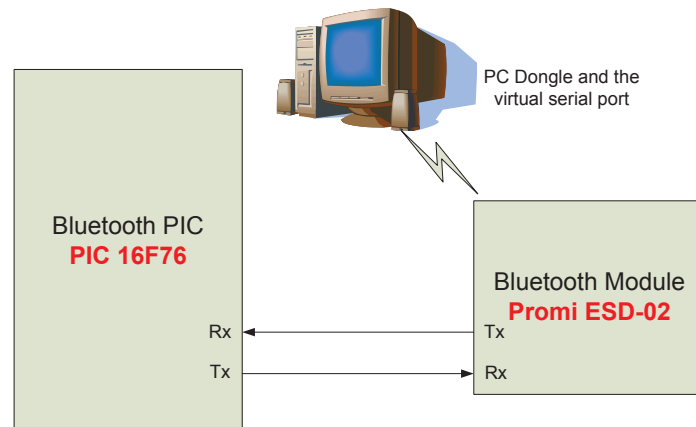


Figure 3.20: Communication between PC – Bluetooth module

section and the second function is described in the LED Image Manipulation section. Below each LED panel, there are six RFID tags used for detection of the player's position. The details of how the detection works is presented in Section 3.4.4.

Figure 3.21 and Figure 3.22 show the top and bottom view of a LED display printed circuit board (PCB) respectively. For schematic and PCB drawing of LED panel display, please see Appendix F. Figure 3.23 and Figure 3.24 show the top and bottom view of a LED controller printed circuit board respectively. For schematic and PCB drawing of LED panel controller, please see Appendix E. Figure 3.25 shows the cable connection between LED controller board and LED display board. Figure 3.26 shows the back view of a LED panel with six RFID tags (one hidden between the controller and display board).

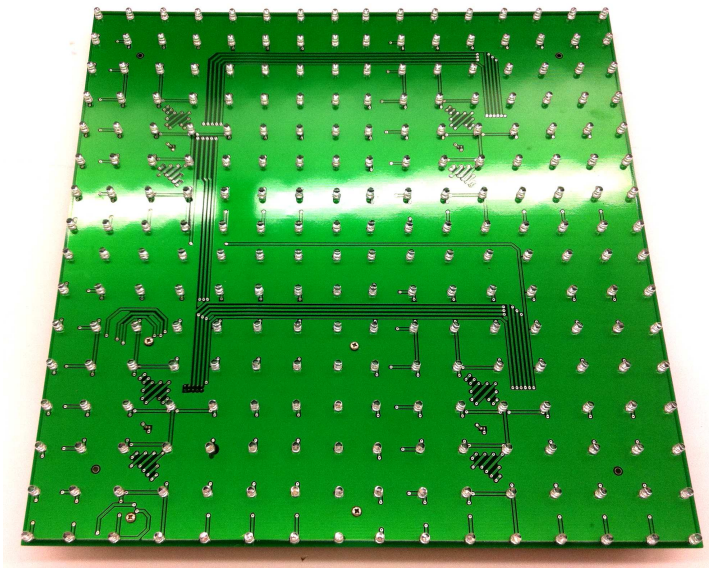


Figure 3.21: Top view of a LED display PCB

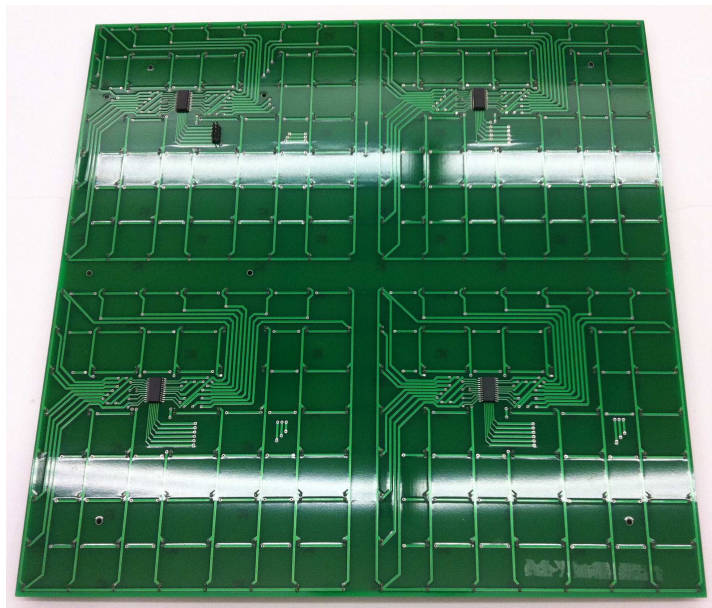


Figure 3.22: Bottom view of a LED display PCB

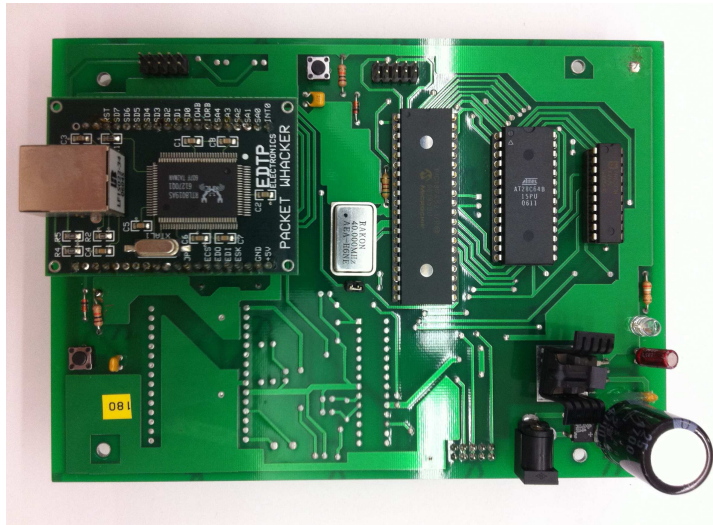


Figure 3.23: Top view of a LED controller PCB

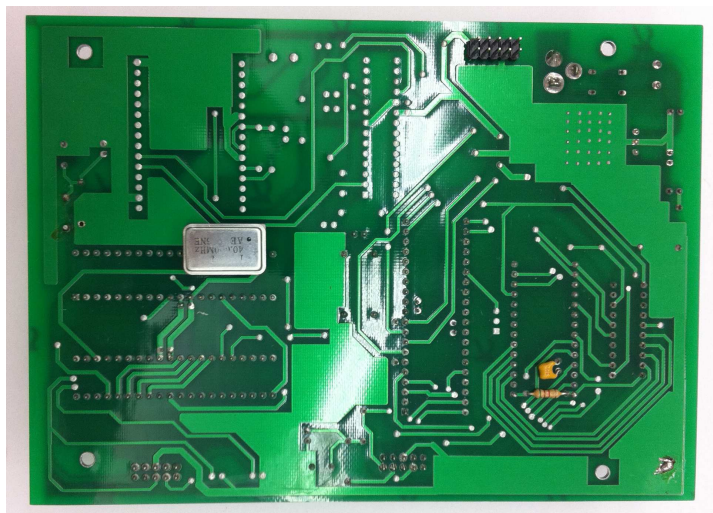


Figure 3.24: Bottom view of a LED controller PCB

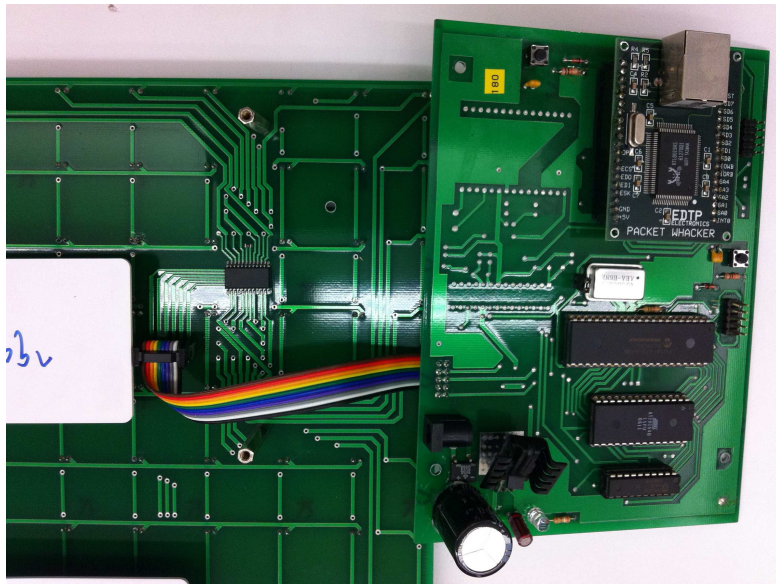


Figure 3.25: LED controller and display board connection

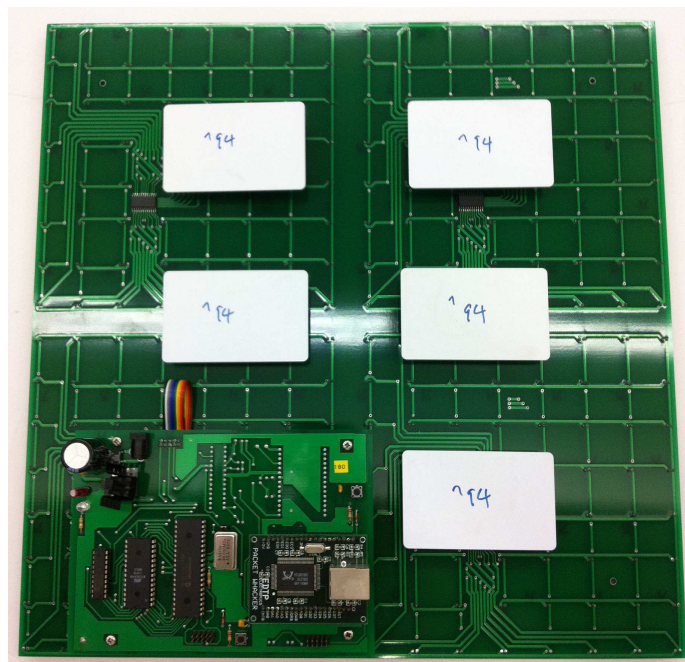


Figure 3.26: Bottom view of a LED panel

3.4.1.1 Embedded Ethernet

Connection between the 45 LED display boards and the game server is via Ethernet connection. The embedded Ethernet module we are using is EDTP Packet Whacker from EDTP electronics. This is a 10Base-T Ethernet module that allows adding Ethernet capability to any microcontroller or microprocessor including the Microchip PIC which is used.

The Packet Whacker is based on the Realtek RTL8019AS Ethernet IC. All pins of the RTL8019AS that are used to implement Ethernet connectivity with a microcontroller are brought out to standard .100 inch center holes. Onboard status LEDs, 20MHz crystal and consolidated magnetics/RJ-45 in the form of an LF1S022 make the Packet Whacker easy to deploy in any application.

Starting IP address from 192.168.0.151 – 192.168.0.195 reserves the IP's for display boards. All embedded modules are pre hard coded with a unique IP address and a MAC address. This module is capable of plug and play detection and auto initialize if it fails to initialize at the beginning.

To control the behavior we use the PIC 18F452 micro-controller. Below (Figure 3.27) is the flow chart of the micro controller firmware. Address Resolution Protocol (ARP) is used to locate the Ethernet address associated with a desired IP address. Internet Control Message Protocol (ICMP) messages are typically generated in response to errors in IP datagram, for

diagnostic or routing purposes. For example, the ping function is implemented using the ICMP “Echo request” and “Echo reply” messages. `udp()` function is responsible for receiving the data from game server and sending them to the LED PIC using serial communication between the two PIC micro-controllers.

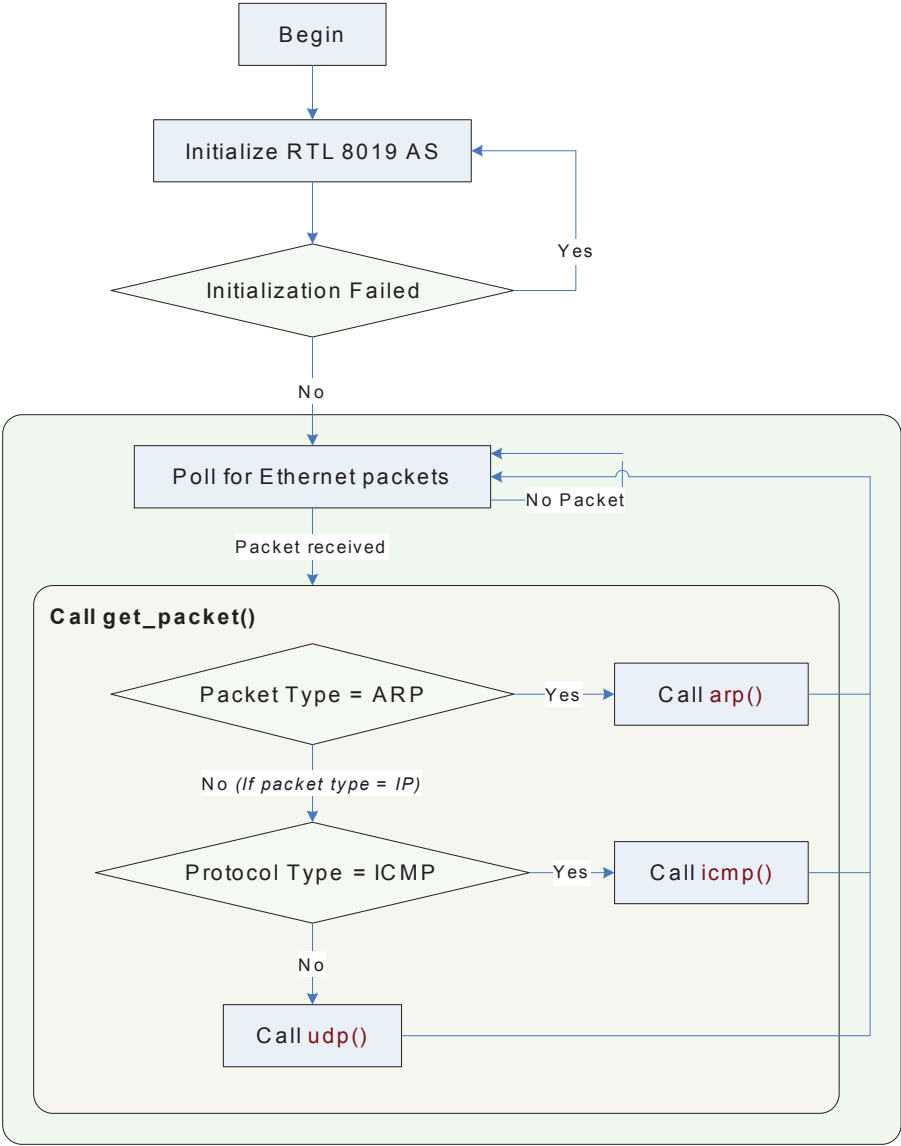


Figure 3.27: Ethernet Microcontroller - Flow Chart

3.4.1.2 LED Image Manipulation

MAX 7219 Serial Data communication

There are a total of 256 LEDs on each LED board. It is not possible to use one microcontroller to control all 256 LEDs at one time, so 4 MAX7219 chips are used to control 64 LEDs each. As shown in Figure 3.28, all the MAX 7219 ICs are serially connected and each of them aid in directing the serial data to the next MAX IC's DIN pin. The ICs arrangement on the LED panel is shown in Figure 3.29. We are using non-decode mode for all the ICs because we don't use them as seven segment drivers.

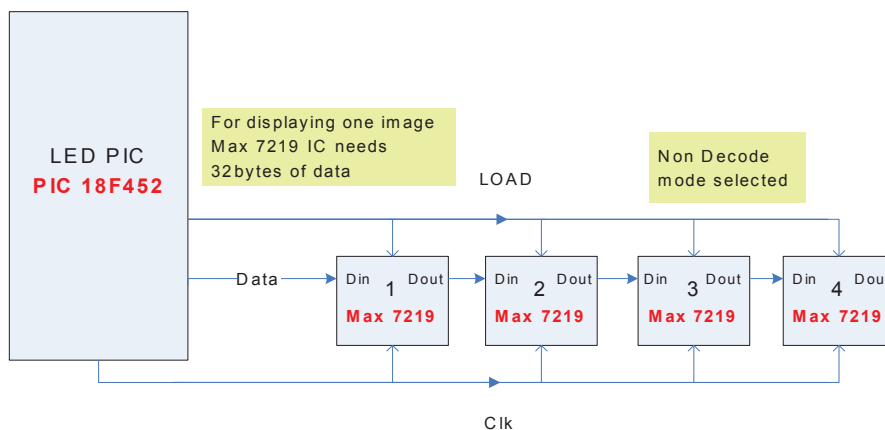
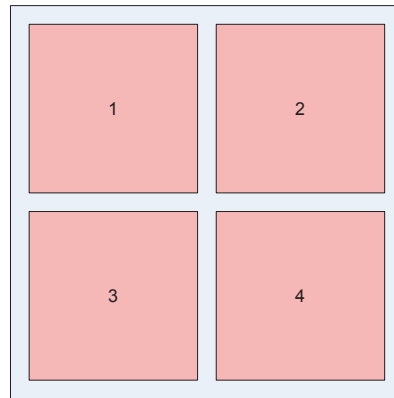


Figure 3.28: MAX 7219 Serial Data Communication

Storing and displaying images from the EEPROM

As shown in Figure 3.30, in this project we are using the AT28C64B EEPROM which is capable of storing 256 images. We can use our programming toolkit to draw the image and sends the data to burn onto the EEPROM located on each controller board. Each image is stored as 32 byte



Display Board & Max IC arrangement

Figure 3.29: MAX 7219 arrangement in a single display block

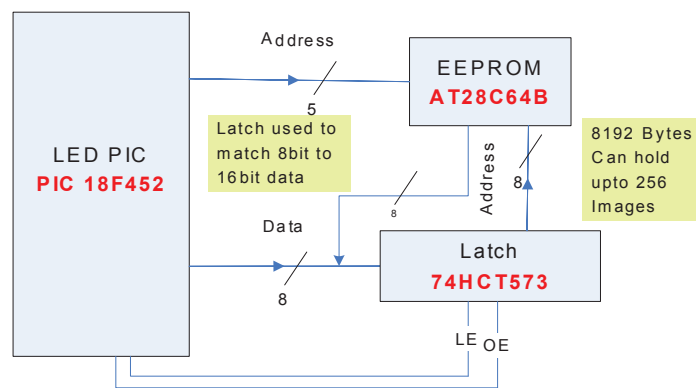


Figure 3.30: EEPROM, Latch and LED Microcontroller Arrangement

words in the EEPROM so that 256 images can be held in the total memory of 8 Kbytes.

Figure 3.31 is the mapping of EEPROM and the display board. Right hand side represents the EEPROM internal structure and left hand side represents the corresponding image pattern displayed on the LED board.

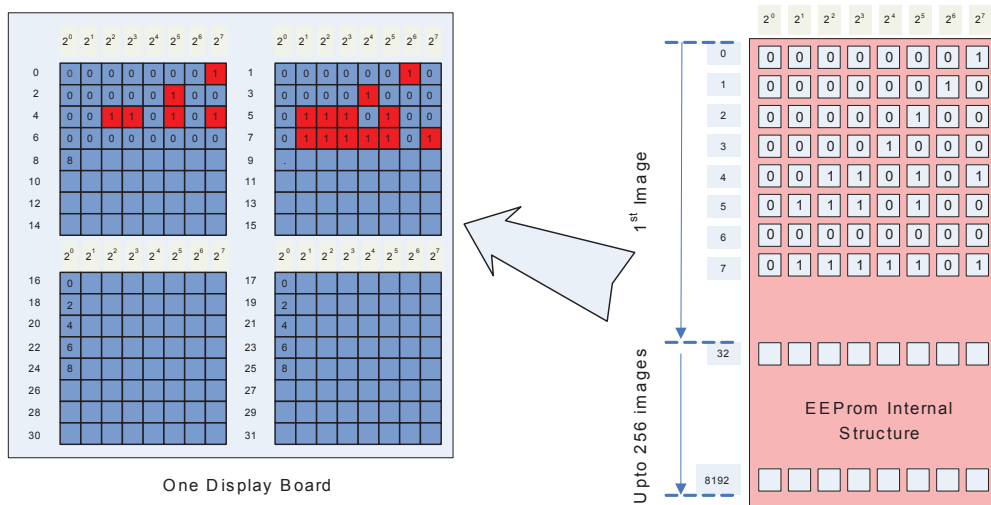


Figure 3.31: EEPROM data structure

3.4.2 Bluetooth Controllers

Below (Figure 3.32) is the firmware flowchart of the Bluetooth controller.

As the user presses the button on the Bluetooth controller, the microcontroller (PIC 16F76) will send the Gun_ID as a character to the game server via Bluetooth connection. In this way, the game server recognizes the player who launches the laser because each Gun_ID is linked to a Player_ID.

Figure 3.33 shows the bluetooth controller case and Figure 3.34 shows the inside view of the case. Figure 3.35 and Figure 3.36 show the printed circuit board of the Bluetooth Controller. For schematic and PCB drawing of Bluetooth controller, please see Appendix A

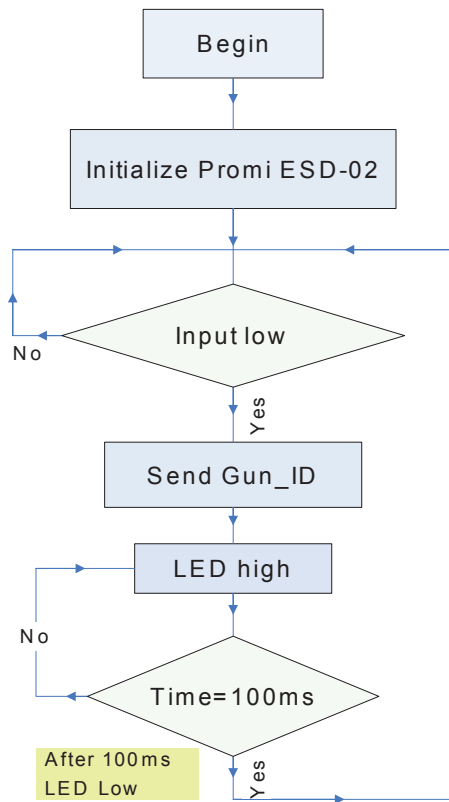


Figure 3.32: Bluetooth Controller Flow Chart



Figure 3.33: Bluetooth Controller case



Figure 3.34: View inside Bluetooth Controller case

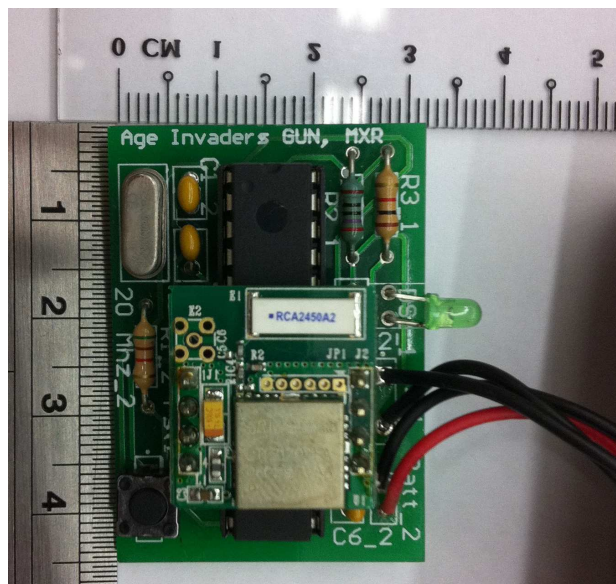


Figure 3.35: Top view of Bluetooth Controller PCB

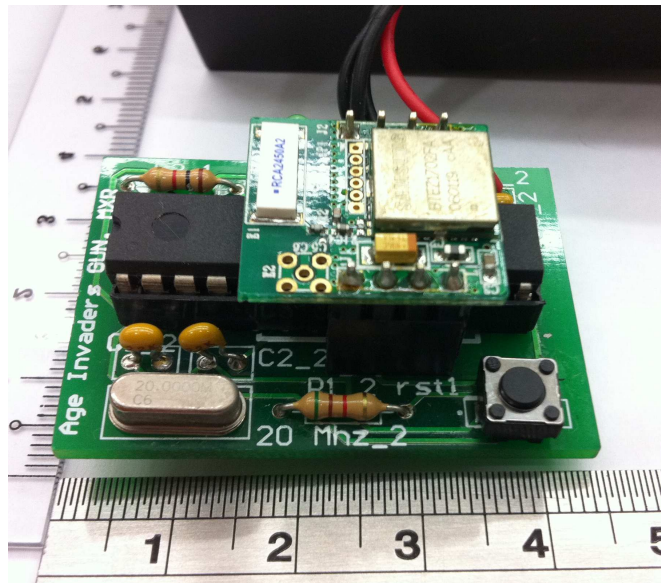


Figure 3.36: Bluetooth Controller PCB

3.4.3 Bluetooth Displays

Figure 3.37 shows the firmware flowchart of the Bluetooth display.

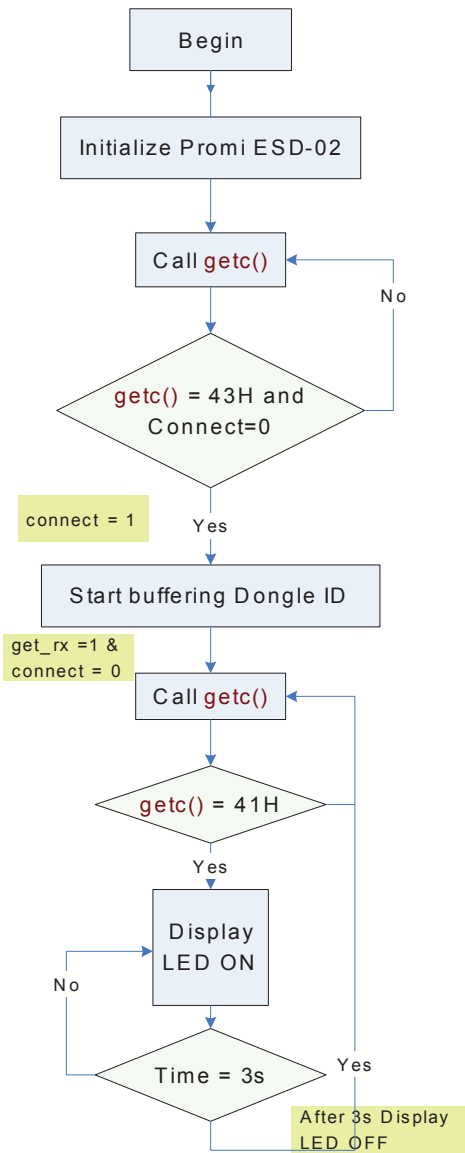


Figure 3.37: Bluetooth Display Flow Chart

The Bluetooth Display microcontroller polls for a character from the game server to be received via Bluetooth serial connection. Upon receiving the character, it displays a constant image pattern (Figure 3.38) for three

seconds indicating that the player is hit by a laser. Figure 3.38 shows the Bluetooth display worn by a player. Figure 3.39 and Figure 3.40 show the printed circuit board of Bluetooth display in front and back views respectively. For schematic and PCB drawing of Bluetooth display, please see Appendix B



Figure 3.38: Bluetooth Display worn by a player

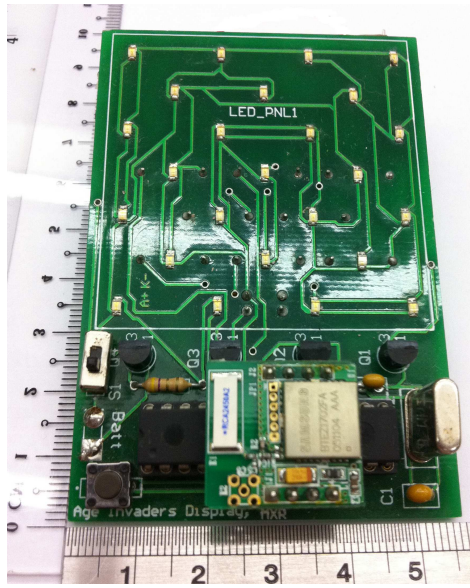


Figure 3.39: Top view of Bluetooth Display PCB

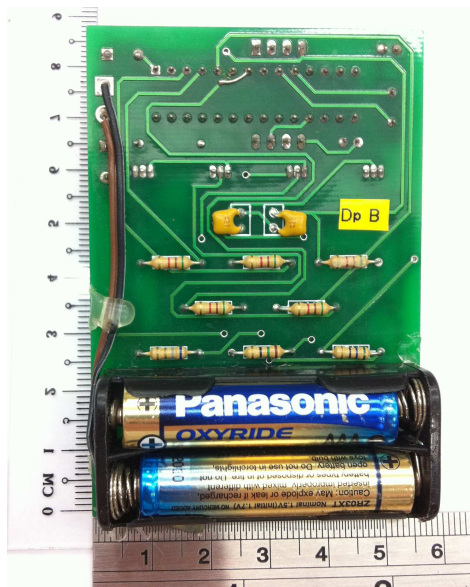


Figure 3.40: Bottom view of Bluetooth Display PCB

3.4.4 Bluetooth Slippers

As shown in the Figure 3.41 below, series 2000 micro reader by Texas Instruments is used to read the transponders placed under each LED panel. It reads the Block_ID which the player is standing on, and sends it along with the Player_ID via Bluetooth serial connection. The RFID reader and PIC 16F76 microcontroller circuit is hidden in a small compartment on a slipper and the antenna is placed in the sole.

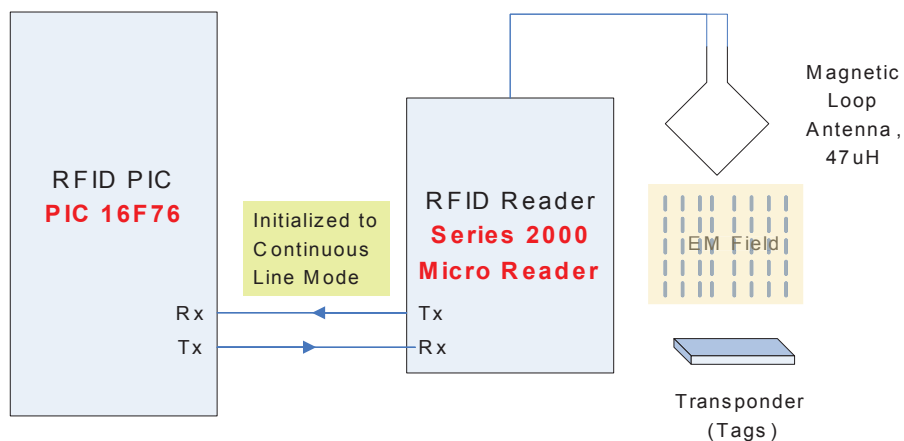


Figure 3.41: RFID Tag detection and communication with microcontroller

Below (Figure 3.42) is the firmware flow chart for the Bluetooth slipper.

Figure 3.43 and Figure 3.44 show the top and bottom view of the Bluetooth slipper printed circuit board. For schematic and PCB drawing of Bluetooth Slipper, please see Appendix C

In a later prototype, two pressure sensors was added at heel side and toe side of the slipper. The resistance of the pressure sensitive pad is of the order of Mega ohms in the absence of pressure and drops to a few kilo to hundred

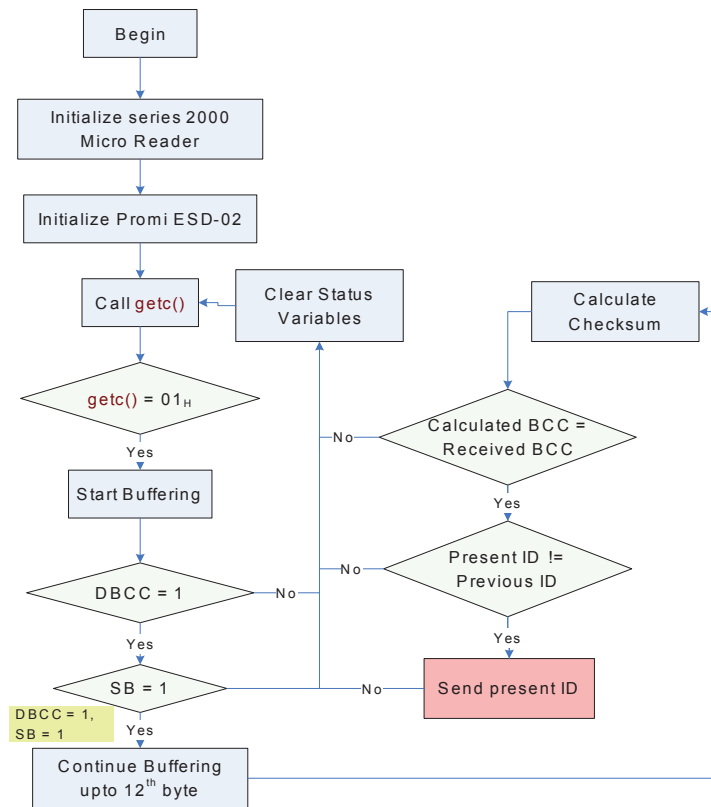


Figure 3.42: Bluetooth Slipper Flow Chart

ohms when low or high pressure is applied. The analog pressure values are converted by an analog to digital module in the PIC micro-controller to 8-bit digital data and transfer to a host application on the game server through Bluetooth connection.

Figure 3.45 and Figure 3.46 show the top view of the new Bluetooth slipper printed circuit board with and without the RFID microreader respectively. Figure 3.47 shows the bottom view of the circuit. Figure 3.48 shows the connection between the Bluetooth slipper printed circuit board with battery, antenna and two pressure sensors. For schematic and PCB

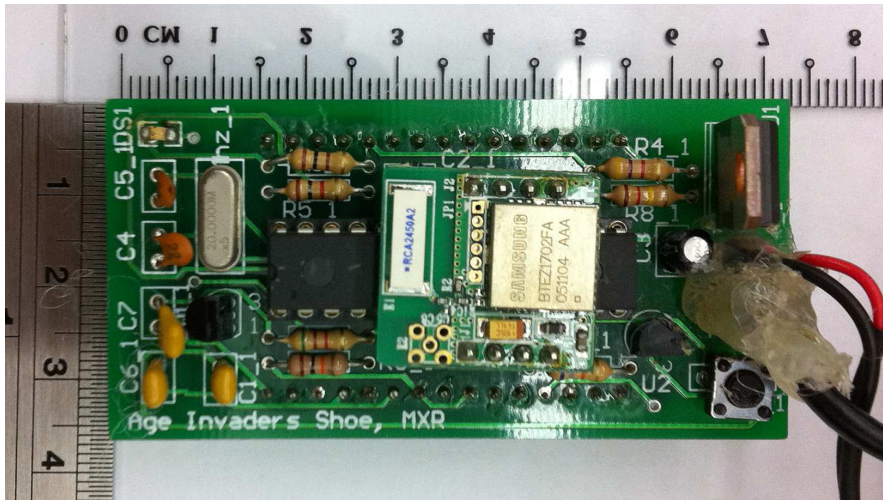


Figure 3.43: Top view of Bluetooth Slipper PCB

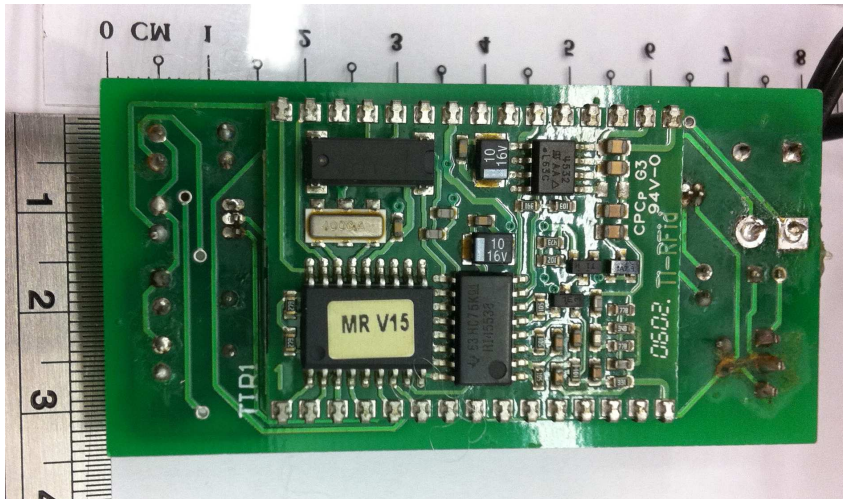


Figure 3.44: Bottom view of Bluetooth Slipper PCB

drawing of new Bluetooth Slipper, please see Appendix D

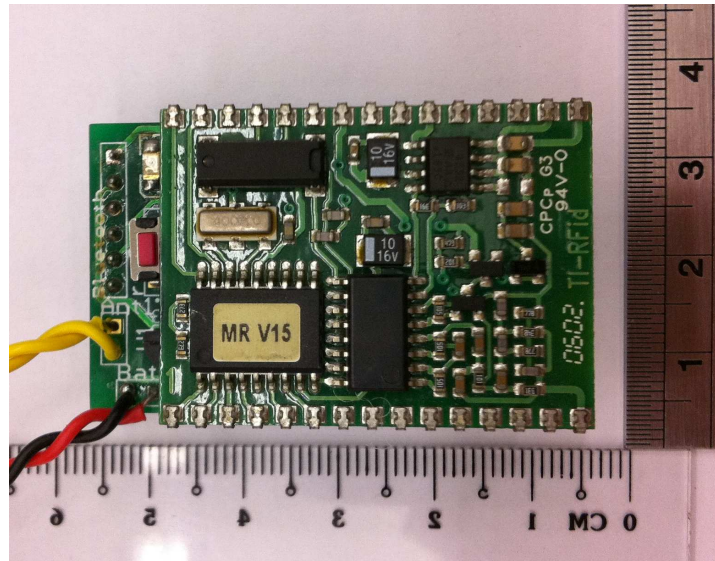


Figure 3.45: Top view of new Bluetooth Slipper PCB with RFID microreader

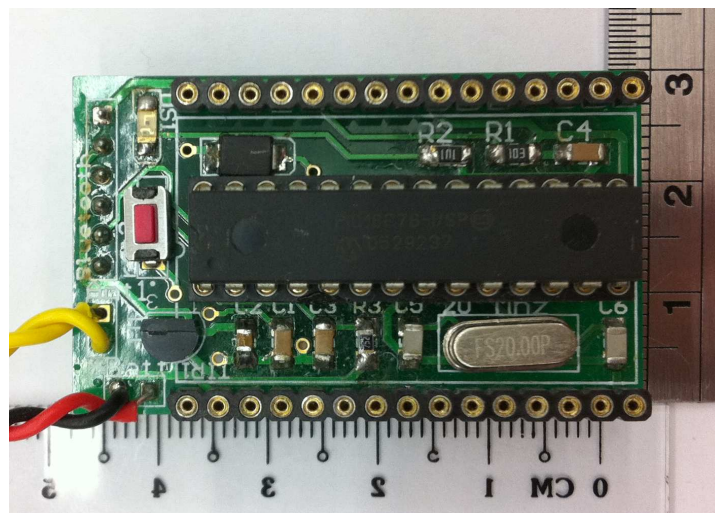


Figure 3.46: Top view of new Bluetooth Slipper PCB

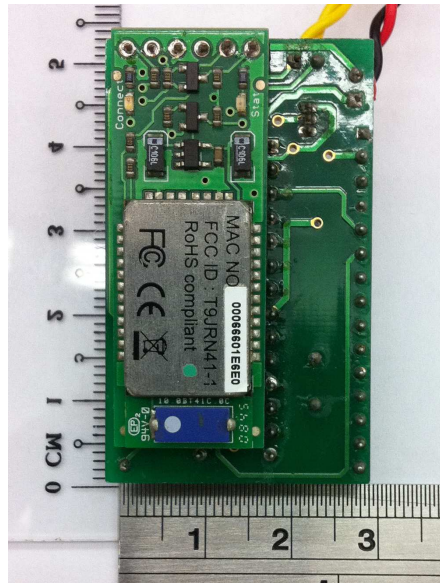


Figure 3.47: Bottom view of new Bluetooth Slipper PCB

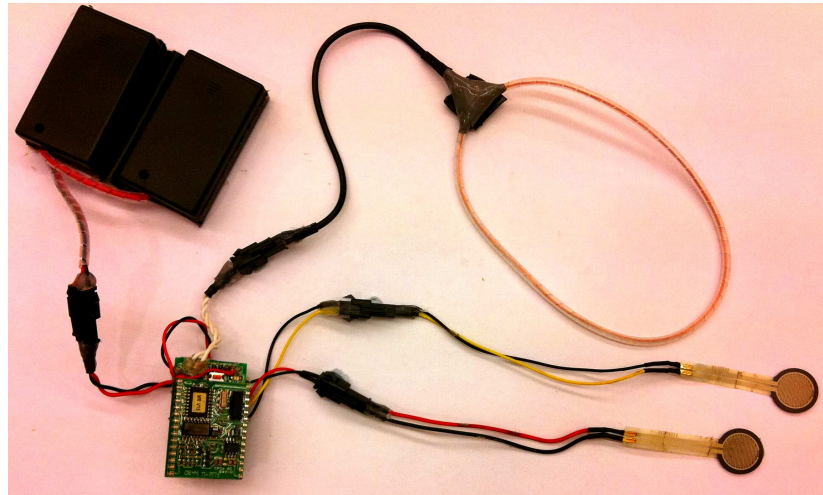


Figure 3.48: Bluetooth Slipper PCB connections

Figure 3.49 shows the printed circuit board is housed in the slipper's bunny head. Figure 3.50 shows a customized bunny slipper with velcro strap for easy removal and installation of the electronic components. Figure 3.51 shows the placement of the RFID antenna and front pressure sensor in the sole.



Figure 3.49: PCB is housed in the slipper's bunny head



Figure 3.50: Velcro strap for easy removal and installation

Figure 3.52 shows the exterior view of the Bluetooth slipper

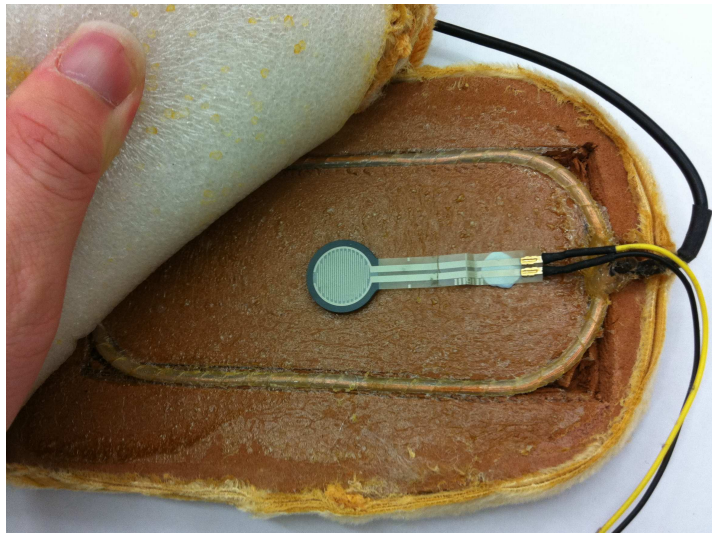


Figure 3.51: Placement of antenna and pressure sensor in the sole

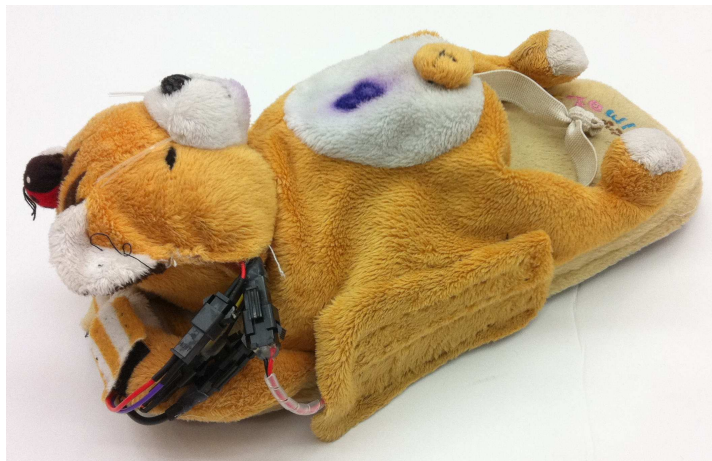


Figure 3.52: Exterior view of a Bluetooth Slipper

3.4.5 Online Player Virtual Client

The virtual client is an application that allows online players to be connected to the game as either a passive client or active client. The virtual client should run on a personal computer connected over the internet to the game server. The server will exchange data with all its connected clients to allow them to see the game updated in real time. Active clients can participate

in the game by drag and drop items onto the virtual game board, which will appear on the physical board. Passive clients can only view the game. OpenGL libraries are used for manipulation of the 3D graphics and the application is coded in C++.

3.4.6 Game Server

The Game Logic of the game Age Invaders resides with the central Game Server to serve as the brain and soul of the overall system. It ensures the synchronization with the virtual player clients and the physical devices. The Game Logic processes all the inputs that the Game Server receives, and produces the correct graphical data to display.

Issues such as processing client data, scoring, health levels, collision detection, etc are all handled and processed by Game Logic. With multithreading, the Game Logic is also able to animate the laser shooting, explosion and footprint pattern. A Game Database is maintained by the Game Logic to register the status of all game elements.

3.4.6.1 Game Database

Game Database caches the status of all elements in the game, such as the object within a particular block, the current position of a player, the status of the game, etc. These are essential when incoming data is processed and a correct response is made by Game Logic. Game Logic checks the Game

Database, recognizes the situation accordingly, updates the database and finally makes an appropriate response. There are 3 main components in the Game Database: Block Status, Player Status and Game Status.

Block Status

Each LED panel is considered as a block in the game space, and assigned with an Id. Hence on the Game Board there are only 45 distinct positions identifiable by the system. For software design and implementation, a class called BlockStatus is used store the information of the types of objects occupying each game space in real time. The objects could be Invader, Defender, Laser, Barrier, Bonus, and Footprint.

Player Status

Since the system needs to always keep check of the health status, scoring of the physical players, it is necessary to have a data structure to store all related information of a player. The class PlayerStatus is aimed for this purpose. It wraps the information such as player Id, health status (bonus), score, position, old footprint position and new footprint position. Table 3.6 explains the attributes of PlayerStatus. An array of 4 PlayerStatus elements constructs the Player Database.

Game Status

When either the invader team or defender team lose, the game is considered over. Since the system should not allow the players to trigger any events like laser shooting or putting a barrier, a global variable GameS-

Variables	Type	Description
<i>Pid</i>	int	Player Id
<i>Role</i>	int	Role of player, either Invader or Defender
<i>Health</i>	int	Health level of a player. Increased when bonus is collected and decreased when player is shot by enemies or Invader fails to follow footprint in time
<i>Score</i>	int	Score of player. Same for one team. Increased when player shoots opponents
<i>Position</i>	int	Position of player. Updated when player moves from one block to another
<i>OldFootprint</i>	int	Position of old footprint for Invader
<i>NewFootprint</i>	int	Position of new footprint for Invader
<i>LastLaserTime</i>	DWORD	Timestamp of the last laser by the player. To constraint player from continuous shooting. Updated each time player shoots.

Table 3.6: Attributes of PlayerStatus

tatus is used to detect when the game is finished. As the game is going on, GameStatus is set to START. When either side loses or the game is manually terminated, GameStatus is set to END.

3.4.6.2 Player Logic

Player Logic takes care of all the behaviors of physical players, including moving, shooting, and collecting bonus. These behaviors occur physically on the game board, and they are communicated to the server by sending data over Bluetooth.

Bluetooth data

This process determines if the data coming from Bluetooth serial port is from the Bluetooth Controller or Slipper.

Player Moves

The action of a player moving from one block to another can be divided into 2 actions: player leaving his original position and going to a new block. It is noted that player can only move to a block where there is (1) no object, (2) his own footprint, or (3) bonus.

Figure 3.53 shows a player trying to avoid an approaching laser and moved to an adjacent empty square. Figure 3.54 shows a child moved to collect his footprint. Any movement violating these restrictions is considered invalid. In Figure 3.55, a child trying to move over to a square which is occupied by another player. This violates rule 1 and thus the player cannot move. Player Logic carries out validity check every time a player intends to move.



Figure 3.53: Player moves to an empty square to avoid incoming laser.



Figure 3.54: Player moves to collect footprint



Figure 3.55: Square is occupied and player is unable to move

Player Shoots

By accessing the game rule, it is found meaningless to allow a player to keep shooting lasers all the time. Players are encouraged to move around and enjoy the fun, instead of just standing and triggering laser. Hence

some constraint is imposed on player shooting behavior: (1) Players are not allowed to shoot until their last laser terminates, either explodes or disappears on the game board. (2) Players are not allowed shoot a second laser within 2 seconds.

Player can only shoot when the two rules above are satisfied together. Whenever player triggers to shoot, a validity check is carried out. Any trigger by player violating this restriction is ignored by the Game Logic. Figure 3.56 gives an example of a case where player is unable to launch laser as he had launched an earlier laser less than 2 seconds ago. Once a shooting is checked to be valid, the path of the laser would be predicted and then a Laser Thread would created to simulate the traveling of a laser. Figure 3.57 shows a child successfully launched a laser.

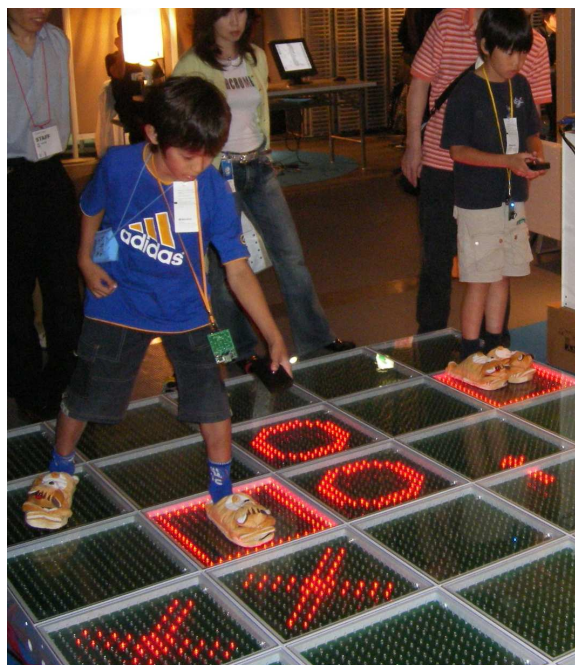


Figure 3.56: Player is unable to launch laser



Figure 3.57: Player is successful in launching laser

3.4.6.3 Laser Logic

Laser Logic takes care of the behaviors of a flying laser, such as hitting a block, leaving a block, triggering explosion, and terminating. These behaviors are simulated within the virtual game space and then actuated by animating LED display, playing sound and synchronizing virtual player display.

Laser Thread

After a player successfully triggers a fire, a new laser thread is created and starts to simulate the traveling of a laser, taking care of all Laser Logic. Then the main logic thread can be released to handle other events.

Synchronizing with LED Display

One of the challenges faced by the Laser Thread is to animate the LED display on Game Board and make sure the laser transition between blocks on the display is smooth. As discussed earlier, the blocks are independent of each other and loosely coupled by connecting via a switch. The transition of laser between blocks should be handled by the Laser Thread with precious timing.

Synchronizing with Virtual Player

Whenever the laser shifts once, the Laser Thread is supposed to synchronize with the virtual player client by calling the function *Laser_Sync_Client()*. This function is taking the block id and offset within the block as argument and converts them into OpenGL coordinates for the client.

Collision Detection

As Laser Thread is simulating a laser flying, it should check for collision by every pixel. When the laser hits a block, the Laser Thread check the object within the block to determine whether to let the laser go ahead or trigger explosion based on the following rules:

- When a player's laser hits an opponent, it terminates, and then triggers explosion on the block of the victim. Health level of the victim is reduced, and score of the shooter is increased.
- When a player's laser hits a partner or a barrier, it terminates, and then triggers explosion.
- When a player's laser hits a bonus, the bonus is removed and laser goes on.

Figure 3.58 shows a laser hitting the barrier placed by a virtual player and exploded.

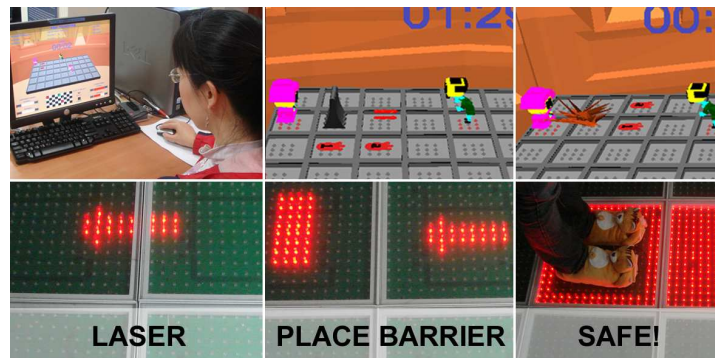


Figure 3.58: Laser hitting a barrier and exploded

3.4.6.4 Virtual Players Logic

In the process where the virtual players are executing an action, the data will first be sent to the server and processed before sending it back to the virtual players. Only when the virtual user mode received the data from the server, the client 3D display will be updated. This is to ensure that

the displaying of the 3D graphics for the game play is being carried out in real time. It is also to ensure that all the virtual players will be viewing the game play with the same progress speed. Therefore any actions by the virtual players will be appearing at the all the virtual user mode displays well as the hardware side at almost the same time.

Placement and removal of helper objects

During the game, virtual players are allowed to place helper objects onto the game board to assist the physical players. In the current game system, there are two objects that the virtual players can place: the bonus and the barrier. The bonus can help increase the health of the players while the barrier can prevent a laser from hitting the player standing behind the barrier. When it is detected to be a placement of object, the function *Helper_Puts_Barrier()* for barrier or *Helper_Puts_Bonus()* for bonus will be called to check if the location that the virtual players wanted to place the objects are available, based on the following rules:

- For barrier, if the grid does not contain any players, any footprints or any other helper objects, the server will allow the barrier to be placed.
- For the bonus, if the grid does not contain any players or any other helper objects, the server will allow the bonus to be placed.

Adjustment of game statistics

The game statistics such as the invaders' footprints speed and the players' laser speed are allowed to be adjusted by the virtual players during the game play. Every time when the function *Process_ClientData()* is being called, the server will do a check on the game statistics by calling *Helper_Adjusts_Speed()*. In this function, the server will update the respective speeds of the game play with the speed stored in the data structure sent over from the virtual players. The array variable *action[3]* is being set to 1 whenever the virtual user mode sends an updated game statistics over to the server. The server will then send these statistic values back to the virtual players acknowledging its changed and set the array *action[3]* back to 0. When the virtual user mode received the new statistic values from the server, it then will change its 3D display of the game statistics.

Figure 3.59 shows the virtual client interface, where the player can adjust the game parameters such as the footprint and laser speed on the bottom left and right corner of the screen.

Synchronization of VR coordinates

The main game platform of the Age Invaders is a game board of 45 LED blocks. On the server side, each block is assigned a block ID. The position of the players and the objects are being determined and assigned in terms of the block ID. On the other hand, the virtual user mode determines and assigns the position of the players and the objects in a 3 axis coordinates

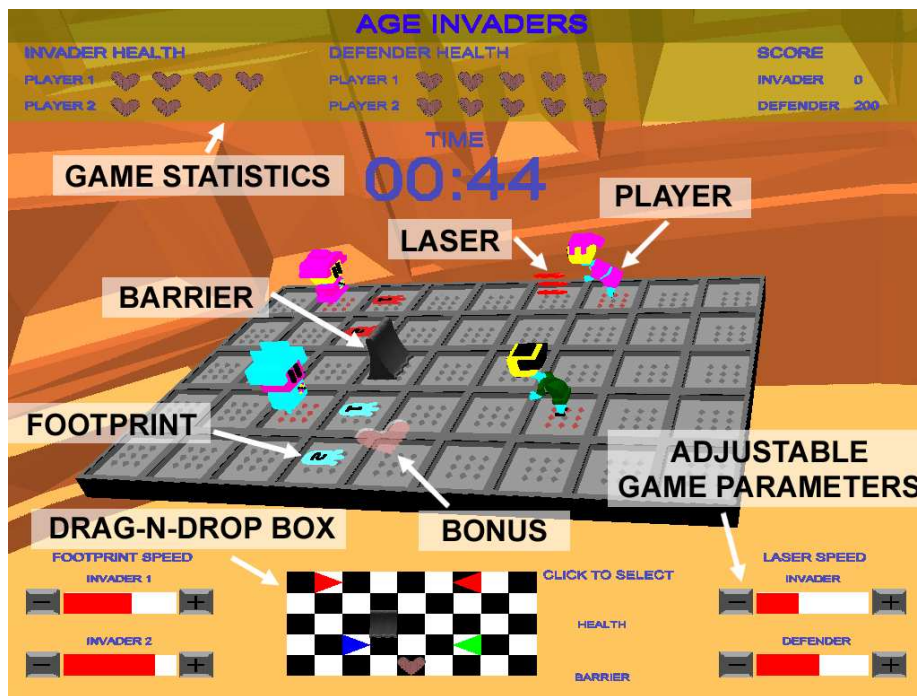


Figure 3.59: Adjustable game parameters in virtual client interface

format. They are the x-axis, y-axis and z-axis. This is due to the nature of the OpenGL programming where the 3D objects are being rendered in the 3 axis coordinates format. As the 3D display of the virtual user mode is a total replication of the actual game events, there is a need to synchronize the coordinates with the block IDs. Conversion functions are written in the game logic to convert the positions from block IDs to coordinates before sending them to the virtual user mode for display. Figure 3.60 shows the seamless link between the physical game world with the online virtual world.



Figure 3.60: Synchronization of physical world and virtual world

3.4.6.5 Invaders' Footprint Logic

In Age Invaders, only the invaders will have the footprints and they will have to remain in the grids with footprints. The objective of introducing the footprints is to create more challenge for the young players. Each invader will have 2 footprints for them. In any time when they are not in the grid that has their footprint on it for a certain period, their bonus will be deducted. This period is determined by the invaders' footprint speed of the game statistics. This statistics can be adjusted by the virtual players at any time.

Initialization of Footprint

Each invader will have a separate thread to generate his/her footprint on the server. In the thread, the function *Display_Footprint()* is being called.

The footprints will first be initialized at the grid that the player is standing on. It will then be generated once by calling *Generate_Footprint()*. Unless the player is not stepping on either of the footprints or the player is dead, the footprints will be kept generating until the server is closed or the game ended.

Generation of Footprint

The function *Generate_Footprint()* is to generate new location grid for the footprints. A random number between 1 to 4 is selected. It represents the 4 grids (top, bottom, left right) directly next to the grid that is stored in variable *NewFootprint*. When a number is chosen, a check is done on that grid by calling *Check_FPNewPos()* to see if the footprint can be allocated. The conditions for allocating the footprint is that there must not be any players on that grid, there must not be a barrier on the grid, there must not be any footprints on the grid and there must not be any laser at less than a grid distance traveling towards the grid.

3.4.7 Software Libraries and Toolkit

The software libraries and toolkit were developed to allow artists and designers, who may not be proficient in C++, to program the Age Invaders system easily. The software libraries and toolkit allow them to program interactive games and experiences without the knowledge of the firmware and hardware details of the system.

A C++ library was developed using Visual Studio, which provides an application programming interface (API) for the floor display platform. This library communicates to the platform via Ethernet using the UDP protocol. Two libraries were built. The “Tier 1 library” is a collection of functions that serve as an interface between the programmer and the platform. It allows the programmer to access the instruction set of the firmware without knowledge of the exact bytes that need to be sent. The “Tier 2 library” allows the programmer to regard the entire platform as a single entity. This library lets the programmer feel as though she is programming something similar to a computer monitor instead of a platform that consists of many individual blocks. The library handles shifting of images across blocks automatically. In the tier 2 library, an image class, `AllImage`, is defined. This class handles all the manipulation of images on the board. It has parameters such as picture number, x and y coordinates, layer, type, and priority. Several functions allow the programmer to alter these parameters and manipulate the images.

The library layer is coded in the C++ language, and thus requires a programmer who is adapt at C++ to program new applications. In addition, it does not update the boards automatically. Every time a change is made, the programmer has to update it accordingly. A toolkit was thus created in MAX/MSP visual software programming environment to help to simplify the programming task. MAX/MSP supports both high level and low level

programming. It allows programmers and engineers to program in the C and C++ languages and designers and artists, who may not be proficient in programming language, to program in a simple visual programming environment. External objects were created in the MAX/MSP environment, which allows the programmer to communicate with the floor platform easily as well as to retrieve input from various Bluetooth devices for example the body display, shoes and controller. To use these objects, the user simply clicks on the object box and types in its name. The designer can also use any existing objects in MAX/MSP to connect to the library's objects.

Few of the external objects that were created are presented below:

Aipic object: This object has 4 inlets. The first inlet accepts integers as well as messages. The other three inlets accept integers. There are two outlets in this object, the first one outputs the picture number, and the second one outputs the coordinates of the image. Each Aipic object represents an image on the Age Invaders platform. On each panel, there are 4 layers and thus 4 of such objects can be displayed on a single panel at the same time. Several images can be grouped by putting them in the same channel and moving them all at once.

Shoe object: This object allows the shoes to read the shoes position on the board using RFID reader and send the shoe and position information back to server via Bluetooth.

Convert object: This object convert the board position to coordinate for

displaying images as a shoe position is tracked.

Instrument object: This object allows the user to load a VST instrument* and play music notes. The first inlet accepts a bang. The 2nd to 4th inlets takes in integer inputs and the last inlet takes in messages.

Burn object: This object allows the designer and programmer to simply draw a new image and burn it to the EEPROM in real time. Previously, in order to store an image into the EEPROM, each EEPROM (45 in total since there is one in each board) had to be physically removed and placed into the EEPROM burner. Now the image can be burnt into the EEPROM via the Ethernet connection and the images can be displayed immediately. The ease of adding and displaying images makes the toolkit ideal for artistic creation. It provides instant feedback and the ability to adjust the layout directly on the board.

Screenshots of the Aipic and Burn objects are shown in Figure 3.61 and 3.62.

*Steinberg's Virtual Studio Technology (VST) is an interface for integrating software audio synthesizer. VST uses Digital Signal Processing to simulate traditional recording studio hardware with software.

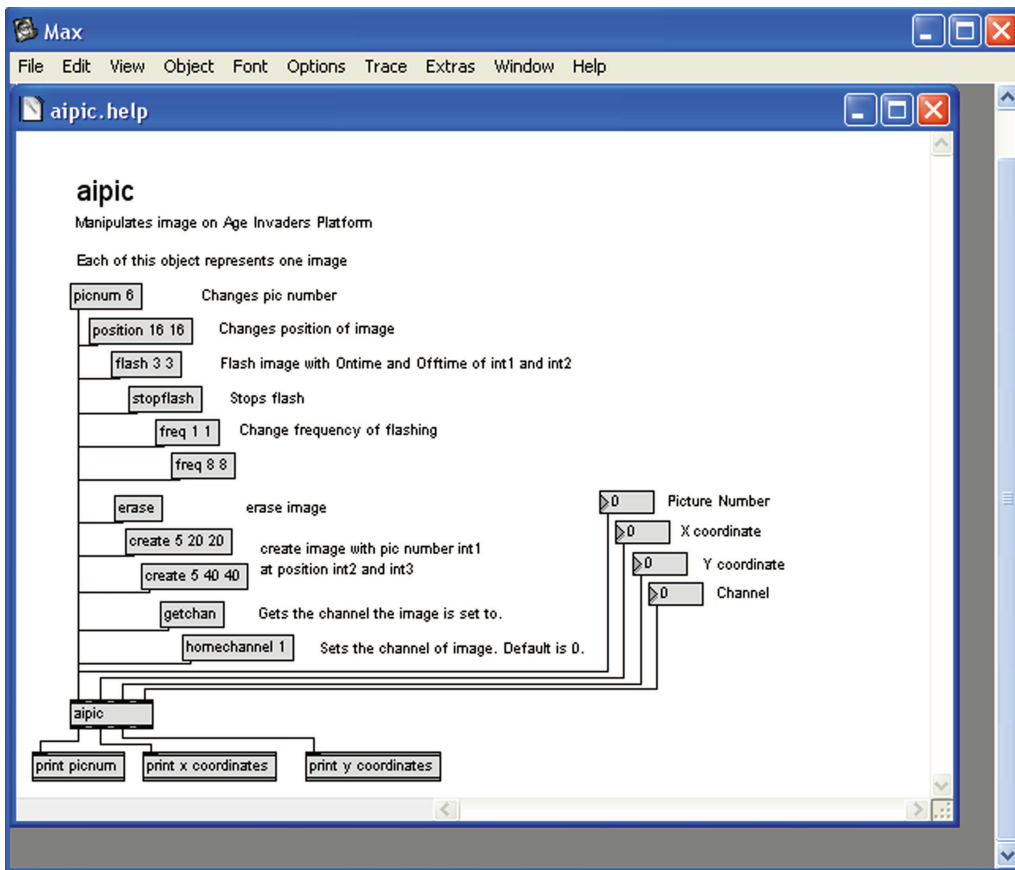


Figure 3.61: Aipic MAX/MSP external object.

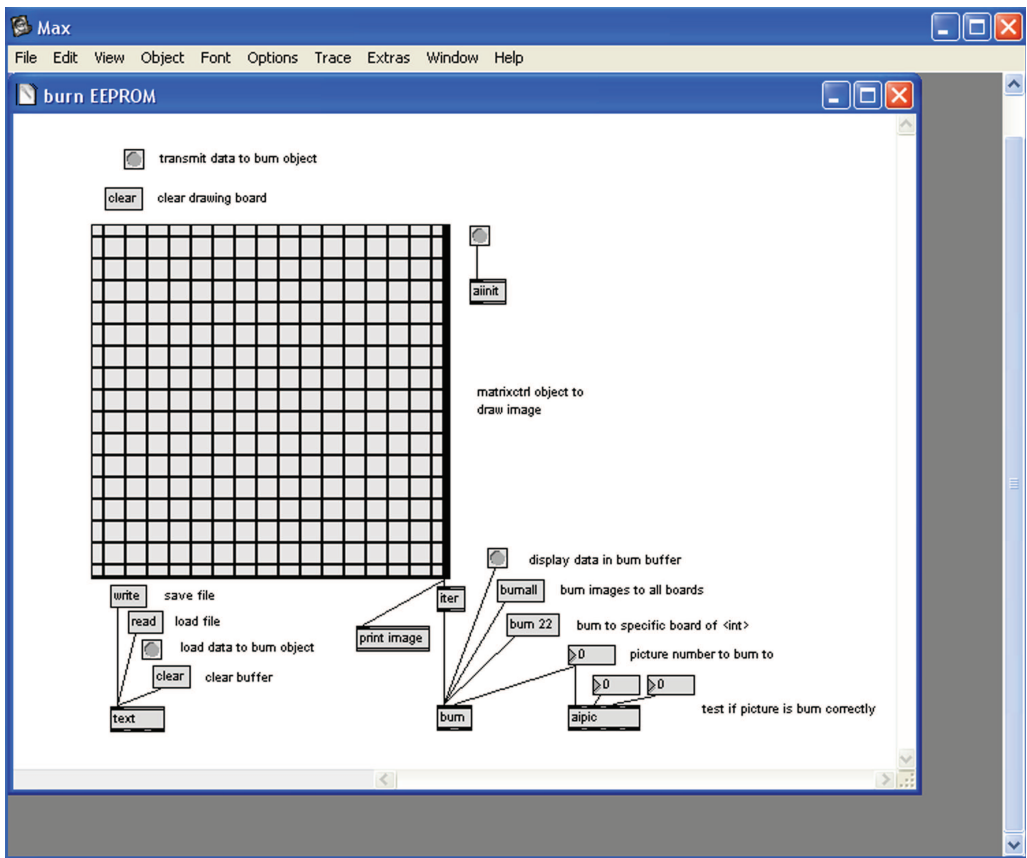


Figure 3.62: Burn MAX/MSP external object.

3.5 Designing Cultural Play

3.5.1 Problem Exploration

While conducting studies and showing demonstration of our physical play system, we have also gathered suggestions for new forms of intergenerational play system. The location of our lab is in Singapore, hence the suggestions are influenced by Asian culture. Many elderly users suggested using play-like system to let the children learn about traditional values. When asked about what they meant by traditional values, some mentioned Confucian values, Eastern values and family traditions. They have highlighted that since the children are spending substantial time in using computers, it would be beneficial if there are applications that allow them to explore cultural values in a fun way. This would serve as an activity that they could do together with the children. Many children also showed interest in exploring cultures using games or interactive systems. Some of them said that their parents bought educational software for them to learn traditional values. The contents are normally presented in text with illustration, comics and video.

We carried out a survey with parents and younger siblings of university students. A total of 20 parents between the age of 46 to 53, and 15 children between the age of 11 to 16 took part in the survey. The participants were prompted on whether they would like to learn or explore traditional

cultural values, for example Eastern values using interactive media, such as games and social network chat. Many parents think that the idea is interesting and may appeal to the children. If available, they would like to use it together with the children. Most children reported that it would be fun to learn about the cultural values through games or chat with historical figures. The participants were asked the current method the family members communicate about traditional cultural values. Most of them replied that there is currently no method in place and few mentioned that they talked about those issues when they arose naturally. In another question on whether they are currently reading any traditional cultural content on books or on the Internet, a few parents reported read the books or searched for those material online and few children mentioned that they do read those books in school. A further question is on the enjoyment of reading those cultural content. The parents reported that the activity is meaningful and enjoyable. Most children reported that the activity is not very interesting.

3.5.2 Design Goals

Based on the observations above, we established the design goals for the cultural play as listed below:

(1) Intergenerational cultural communication: Studies have shown that strong traditional Confucian norms, such as filial piety and elders' contribution to family harmony, have resulted in youths having more positive

images of old age, closer psychological proximity and thus more respectful communication with older adults in Asia. Therefore, we wanted to create a play system that would facilitate discussion of traditional Eastern cultural values between grandparents and parents with their children. In this way, children may have a better understanding of the cultural values embraced by their parents and grandparents.

(2) Dynamic interaction to explore culture: Currently, Eastern cultural values and teachings are communicated orally in a family and are available in the traditional media. Traditional media, for example books, animation or videos only provides a linear presentation of the subject matter, and the user is normally a passive receiver of the information. However, children today possess high level of digital literacy and are more inclined to explore new knowledge using digital media. This motivates us to design a new form of cultural play system, where the children can explore cultural values by actively contributing to the discussion using modern digital media, together with their parents.

3.5.3 Design requirements

3.5.3.1 User needs

We considered various cultural content which is relevant for the users, for example Confucius, Mencius, Lao Zi and traditional Chinese concept of Yin and Yang, many of which were recommended by the parents. We decided

to start with Confucius as his philosophies and values have deep influence in Asian Chinese culture. Confucianism has gained popularity in books, animation and movies. For instance, the book written by Yu Dan about Confucius [114] has witnessed phenomenal sales, indicating a high demand for Confucian knowledge in modern Chinese societies.

Another important factor for choosing Confucius for the content of our cultural play is that his philosophies have significant influence on Asian Chinese family values. The significance of family can be seen from the following statement outlining the process of Confucian moral cultivation in the Da Xue (Great Learning) chapter of the *Book of Rites* [25],

Extension of knowledge lay in the investigation of things. Things being investigated, knowledge became complete. Their knowledge being complete, their thoughts were sincere. Their thoughts being sincere, their hearts were then rectified. Their hearts being rectified, their persons were cultivated. Their persons being cultivated, their families were regulated. Their families being regulated, their states were rightly governed. Their states being rightly governed, the whole kingdom was made tranquil and happy. [78]

Apparently, family is the first test ground beyond the individual self for a cultivated person to manifest himself before he can make an impact

on the society. Furthermore, out of the traditional five cardinal interpersonal relations (father-son, husband-wife, younger and elder brother, ruler-subordinate, and friends) , three are family-based. Discussions on filial piety are disproportionately abundant in Confucius literature. This factor is particularly important, as our aim is to facilitate intergenerational communication by allowing the children to better understand their family values.

3.5.3.2 Context of use

The system is envisioned to be used in a home setting by the children and their parents. The content should be in English as this is a standard language medium for Singapore children’s educational material. The system should be a simple application or accessible from a website, and is available whenever the parents and children want to explore the traditional cultural values. The system should allow the users to input questions or statement to promote their discussion and reflection on the system output. To facilitate learning and discussion, a record of their interaction would be available for the users to review at later time.

3.5.4 Design Idea Generation

We started our brainstorming session by examining the current media that support exploration of traditional culture. Traditional Eastern cultural val-

ues are typically preserved in the printed media, for example books, which were often written in an esoteric way has not only limited appeal to young users, but their sheer volume simply scares them off (Figure 3.63). Existing endeavors in making traditional texts more friendly to young readers have not gone beyond the hard core medium of books. The methods they employ include transforming traditional characters to simplified Chinese, sometimes accompanied by modern language interpretation, and even inserting caricatures to assist understanding. Figure 3.64 shows a person reading the popular book about Confucius written in English. Others have ventured into the digital media by producing movie clips, for example “Biography: Confucius DVD” (Figure 3.65) and comic series, for example “The Complete Analects of Confucius” (Figure 3.66) However, these methods still limit the users as a passive receiver of the information.



Figure 3.63: Example of books about Confucius

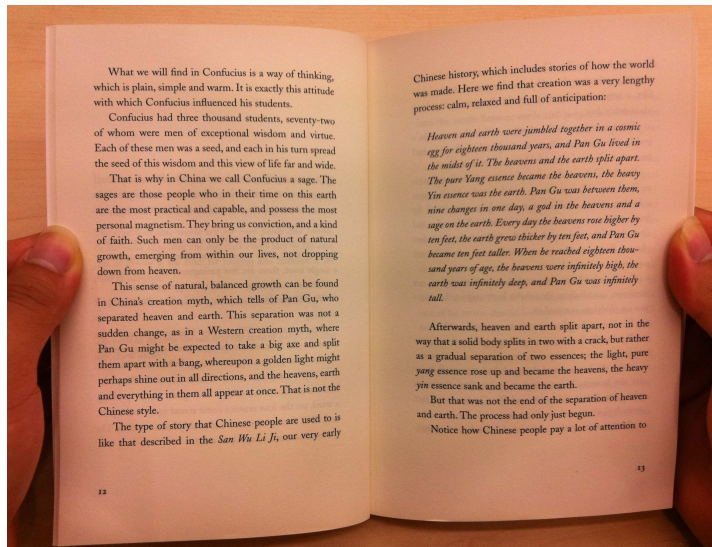


Figure 3.64: Example of a person reading a book about Confucius



Figure 3.65: Screenshot of Biography: Confucius DVD cover

On the other hand, children today possess high level of digital literacy. Through modern networked and social digital media such as the Internet, Facebook, and MSN etc, they make friends, explore new forms of entertainment, and expand their knowledge. In the U.S., nearly half of online teens aged 12 to 17 visited MySpace and Facebook in May 2009 (45% and

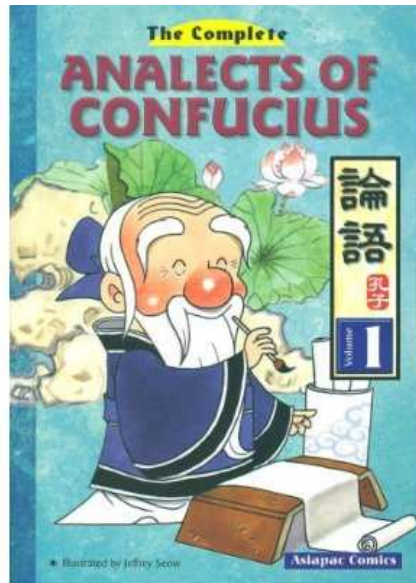


Figure 3.66: Screenshot of The Complete Analects of Confucius cover

44%, respectively). Teens are also prolific online publishers. Sixty-seven percent of teen social networkers say they update their page at least once a week. However usage of such media should not be seen as only for leisure, as Nielsen Study [94] in 2009 shows that teenagers look to their social networks for much more than gossip and photo-sharing. To them, social networks are a key source of information and advice in a critical developmental period: 57% of teen social networkers said they looked to their online social network for advice, making them 63% more likely to do this than the typical social networker.

In view of this, we would like to design a system which the users can interact dynamically with a virtual historical character in a social network chat environment, as a mean to explore and understand traditional Eastern

values. The user is no longer a passive receiver watching or reading the cultural content; instead he will be an active enquirer engaging in stimulating dialogue with the historical giant who shares his or her values and wisdoms. In this way, the knowledge is also presented in the user's context, which would be more meaningful and personalised.

3.5.5 Prototype Iterations

In this section, we provide an overview of the prototype iterations from the first prototype which addressed more technical issues, through the more recently tested prototype, which supports more accurate system output, and additional interaction features.

We now describe the features of the prototype, the user involvement in the design, what design issue each prototype was attempting to answer, the user testing after the realization of the prototype, and the lessons learned which were carried to the subsequent iterations of the design cycle. The prototype iterations are shown in Tables 3.7 - 3.9.

Prototype 1 was a simple proof of concept system, which consisted of a simple application which allow user to input a question or statement. For prototype one and two, we collaborated with a Confucius scholar who had a Master degree in Confucius study, to provide us the relevant Confucius knowledge content. The system uses Artificial Intelligence Markup Language (AIML) [107] to create a database of templates with answers to

Table 3.7: Cultural Play Prototype Iteration 1

Design requirements	
- Features to be tested	Simple application which allow user to input a question or statement. Identify potential usability issues.
User needs	
- Human factors issues	Confirmation that the users are able to have text based conversation with virtual Confucius using the chat application.
Context of user	
- Player composition	Lab members.
- Location	Laboratory setting.
- Use scenario	Enter an input sentence to trigger a virtual Confucius reply.
Idea generation	
- Drawing/sketches	Artist/engineers drafted designs of the chat application and ideas of technical challenges.
- Meetings with users	Review of existing implementation of automated chat agent.
- Meetings with designers	
Prototype creation	
- Brief specs	Simple chat application implemented using Python. No graphical user interface, only plain text input and output.
- Features introduced	Uses Artificial Intelligence Markup Language (AIML) to create a database of templates of Confucius's answers to questions which are frequently asked.
Usability studies	
- Test requirements	Users are required to have a conversation with virtual Confucius using the chat application.
- User profile	They will enter a sentence and wait for the system to reply.
- Test description	
Lessons learned	
- What works well?	Text chat with virtual Confucius is intuitive.
- What is lacking?	We noted the limitation of pattern matching algorithm of AIML. Sometimes when user asked a question in a different sentence style, the system failed to retrieve relevant output.
- Future improvements?	

questions which are frequently asked. More detail about how AIML works is elaborated in Section 3.7.1. These templates range from casual chat, for example “Hi. How are you?” to important concepts, historical persons and texts. For instance, if the user asks “who is Yan Hui?”, Confucius’s reply will be taken directly from our AIML database, which replies “Yan Hui is my favorite disciple.” This AIML database consists of short introductory statements about the figures appear in Confucius’s responses (mostly Confucius’s disciples), classical texts from which Confucius often quotes (like the Odes), and certain names of ancient countries and dynasties (like the state of Lu and the three dynasties of Xia, Shang and Zhou). This database

will also include certain information about Confucius as an individual. Since user may be curious about Confucius as a person, they may ask about his personal particulars such as his age, his date of birth, and his hometown etc. We gather this information from the earliest reliable historical text of Shiji by Sima Qian (ca. 110B.C.) and formulate them into Confucius's answers. Besides, we also prepared a few series of dialog sequences, which would be initiated by virtual Confucius asking the user a question. This would make the conversation between the user and virtual Confucius more interactive. The prototype was tested with project team members and lab members to gather feedback and identify potential usability issues. In this prototype we noted the limitation of pattern matching algorithm of AIML, where sometimes when user asked a question in a different sentence style, the system failed to retrieve relevant output.

Table 3.8: Cultural Play Prototype Iteration 2

Design requirements	
- Features to be tested	To address the limitation of AIML pattern matching, semantic similarity measurement is introduced to the chat system. A web based graphical user interface is created with virtual Confucius portrait and matching design style.
User needs	
- Human factors issues	Confirmation that the intergenerational users are able to use the chat application to explore cultural values.
Context of user	
- Player composition	6 pairs of Singapore Chinese parent and child participated in the study. The children are aged 7 to 11, while the parents are aged 38 to 52
- Location	Laboratory setting.
- Use scenario	Three chat interaction scenarios tested: alone, use together with peer, and use together with either parent or child.
Idea generation	
- Drawing/sketches	Meeting with designers and engineering team.
- Meetings with users	Sketches of the style and layout of the graphical user interface were reviewed.
- Meetings with designers	
Prototype creation	
- Brief specs	Semantic similarity measurement method is introduced to overcome the limitation of simple pattern matching in the previous prototype.
- Features introduced	A Java web application was created so that users can access the system from any web browser. A database of Confucian statements from four classical texts was created.
Usability studies	
- Test requirements	General usability issues with the chat interface and interaction between the two paired users.
- User profile	Tested in the lab setting with 12 users aged 38 – 52 (parents), 7 – 11 (children) and demonstrated at many conferences and exhibitions.
- Test description	Photo and video recording of user interaction. Questionnaires involving closed and open-ended questions. Different users' chat histories were saved in a single text file for content analysis.
Lessons learned	
- What works well?	Parents and children enjoy using the system together.
- What is lacking?	Users find it fun and enjoyable to talk to virtual Confucius.
- Future improvements?	Virtual Confucius chat output accuracy could be improved.

In prototype 2, we use similarity measurement method to overcome the limitation of simple pattern matching in the previous prototype. With the help of the Confucius scholar (same as prototype 1), we created a database of Confucian statements from four classical texts: the *Analects*, Confucius sayings in the Mencius, passages directly related to Confucius in the *Book of Rites* and the entire *Classic on Filial Piety*. We chose to use James Legge's translation for all four texts. Since his translation is more than a century old, and is less literal, we hope it can help to give virtual Confucius reply a

more archaic feeling so that user can feel that he is talking to someone who walks out from history. On encountering disputable interpretation, we will consult two other popular translations in the field by D.C. Lau and Simon Leys to derive at what we think is an appropriate, and more pertinent to our modern user translation. We eliminate passages that are too historically specific in nature and out of which no real meaning can be extracted. An example of such elimination is “to Zhou belonged the eight officers, Bo Da, Bo Kuo, Zhong Tu, Zhong Hu, Shu Ye, Shu Xia, Ji Sui, and Ji Gua.” [78] Since many of the passages are pretty long (especially those in the *Book of Rites* and the *Classic on Filial Piety*), and are comprised of several parts each with a distinct meaning, instead of transporting the whole paragraph of text into our database as one entry, we separate them into short phrases but each is a self-sustained statement loaded with meaning. For instance, the opening passage of the *Analects* becomes three entries in our database:

1. Is it not pleasant to learn with a constant perseverance and application?
2. Is it not delightful to have friends coming from distant quarters?
3. Is he not a man of complete virtue, who feels no discomposure though men may take no note of him?

In this way, our database is expanded to 2069 entries. The Confucius scholar assigned every Confucius database entries as a vector, with a combination of topics which best describe them. In this way, the system would identify the topics in user input sentence and compare with the database entries to find the closest match based on the

Table 3.9: Cultural Play Prototype Iteration 3

Design requirements	
- Features to be tested	Revised chat system with improvement on the retrieval accuracy. A personal chat log with feedback rating.
User needs	
- Human factors issues	Enjoyment and usability issues of parents and children using the chat application to explore cultural values.
Context of user	
- Player composition	A total of 83 users who are parents and children took part in this study.
- Location	The study was conducted during a community event.
- Use scenario	The participants either use the system alone or in pair, with a parent or child.
Idea generation	
- Drawing/sketches	Various machine learning and classification algorithms were reviewed.
- Meetings with users	Meeting with Confucius scholars.
- Meetings with designers	
Prototype creation	
- Brief specs	k-NN classification method is used to further improve the retrieval accuracy of the system. 5 Confucius scholars provided training and evaluation data for our system.
- Features introduced	A personal chat log, corresponding to a unique username was created so that user can review their previous interaction with virtual Confucius and provide rating feedback on each input-output pair.
Usability studies	
- Test requirements	Enjoyment and usability issues of parents and children using the chat application to explore cultural values.
- User profile	Tested in a residential area setting with 83 parents and children users.
- Test description	Photo and video recording of user interaction. Questionnaires involving closed and open-ended questions. Different users' chat histories and their ratings on enjoyment and relevance were saved based on username.
Lessons learned	
- What works well?	With k-NN classification, the retrieval accuracy is improved significantly.
- What is lacking?	Users have reported high level of enjoyment using the system and given high rating on the relevance of the system output.
- Future improvements?	

semantic closeness of the input topics vector and the database entry vectors.

We have also created a web application, so that users can access the system from any web browser. A pilot study was carried out with 6 pairs of parents and children to identify usability issues and their interaction experience.

In prototype 3, the current prototype, a personal chat log, corresponding to a unique username was created so that user can review their previous interaction with virtual Confucius. We have also incorporated rating feedback on the website so that users can rate each input-output pair. This

information is collected for future improvement of the system.

To improve the retrieval accuracy of our system, k-nearest neighbor (k-NN), a widely used method in text classification [90] was employed. Text classification is the process of identifying the class to which a text document belongs. In our case, each database entry is treated as a unique class, described by a set of vectors manually assigned by Confucius scholars. When a new input sentence is entered to the system, k-nearest neighbor algorithm will determine the most relevant class it belongs to, based on the similarity of the input sentence and the vectors describing each database entries. The database entry corresponds to the selected class will be output. Given the limitation on the resources of Confucius scholars, we have decided to reduce the database entries to only those relevant to the family topic. Family topic is chosen because of its relevance for intergenerational communication and its importance in Confucius teaching.

Five Confucius scholars, who are NUS graduate and final year undergraduate students, recommended by a faculty member who taught them during a Confucius studies module, were involved in selecting those entries that are only related to the family topic. A total of 108 database entries were selected. First, the Confucius scholars have to provide a set of topics which could be used in combination, to describe each of the 108 entries. This is an iterative process where the scholars provide a set of topics and manually check through the entries to identify new topics, which is unique

Table 3.10: Set of Family Topics

Topic	Topic description
1	Entry is related to parents.
2	Entry is related to the children in a familial context.
3	Entry is related to sibling.
4	Entry makes references to the young in the general sense or as a collective group of people.
5	Entry is related to the elderly.
6	Entry is related to the ancestors.
7	Entry is related to rites and ceremony.
8	Entry is related to obedient behaviour or conduct.
9	Entry is related to either conflict or harmony in the family.
10	Entry is related to love.
11	Entry is related to respect or reverence.
12	Entry is related to treat or serve another person.
13	Entry is related to death.
14	Entry is concerned about being morally upright.
15	Entry is related to marriage.
16	Entry is related to food.
17	Entry is related to the transmission or acquisition of knowledge.
18	Entry is related to money.
19	Entry is related to filial (Only if the entry is directly talking about filial and not for those that implied filial).
20	Entry is related to relatives or neighbors.
21	Entry is related to health or well-being.
22	Entry related to family (Only for general entry that refers to family. If the entry refers to specific family members like father and mother, please choose other topics)
23	Entry is related to friends or peers.

to the existing pool of topics and is important to describe the database entries. The new topics are added to the pool of topics, and the process repeats until they felt that the set of topics are sufficient to describe each database entries. The final set of topics, a total of 23 topics, is shown in Table 3.10.

A list of keywords and their corresponding synsets of the words in WordNet [2] lexical database were then identified. The synsets are used in the similarity comparison process, to identify the semantic closeness of the user input sentence’s keywords with the topics. This step is described in detail in Section 3.7.2.2. Next, the five Confucius scholars will each provide an input-output data sets, out of which, one randomly chosen set will be used

for evaluation (elaborated in Section 4.2.1.1) and four other sets will be used for k-NN classification and training. For each database entry, the scholars will compose an input sentence, which in their opinion should trigger the entry as the virtual Confucius chat output. The input sentence can be either a question or a statement. For each of the 108 input sentences, the scholars will identify two to three keywords. Then, for each keyword, they will identify at least one topic from the list in Table 3.10. A maximum of three topics are allowed to be assigned to an input sentence. The combination of topics provided by the four Confucius scholars will be used as the vectors to describe each entries. A total of 432 vectors, 4 each to describe a database entry, are obtained. To use k-NN algorithm, k value which yields the best performance need to be identified during a training process. A k-fold cross validation method, a widely used method to estimate the k value of the k-NN classifier [92], was used. More detail about this step is described in Section 3.7.2.3. Finally, the system performance is evaluated in a glass-box evaluation, where the system's selected keywords, topics and database entry will be compared to the evaluation set provided by the scholar, who is the expert in Confucius knowledge domain.

3.6 Cultural Play Description

Confucius Chat system, which is designed for users to engage in cultural play, is now described.

3.6.1 Confucius Chat

In Confucius Chat system, the user interacts with a virtual Confucius, which is modeled after Confucius knowledge and teachings. The users are encouraged to discuss about topics related to their family issues with a virtual Confucius. The users can launch Confucius Chat application using a web browser, as shown in Figure 3.67, and start interacting with the system by typing a sentence or question and enter into the chat box.

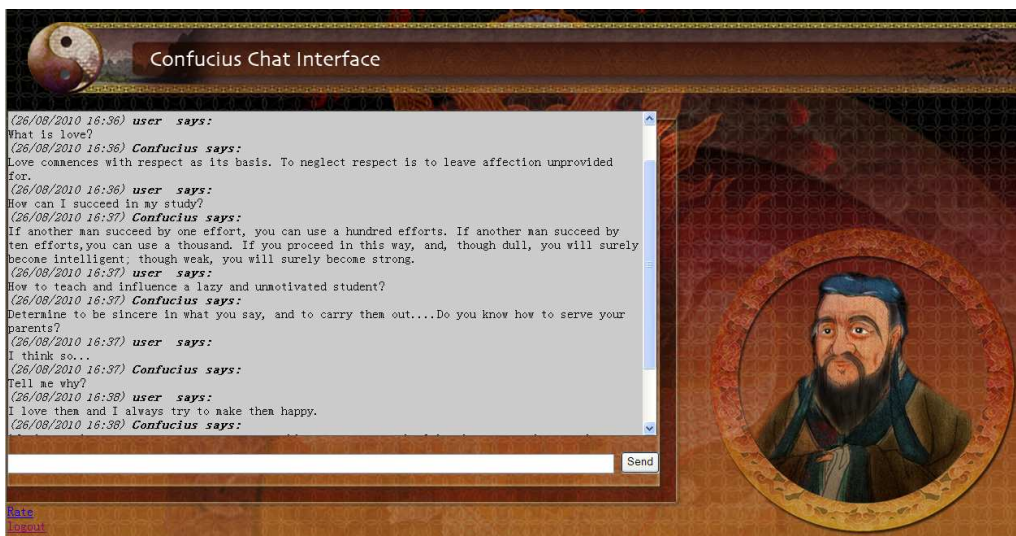



Figure 3.67: Confucius Chat Interface

Virtual Confucius reply will be shown in the chat box, and users can reflect and discuss to understand Confucius's values on the questions or statements that they entered. Figure 3.68 shows the instructions given to the users on how to use the system. The user can either use it alone or with another person, for example with a parent or a child. Figure 3.69 and Figure 3.70 show a child and parent using Confucius Chat system individually. Figure 3.71 shows a parent and child pair using Confucius Chat system together. Each user would have a unique login name and password. The users can also review their chat interaction with Confucius by browsing through the chat history. Users are encouraged to provide rating feedback on the relevance and enjoyment of each input-output pair.


CONFUCIUS CHAT

BRIDGING INTERGENERATIONAL COMMUNICATION THROUGH SOCIAL NETWORK CHAT




Share your stories, hear his wisdom.


*Please use complete English sentences.




What is parent child relationship?



...When the family is regulated by the rites, there is affection between father and son, and harmony among brothers.




I have very few family members...




...By treating the masses of the people as children, they will be led to exhort one another to what is good.


Discuss about the below topics:





Family



Filial Piety



Parental Love

Mixed Reality Lab/CUTE Center,
National University of Singapore

Website: <http://www.mixedreality.nus.edu.sg/>
Contact: intergeneration@mixedrealitylab.org

Figure 3.68: Confucius Chat user instructions



Figure 3.69: A child using Confucius Chat alone

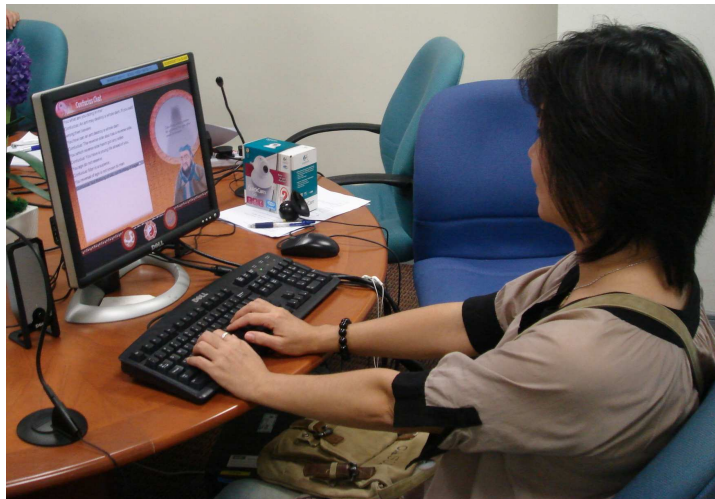


Figure 3.70: A parent using Confucius Chat alone

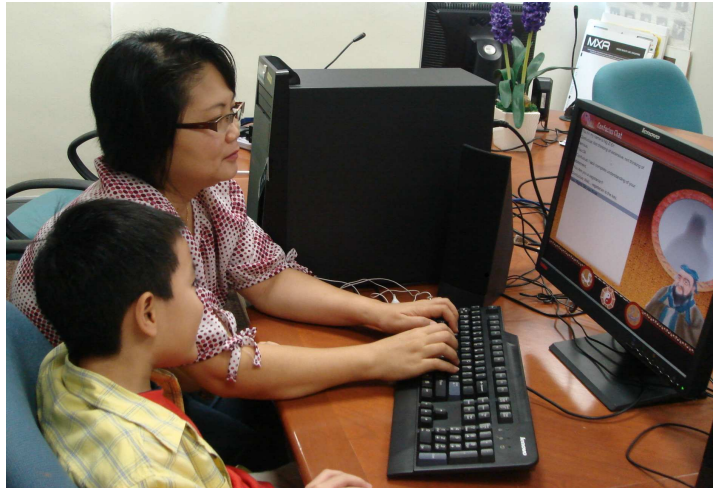


Figure 3.71: A parent and child using Confucius Chat together

3.7 Cultural Play System Description

When the user enters Confucius Chat URL into their web browser, it would load Confucius Chat webpage written in HTML and JavaScript (JavaScript for AJAX request and return processing). There is a chat box where user can type a sentence(s) using the computer keyboard. Upon pressing the Enter key or mouse-click the Send button, an AJAX request containing the input sentence will be sent to the Web Server, running on Apache HTTP server version 2.2.9. Upon receiving incoming query at port 80, Apache external handler will pass the query to port 8088 of localhost. The core of the system is the Chat Server running on Python 2.5.2. There are three functions of the Chat Server. Firstly it would listen to any incoming query at port 8088. Upon receiving the query, it would process the query and then

return virtual Confucius's reply to Apache external handler. The processing of the Chat Server is shown in Figure 3.72, and will be elaborated in the following sections.

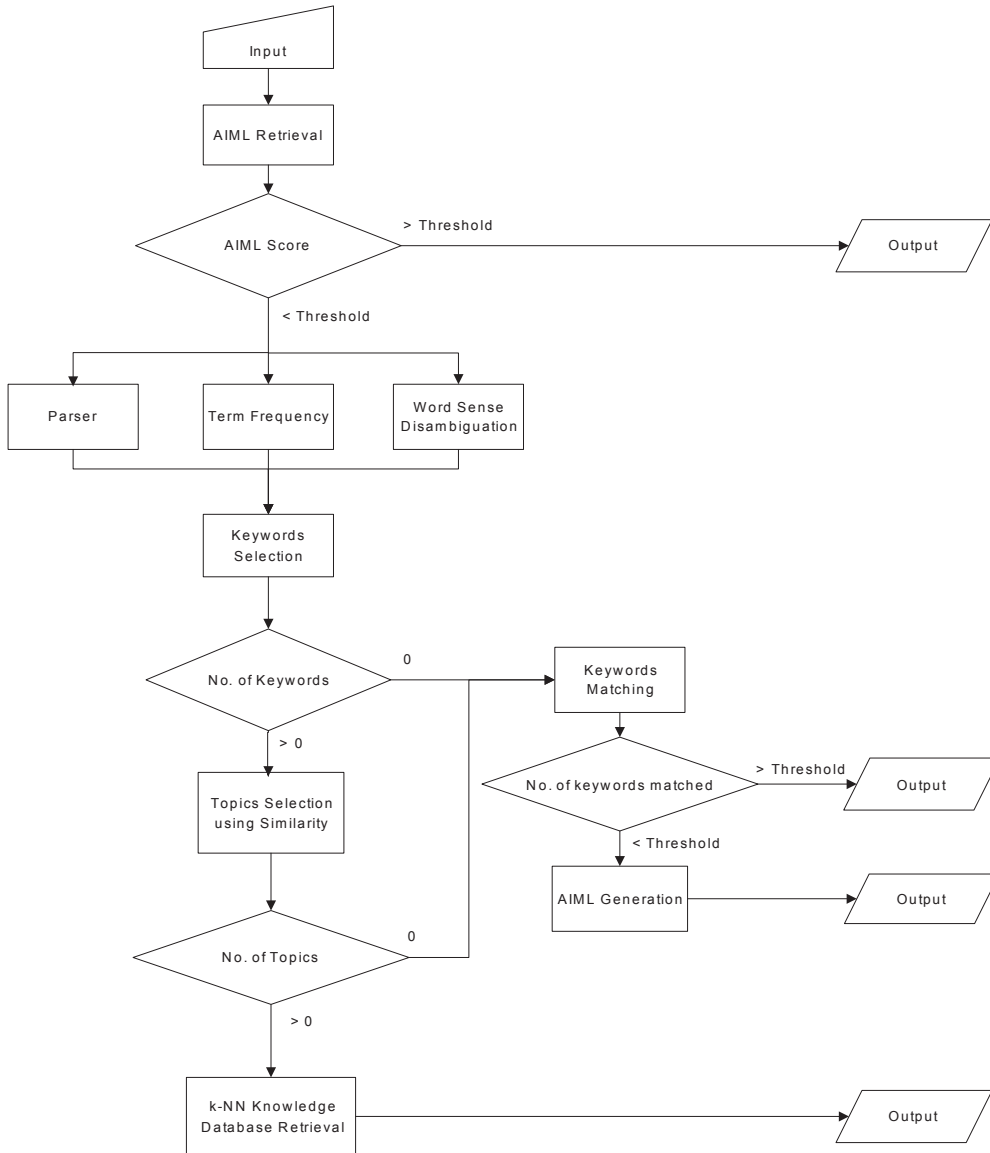


Figure 3.72: Flow chart of Confucius Chat Server

The output from the k-NN method will be retrieved from Confucius Knowledge Database. Virtual Confucius's reply is then updated on the

user's web browser using AJAX return process. The chat input, output, time, unique index number and the details of the processing are also stored in Chat History Database, running on MySQL 5.1.53. When the users finished chatting, they can click on Rate button to go to the rating webpage. They can provide ratings for relevance and enjoyment for each of the dialog entries, by clicking on the rating from 1 to 5 stars, which will be stored on the Chat Rating Database with the same index number stored in the Chat History Database. The common index number allows for further analysis of the information in the future. After the rating database is updated, the rating webpage is updated using AJAX return process. Figure 3.73 shows the block diagram of the overall system described above.

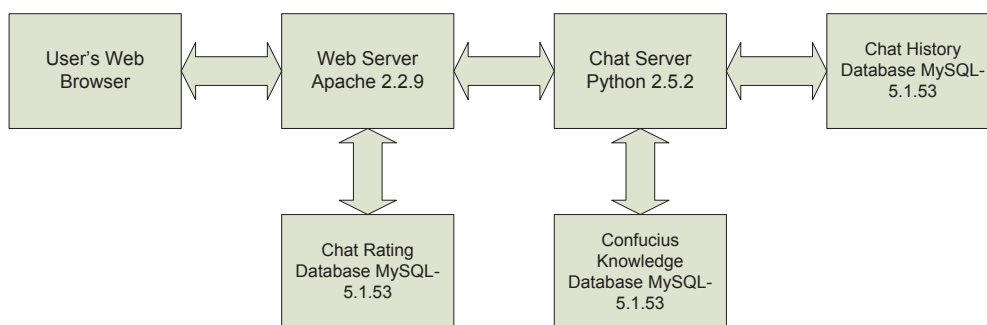


Figure 3.73: Block diagram of the Confucius Chat system.

3.7.1 Artificial Intelligence Markup Language Retrieval

The user input sentence is first put through Artificial Intelligence Markup Language (AIML) database [107] to retrieve an output. The output sentence is then evaluated for its score (from 0.0 to 1.0). The score evaluation is

based on the number of matched words in the input sentence, discounting randomness and a list of words that Confucius will not talk about.

For example, the user input “What is your name please” which maps to two templates in the AIML database. First is the template “_PLEASE” which means that if the sentence ends with the word please, the reply from this template will be used and the words before the word please will be used to search for a second template, “WHAT IS YOUR NAME”. The reply for first template is “Thank you for being polite.” and the reply for second template is “My name is Confucius”. Hence the reply for the user input is “Thank you for being polite. My name is Confucius.”

For this example, there are two templates which match all the words in the input sentence, hence the score is 1.0. The score is divided by half for the more general templates in AIML database which offers random output. If the output sentence contain any word in our forbidden word list which is a list of words Confucius will not discuss, for example God, Jesus, etc, the score will be 0.0. If the score is above a predetermined threshold value, currently set at 0.7, the output from AIML will be used. Below the threshold value, the input sentence is passed to knowledge database retrieval step for further processing.

3.7.2 Knowledge Database Retrieval

The core of our system is a Similarity module, which calculates the highest similarity score for each keyword in user input sentence with the topics to identify a topic for each keyword. The set of topics are then used to retrieve the closest matched database entry based on k-NN method.

3.7.2.1 Identifying Keywords

To achieve the above, first the computer must understand the input sentence. This is not an easy task, because the user's input is natural human language, which has very complicated structure and even slight changes of the order of the words may alter the meaning of the sentence. Therefore, simple keyword matching will not work well and we need a more sophisticated method to analyze the meaning of the input. The user input is fed into a parser to get the grammatical structure of the sentence. Our system used the Stanford Parser [41] because of its speed and reliability. The last noun of each noun phrase is selected as Head Word [45] of the sentence. Usually they are the topic the user is talking about. However, sometimes there are no nouns in the user input, or there are some important words that are not nouns. Therefore, we employ another method called inverse term frequency to find the important words. An inverse term frequency database is created by calculating the frequency of appearance of each word in a large corpus. Study shows that the more frequently used words such as

‘the’ and ‘and’ do not contribute much to the real meaning of the sentence, whereas the less frequent words, ‘loyal’ and ‘conflict’, for example, are the more important words [49].

With the result from the above two methods combined, the system will select three keywords, either from the headword method, or in the event that there is not enough headwords, the remaining words will be selected from inverse term frequency method. Furthermore, the user input is passed through a Word Sense Disambiguation (WSD) module, so that we not only know what are the keywords of the input, but also the meaning of these words in the context [74].

3.7.2.2 Identifying Topics

We then compute the semantic similarity between these selected keywords and the 23 topics provided by the Confucius scholars. This is done using a WordNet-based similarity module WordNet::Similarity developed by Ted Pedersen. For each topic T_x , there are several topical words,

i.e.

$$T_x = \{T_x W_1, T_x W_2, \dots, T_x W_y\}, \quad (3.1)$$

where y is the number of topical words for topic x .

For each topical word, there may exist several suitable senses in WordNet, i.e.

$$T_x W_y = \{S_{xy1}, S_{xy2}, \dots, S_{xyz}\}, \quad (3.2)$$

where z is the number of senses for the y^{th} topical word of topic x .

For each keyword in the user input, the topical word with the highest similarity score between the keyword and the topical word's synset will be selected. Selected topic T for a keyword K , is shown in the equation below.

$$T = \arg \max \{Sim(S_{111}, K), \dots, Sim(S_{xyz}, K)\} \quad (3.3)$$

User input sentence can then be represented as vector \vec{v}_i

$$\vec{v}_i = a_1\vec{t}_1 + a_2\vec{t}_2 + a_3\vec{t}_3 + \dots + a_n\vec{t}_n \quad (3.4)$$

where n is the total number of topics (23), \vec{t}_n is the basis vector representing the n^{th} topic, a_n is the binary weight of that topic. A selected topic will have a weight of $a = 1$, and not selected topics will have $a = 0$.

3.7.2.3 Identifying Confucius Entry

To improve the retrieval accuracy of the system, we have employed k-nearest neighbours algorithm (k-NN) to classify the database entries based on the training examples provided by the Confucius scholars, who are the domain expert. The k-nearest neighbor algorithm is simple and widely used in text classification [90]. An object is classified by a majority vote of its k nearest neighbors. Each input sentence, as well as each entry in the Confucius database, can be digitized as a point in a high dimensional space. The

Euclidean distance between each pair of the points is used as the distance metric. For an input sentence x , the class of x , denoted by $c(x)$, is given by

$$c(x) = \arg \max_{c \in C} \sum_{i=1}^k \delta(c, c(y_i)) \quad (3.5)$$

where C is the collection of all classes $c(y_i)$, is the class of y_i, y_1, \dots, y_k , are the k nearest neighbors of input sentence,

$$\delta(u, v) = \begin{cases} 1, & \text{if } u = v \\ 0, & \text{otherwise} \end{cases} \quad (3.6)$$

Five Confucius scholars were recruited; each of them classified the 108 entries using a combination of up to 3 topics. The scholars' tagging for each Confucius entry in the database can also be represented as a vector \vec{v}_0 in the same high dimensional space as \vec{v}_i :

$$\vec{v}_0 = b_1 t_1 + b_2 t_2 + b_3 t_3 + \dots + b_n t_n \quad (3.7)$$

where b_i is the binary weight of the corresponding topic. Topics tagged by the scholar will have a weight of $b = 1$, and topics not tagged will have $b = 0$. The similarity between the input sentence and database sentence is inversely proportional to the Euclidean distance, d between point $a = (a_1, a_2, \dots, a_n)$ and point $b = (b_1, b_2, \dots, b_n)$.

$$d = \sqrt{(a_1 - b_1)^2 + (a_2 - b_2)^2 + \dots + (a_n - b_n)^2} \quad (3.8)$$

A smaller d indicates higher similarity between the input and database entry, thus the database entry is deemed as more suitable to be chosen as the output to the user.

We have five sets of data from five Confucius scholars. One data set is randomly selected and reserved as an evaluation set to evaluate the overall output accuracy of our system using the k-NN classification algorithm. Ideally, for any input sentence, the output given by our system should be the same as the one given by the domain expert, which means the system output should be as close as possible to human domain expert output. The rest of the 4 data sets are used to train the classifier.

8-fold cross validation is performed on the 432 data points in our training set, as described in Section 3.5.5. All the data points are evenly divided into 8 partitions D1, D2, ..., D8, with each partition containing the same number of data points from each class, i.e., each partition contains 54 samples. Each partition is used in turn as the test set, while the rest of the partitions are used as training set. To tabulate test sample classification results, a 108 x 108 confusion matrix C is used. All elements in C are initialized to 0. Let w_t denote the true class of the samples and w_p denote the predicted class of the samples. For every test sample, the element C_{w_t, w_p} is incremented by

Table 3.11: Classification accuracy using different value of k

k	Accuracy
1	0.519907
3	0.587269
5	0.515509
7	0.521296
9	0.488194
11	0.458565

1. The accuracy A of the classifier is given by

$$A = \frac{\text{trace}(C)}{n_{total}} \quad (3.9)$$

where n_{total} is the total number of samples that have been tested.

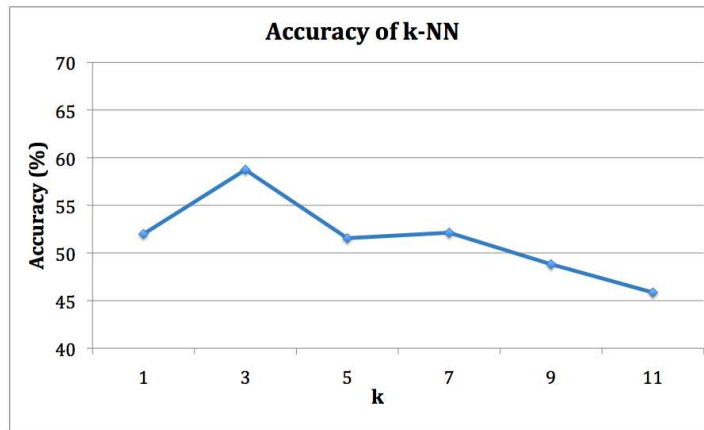


Figure 3.74: Classification accuracy using different values of k

Furthermore, the process is repeated 10 times, repartitioning the samples in each iteration, to get a better estimate of the accuracy. The classification accuracy using different values of k is shown in the Table 3.11 and Figure 3.74. k value for the classifier is influenced by many factors, including the number of Confucius scholar data sets, agreement between the Confucius

scholars' data sets and other nonlinear system parameters. To determine the most suitable value of k for our system, cross-validation method [92], a well established technique to determine the value of k , is used. Based on the different values of k and their corresponding classification accuracy in the test, $k = 3$ is selected using k-fold cross validation method.

3.8 User Study

Besides constant informal and functional testing with designers and lab members, in the following subsections, the studies carried out with real users are presented.

3.8.1 Physical Play Study

Among the data sources reviewed were video recordings from platform demonstrations at conferences, structured game play observation of 49 players in a structured format, questionnaires involving closed and open-ended questions, 3 focus group discussions involving the 49 players immediately after the gameplay and 7 of the older adults 5 weeks after the game play, and 4 semi-structured interviews with the design team and gameplay facilitators.

3.8.1.1 Enjoyment and playability study

This section presents studies that looked into the playability and degree of enjoyment of the game using Prototype 3. These studies were aimed at showing the acceptance and enjoyment of the Age Invaders game by younger players who have familiarity with contemporary electronic gaming. We invited 49 local polytechnic students who were taking electronic games course for our study. These initial sessions involved a total of 37 total participants. The average age of the participants was 19 years old. The gender of these participants was 24 males and 13 females. Age Invaders game was played. Details of the game is described in section 3.3.1.

Prior to game play, the respondents were asked to rate themselves in experience level with electronic games choosing between the categories Newbie, Casual User, Moderate User, and Hardcore User. After the game play sessions, the users answered additional questions pertaining to the game experience. Most importantly, the respondents were asked to rate their enjoyment level with the game.

3.8.1.2 Intergenerational Study

In order to validate the enjoyment and playability issues when played according to the design goals, we conducted intergenerational studies with the same users described in section 3.2.1. The outcome of this study would help to inform on the aspects of the game which were enjoyable and identified

issues impeding the positive experience.

In order to determine their habits with their families, all players were asked if they play any games, non-electronic or otherwise with their families, in the pre-test questionnaire.

In order to “break the ice” and to get the two generations of players to interact and converse, players were organized into 5 teams of 4 players each. Each team was made up of 2 young players and 2 older players. These players made name tags for each other, introduced their teams and the children were designated as the scribes of the teams and would help the older players to fill out the questionnaires in English. Each team was also designated a game studies facilitator from our lab who helped to ensure that the questionnaires were filled out appropriately and honestly. The game sessions were conducted similarly to the previous studies mentioned earlier.

Five weeks after we conducted the initial user study for the older and younger people, we went back to the senior center to conduct a follow up focus group session with 7 of the older players. Our aim was to investigate the longer lasting impact of the Age Invaders game.

3.8.1.3 Experiment

For the experiment, Tap Tap Hearts game was played. Details of the game is described in section 3.3.2.

Hypotheses

In this experiment, the effect of social competition (competing with senior/child opponent versus computer opponent) and balancing game difficulty (no balancing versus explicit dynamic balancing) on dimensions of game enjoyment outlined in In-Game Game Experience Questionnaire (GEQ) [48], as well as the competitiveness of game play, were studied.

H₁. Compared with non-balancing game, the explicit dynamic balancing game provides better gaming experience in the dimensions of Flow, Tension, Challenge, Positive Affect and Negative Affect.

H₂. Compared with competing with a computer opponent, players enjoy more gaming experience in the dimensions of Flow, Tension, Challenge, Positive Affect and Negative Affect, while competing with an intergenerational opponent (senior or child).

H₃. In the game scenarios where the players are engaged in social competition, they are more competitive, as compared to the scenarios where they are playing against virtual opponents controlled by computer. Their playing speed is an indication of competitiveness, in a game where the players are competing to finish the game first. In addition to these hypotheses, we are also interested to find out how our independent variables (social competition and balancing game difficulty) affect the gameplay of seniors and children. The dependent variable is the average number of matches won.

H₄. Explicit-dynamic balancing game challenge will reduce and increase

the number of matches won by children and senior, hence narrowing the win-lose gap.

Methodology

In order to test H_1 , H_2 and H_3 , a 2x2 within-subject study design was adopted with social competition (competing with senior/child opponent versus computer opponent) and balancing game difficulty (no balancing versus explicit dynamic balancing) as the independent variables. The dependent variables are the five dimensions of the GEQ and average speed of player. Each participant played all four game scenarios shown in Figure 3.12 and played each game scenario twice. Latin Square [5] was adopted to address the sequence effects.

In order to test H_4 , a 2x2 within-subject mixed design was adopted. Social competition and balancing game difficulty are the within-subject variables and age group (senior or child) is the between-subject variable. Dependent variable is the number of matches won.

Participants

Users were recruited through newspaper advertisements. A total of 24 users were recruited (12 senior aged 59 to 82 and 12 children aged 9 to 16). All of them are able to walk without assistance. Each participant was compensated with a \$15 gift voucher.

Procedure

Before the start of experiment, the players filled up the pre-test ques-

tionnaire with the help of the facilitators. Next, they were introduced to the system, the game rules and were shown demonstration of the game play by the facilitators. They were then asked to wear the slippers and get familiarized with the system. This process repeated until the facilitators felt that the players were ready to start the study. The players were then asked to play a trial game where their average speed was recorded, to be used in game scenarios A and B. After the trial game, the players were familiar with the system and the game rules.

While taking a short break, they were briefed on the four game scenarios that they will be playing. Visual representations shown in Figure 3.12 were used when explaining the differences between those scenarios to the participants. The participants were asked to explain the differences between game scenario A, B, C and D before the start of the explanation.

The users played all four game scenarios, with a break after each game scenario for them to rest, filled up the GEQ questionnaire and to describe their experience. At the end of the four scenarios, they were asked to give their feedback on their game play experience.

3.8.2 Cultural Play

Among the data sources used for cultural play were video recording, pre and post questionnaires from both the pilot study and the Punggol study. We have also conducted focus group session with the facilitators from both

studies. We have also analysed the chat logs as well as the individual conversation ratings from Punggol study.

3.8.2.1 Pilot Study

We conducted a study with 6 pairs of Singapore Chinese parent and child (12 users) to get their feedback on using our system. The children are aged 7 to 11, while the parents are aged 38 to 52. The users were given a short introduction about Confucius Chat and shown the concept video. They were then shown how to use the systems and had their first try. At this point of time, the facilitators helped the users to familiarize themselves with the user interface and tried out various functions of the Confucius Chat system. Each user then played in three settings, alone, with peers, and with another parent or child (intergeneration). They were asked to fill up a questionnaire after playing in three settings.

3.8.2.2 Punggol study

We carried a user study during a community event in a local residential estate, Punggol, in Singapore. A total of 83 users who are parents and children, took part in this study. However, only 69 users completed the whole study including pre and post questionnaires, and an open ended interview at the end. Most of the users whom did not complete the study left after using the system without filling up the post-questionnaire and interview.

The users either use the system alone or in a pair, with their parent or child. The participants fill up a pre-test questionnaire before using the system. The participants then use the chat system for about 5 minutes. The participants can also request to use the system for a longer period of time. After their interaction with the system, they are asked to fill up a post test questionnaire and a short interview is conducted to capture the feedback from the participants on their interaction experience.

3.9 Data Analysis using Grounded Theory

Grounded theory is a methodology that seeks to construct theory about issues of importance in peoples' lives [34], [35], [93]. It does this through a process of data collection that is often described as inductive in nature [65]. Grounded theory requires researchers to enter the field of inquiry with as few predetermine thoughts as possible, enabling them to “remain sensitive to the data by being able to record events and detect happenings without first having them filtered through and squared with pre-existing hypotheses and biases” [34]. As researchers have no preconceived ideas to prove or disprove, issues of importance to participants emerge from the stories that they tell about an area of interest that they have in common with the researcher [64].

“All is data” is a position held strongly by Glaser with regards to grounded theory. In the book “The Grounded Theory Perspective” [36],

Glaser wrote:

“All is data” is a well known Glaser dictum. What does it mean? It means exactly what is going on in the research scene is the data, whatever the source, whether interview, observations, documents, in whatever combination. It is not only what is being told, how it is being told and the conditions of its being told, but also all the data surrounding what is being told. It means what is going on must be figured out exactly what it is to be used for, that is conceptualization, not for accurate description. Data is always as good as far as it goes, and there is always more data to keep correcting the categories with more relevant properties.”

Grounded theory begins with data collection. For our case studies, this took the form of observations, conversations and interviews. For both play systems, we conducted first hand observations of users interacting with the system as well as looking through the systems’ records of how the users have been interacting with the system e.g. in the case of cultural play system, we examine what the user discusses with the system. We also interviewed the users asking them about their play experience as well as the facilitators about what they noticed about the users. In addition, we have also administered questionnaires to all our users.

After each bout of data collection, the key issues are noted down and

this process is known as “note-taking” [21]. We reflect on the observations and user statements of players and spectators engaged in the system during a study and note down the key similarities between them.

After note-taking, we start to do coding. Constant comparison of data is at the heart of coding. We begin by comparing data with data, for example, comparing what user A has said to the system to what user B has said to the system. This then progressed to comparisons between their interpretations translated into codes and categories, and deriving more data. When theory begun to emerge, the data is then compared to theory in order to see if the theory is good enough to explain the phenomenon.

Through this coding process, categories are developed. A category is a theme or variable which makes sense of what the user has said. It is interpreted in the light of the situation under study, and other interviews, and the emerging theory. After some time, a core category will emerge from all the categories. In the words of Glaser [34], “it always happens that a category will emerge from among many and ‘core out’ of its own accord.” A core category is distinguished by the fact that it is mentioned with high frequency and is well-connected with other categories. However, there may be more than one core category which emerges.

In tandem with data collection, note-taking and coding, is the process of memoing. As we do data collection, note-taking and coding, we make use of memo to make a note about our own hypothesis of a category or property, or

about relationships between categories. Memoing is valuable as it allows us to establish relationships between emergent categories. Note-taking, coding and memoing are overlapping and concurrent stages of grounded theory. Grounded theory is an iterative process which means that if there are problems which occur at the memoing or coding stage, the research has to go back to the data and start over again.

Sorting is a process to facilitate the delimiting of theory. Modifications of memo and categories are mainly on the order of clarifying logic, taking out non-relevant properties, integrating elaborating details of properties into the major outline of interrelated categories and reduction. Through sorting, the research may discover underlying uniformities in the original set of categories or their properties and can then formulate the theory with a smaller set of higher level concepts [35].

As more of the themes emerged, some categories of issues affecting user experience provided a framework to organize the concepts. Subsequent review of data gathered codes and memos helped to confirm these categories. With the categories defined and researcher notes gathered, the process of producing the theory of the user experience issues in the form of linear and coherent statements was undertaken.

Chapter 4

Results

In this chapter, the technical results based on the evaluation of the performances of both physical and cultural play systems are presented. Subsequently, the user study data gathered in these two cases were first subjected to analysis separately using grounded theory. Intergenerational study with 10 students aged 10 to 12 and 10 elderly aged 60 to 80 were carried out to validate the enjoyment and playability issues on the physical play system. An additional experiment with 12 elderly aged 59 to 82 and 12 children aged 9 to 16 were conducted. For the cultural play system, a pilot study involving 12 parents and children was carried out. A user study was also conducted during a community event in a local residential estate, Punggol, in Singapore. A total of 83 users who are parents and children took part in this study. After analysing both cases separately, a cross-case analysis was conducted, whereby we compare and contrast the findings of each individual case with each other. The categories which emerge were presented.

4.1 Physical Play

4.1.1 Technical Results

This section presents user interaction with the physical play system.

Figure 4.1 shows a player jumping over an approaching laser to avoid being hit. If the player failed to avoid the approaching laser, an explosion pattern will be shown on the Bluetooth display worn by the player, as shown in Figure 4.2.

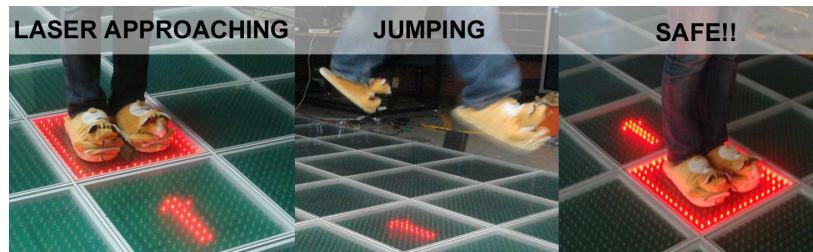


Figure 4.1: Dodging the laser beam by hopping over it

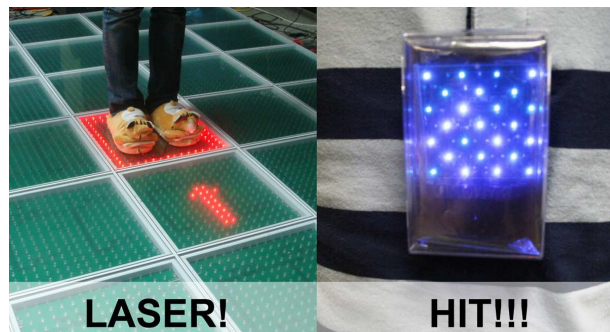


Figure 4.2: Bluetooth display lighted up when hit by laser

Online players using the virtual client, as shown in Figure 4.5, can see a real time representation of the physical board space, including the position of all the players and the virtual objects, thus increasing the link between

the real and virtual world. The statistics of the game like the health level and scores are also shown in the virtual client at the top part of the display screen. Virtual players and physical players will be able to view the health status of the players as well as the scores accumulated by both sides. The screenshot of the board is shown in Figure 4.3.



Figure 4.3: A screenshot of the scores and health board

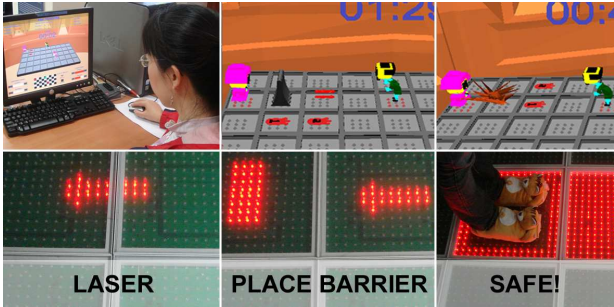


Figure 4.4: Grandparent saved by barrier dropped in virtual world

Users joining as active virtual client can drag and drop items in the virtual world, which will appear in the physical game space. As an example in Figure 4.4, the physical player was saved by the barrier placed by a virtual player. The online players can also adjust the game parameters (e.g. footprint speed and speed of the laser beams) by pressing the ‘+’ or ‘-’ button next to the footprint speed or laser speed indication bar at the bottom left and right on the virtual online interface respectively (Figure 4.5).

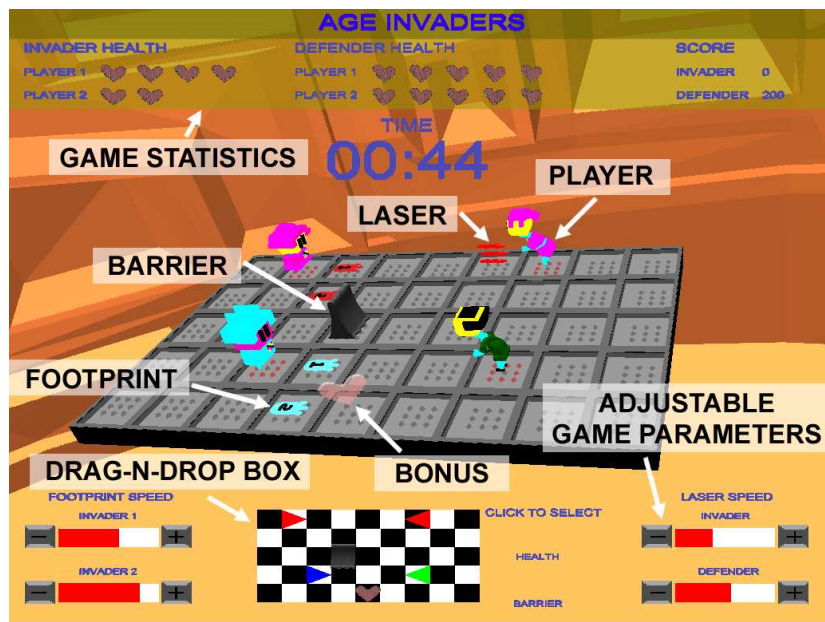


Figure 4.5: 3D virtual world player interface

Figure 4.6 shows participants playing Age Invaders, while Figure 4.7 shows participants playing Tap Tap Hearts game.



Figure 4.6: Age Invaders games in action



Figure 4.7: Photographs of users playing Tap Tap Hearts game

4.1.1.1 LED Panel Display Performance

The firmware implementation has brought numerous improvements to the Age Invaders system. The improvements cover the area of code efficiency, richer instruction set and lower network bandwidth consumption.

Game Server to LED panel network communication

In terms of network performance between the game server and LED

panel, the new firmware (automated) outperformed the old firmware (sending image flashing or animation instruction manually). Measurement of the network performance was done using a commercial program called bandwidth meter. In this program, the number of bytes that have been sent out can be monitored and the network usage is represented in the form of a graph.

In terms of performance for a flashing image over a period of 30 seconds, a total of 6.3kB were sent for the old firmware implementation. On the other hand, the new firmware only sent 94 bytes to achieve a flashing image over a period of 30 seconds and turn it off. Clearly, for a flashing image, the amount of information sent for the old firmware is dependent on flashing frequency and the duration it should be flashing. However, the new firmware is independent of these factors.

For the case of a moving image, a total of 1.92KB were sent to achieve an animation of moving an image from one end of the LED Panel to the other end for the old firmware. However, the new firmware only required 96 bytes to achieve a moving image from one end of the screen to the other.

Refresh rate

We have tested the final firmware for a moving laser. The laser can advance by one pixel every 20ms. This refresh rate is more than enough to handle fast moving images in action based game like Age Invaders. A simulator was run on the code of the new firmware implementation and it

was found that approximately 17 920 clock cycles were required to render one frame of the animation. This calculation was based on the worst case where there are 4 flashing images moving diagonally at the maximum speed. For the computation, all the flashing images are in the “on state, so they have to be drawn by the firmware. Each clock cycle is 10^{-7} seconds, so the new firmware only requires about 1.792ms.

In the Age Invaders game, the virtual player changes the speed of the laser of elderly and children players in real time. The speed of laser ranges from 20ms to 120ms in 10 steps equal interval. The speed corresponds to the time required to shift the laser from one pixel to the next in the direction of the moving laser. Smaller number means higher laser speed. For example, at the speed of 20ms, the laser will move across one floor block in 320ms, while at the speed of 120ms, the laser will move across one floor block in 1920ms. From the intergenerational user study, the average laser speed of the elderly and children players is recorded and shown in Table 4.1. Note that the children laser speed is slower than elderly laser speed, to compensate for the differences in the physical performance of the intergenerational players. Our system is able to refresh the laser speed at 20ms, which is sufficient for the requirement for the fast paced Age Invaders game.

Table 4.1: Laser speed of elderly and children players in Age Invaders game

Average speed of elderly player's laser	Average speed of children player's laser
36ms	62ms

4.1.1.2 System Accuracy and Response

In order to measure the performance of the physical play system, we have carried out an system accuracy and response test. We have recruited 10 university students who are students in the lab. The test is carried individually. Each participant wore the Bluetooth slipper and walked to the starting block for the test. Once the participant is detected on the starting block, the system automatically display a heart object on the floor, in front of the block occupied by the participant. A total of five heart objects are displayed on the floor in a sequential order with one each at one-second interval. The participant is required to move to the block where the heart object is lighted up, and continue to move forward to the next heart object shown after one second. Every time the participant step on a new block, a square border image is shown, indicating that the system has detected the participant's new position. The heart object will also disappear upon registration of the participant's new position on the block. For the blocks that the system was unable to register the user's position, the square border image will not be shown and the heart object will remain on the blocks.

The participants are only allowed to move forward once per step in this test, hence not allowing repeated detection of participant’s position on the same block. Each test requires the participant to move to 5 adjacent squares. Each participant repeated the test for four times, hence performed the position registration for 20 times. The total number of hearts remaining on the floor from each test, i.e. the system failed to register the participant’s new position, were recorded and shown in Table 4.2. Our system is able to register the user’s position with an accuracy of 91.5%, at one second per new position interval. The participants were also asked to rate their perceived system’s position registration response time based on how fast the square border lighted up upon entering a new position on the floor blocks. They were asked to rate the system’s response from a scale of 1 to 5, 1 — too slow, 2 — slow, 3 — acceptable, 4 — fast, 5 — real time. The result is shown in Table 4.3. 90% of the participants responded that the system position registration response time is fast or real time.

Table 4.2: System position registration accuracy

Total number of steps	Total number of steps successfully registered	Total number of steps failed to be registered	Accuracy %
200	183	17	91.5

Table 4.3: System position registration response time

	1: too slow	2: slow	3: acceptable	4: fast	5: real time
Number of participant	0	0	1	5	4
Percentage %	0	0	10	50	40

4.1.2 User Study Results

4.1.2.1 Enjoyment and playability study

The details of this study are described in Section 3.8.1.1. Prior to game play, the respondents were asked to rate themselves in experience level with electronic games choosing from the categories Newbie, Casual User, Moderate User, and Hardcore User. The results showed that 78% of the players were casual to hardcore users. All of the users reported that they play some kind of electronic game on a regular basis.



Figure 4.8: Enjoyment and playability user study game play

Figure 4.8 shows the users playing Age Invaders game. After the game play sessions, the users answered additional questions pertaining to the game experience. Most importantly, the respondents were asked to rate their enjoyment level with the game. Overwhelmingly, the respondents enjoyed the game play and would recommend it to be used for encouraging social interaction within families. The users were asked to indicate their level of agreement with the statement, “I enjoyed the game play experience.” As shown in Figure 4.9d all respondents chose “Agree or Strongly Agree.”

Players were also asked to rate their agreement with the statement, “I would recommend this game to be used to encourage social interaction within a family.” The strength of their positive sentiment is shown in Fig 4.9c. Only one of the players disagreed with the statement.

The players were asked to indicate their level of agreement with the statement, “The skills required by the game were well matched to my skills and experience.” The responses showed that 84% Strongly Agree to Somewhat Agree that the game play experience was well matched to their skill level and experiences. The responses are represented in Figure 4.9d.

The users showed preference to the four-player configuration compared to the two-player format according to their responses. The responses showed again that 84% Strongly Agree to Somewhat Agree that the four-player game was more enjoyable. This is shown in Figure 4.9b. In the focus group discussions, the users explained that the four-player games were more ex-

citing and preferred having a team member to engage in cooperative competition.

Players also had a chance to take part in the game as virtual players. The level of enjoyment was less in the virtual role, but showed positive sentiment towards the virtual play. In this case, the players were asked to indicate their agreement with the statement, “Playing as the virtual player was fun.” The results of the satisfaction levels are shown in Fig 4.9e. In order to determine what was enjoyable vs. not enjoyable, we discussed the virtual game play in the focus group discussions and some themes emerged and were reinforced with additional comments which guided the designers. Because the game system may have spectators, we also asked questions about the experience as an observer. Respondents were asked to indicate their agreement with the statement, “The game seemed fun to play from the observer’s point of view” This data is represented in Fig 4.9f. Additionally, the spectators agreed that watching the game is enjoyable as shown in Figure 4.9g.

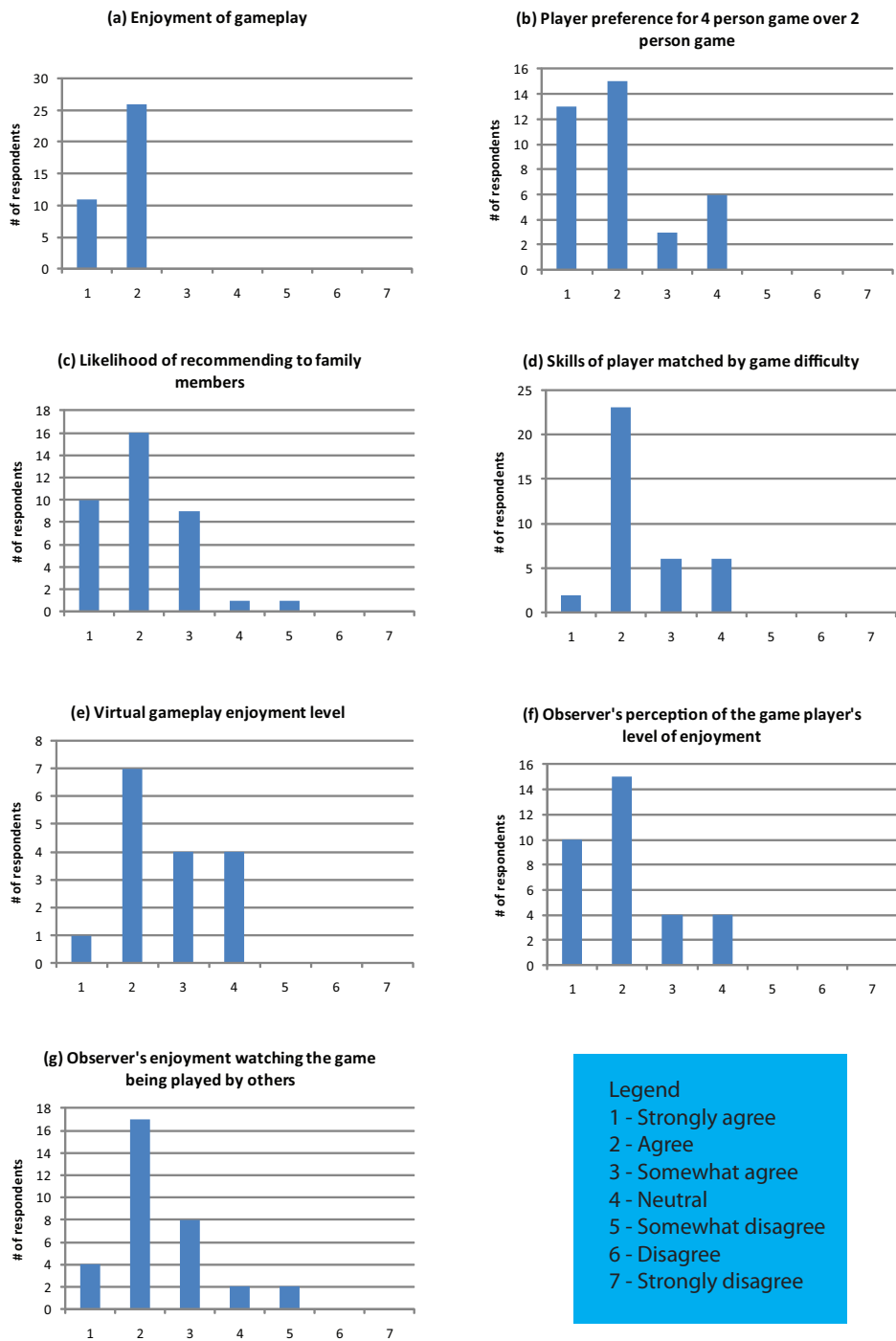


Figure 4.9: Responses to questions based on a Likert scale

4.1.2.2 Intergenerational player study

The details of this study are described in Section 3.8.1.2. In the pre-test questionnaire, sixty percent of the young players reported that they play some type of game with their family, while only 30% of the older players reported playing games with their families. Those who do play games with their families reported similar types of games regardless of age. They reported playing chess, cards and board games.

Figure 4.10 shows the elderly and children playing Age Invaders game. After the game play session, the users fill up a post-test questionnaires. The post-test questionnaires are mostly opened ended. The results are analyzed using grounded theory and are discussed in the section 4.1.2.3. As shown in Figure 4.11, in a specific rating question, “Did you enjoy the game experience”, the users have given overwhelmingly positive response of their user experience. All the children rated either enjoyed or enjoyed a lot, while 90% of the elderly rated enjoyed and enjoyed a lot for this question.



Figure 4.10: Intergenerational player study game play



Figure 4.11: Intergenerational player study game play

Focus group session with older players

Five weeks after we conducted the initial user study for the older and younger people, we went back to the senior center to conduct a follow up focus group session with 7 of the older players as shown in Figure 4.12. Our aim was to investigate the longer lasting impact of the Age Invaders game. When prompted to describe the most memorable aspects about the game, all of them mentioned the launching of lasers, avoiding lasers and chasing after the hearts on the game board. We identified that for the older players, the memorable actions in the game are physical in nature. The player has to press the physical button on the wireless controller to launch the virtual laser and in the cases of avoiding lasers and chasing after the hearts, the players have to physically move their bodies. All the older players were excited about this new entertainment platform.



Figure 4.12: Focus group session with older players

“This is a fresh idea and it was my first time playing,” said an older player. (The other older players expressed their agreement.)

The older people have never performed any computer related activities or played electronic games before and are afraid to attempt them. However, the players see this physical game system as being so different from traditional computer systems that not only were they comfortable to use the system, but they were also having fun interacting with other players while playing.

When asked what skills were involved in playing the game and about the difficulty level, all agreed that the game was easy to learn, and that the game speed was fine. A few mentioned that the pace could be a little slower in order to play for a longer period of time. However, they emphasized that the game speed cannot be too slow, otherwise it would become boring. The current game pace is exciting for them. An interesting description was stated by one of the players:

“The game gives me good exercise. When you see a heart, you have to run to collect it. If a laser is approaching, you have to avoid it quickly. The game is very engaging and can we play it again?”

This supports the design goal of doubling the game as a form of exercise. We also noticed that the older people enjoy moderate physical activity that

challenges their visual-motor coordination.

When asked about how much fun was the game as played, they all gave the maximum rating.

“Thinking about it now, we can’t wait to play again!” said one of them.

It is obvious that the older players have enjoyed the game and have high motivation to play the game again. Of particular interest is the fact that the users do not see a strong connection between this system and traditional electronic gaming and computing in general. This high motivation level is valuable in and of itself as confirmation that older adults can be engaged in new technologies and has high enjoyment levels.

4.1.2.3 Emerging Themes

As the data coding process continued, the themes developed into the following four categories. Issues that were reported by user statements and supported by additional observation are now presented.

Physical interface design issues

In designing an interactive system for older people and children, we aim to have high levels of physical and social interaction among players on interfaces that are easy to use and at the same time require minimal wearable equipment. The large physical floor display replaces the need for

head mounted displays for playing mixed reality games. Virtual objects are displayed on the large display on the floor. The older users reported that they were able to recognise the virtual objects displayed on the floor display immediately and appreciated the bright, easy-to-understand symbols.

To be registered in the game, the players have to wear the smart slippers with a built-in RFID reader. The usability of the smart slippers presented a particular challenge to the older players, most likely due to their reduced mobility and dexterity. All of the adult players agreed that easily adjustable slippers are needed. One generally accepted feature change idea provided by the older players was to use an adjustable Velcro strap to adjust the tightness of fit. On the other hand, all of the older people were able to understand that the game board was registering their physical steps.

Using footsteps as a control mechanism in the game is intuitive for them. Most of the older people in our study recognised the floor platform as similar to the popular Dance Dance Revolution (DDR) dance platform, which they often see young children playing in arcade centers. It is possible that they have already developed a mental model of such a stepping interface, hence it may have increased their acceptance of our floor-sensing interface. Also, many of the older players noted that when they stepped on a square, the light for that square lit up. This gives immediate feedback to the users that their action is being registered by the system and it reinforces that they understood the purpose of this feature.

Each player wore a lanyard style wearable LED display, which hung around their neck that lit up during game events, for example when hit by a laser, collection of bonus items, etc. None of the users in the study looked at their own display. We found out that it is neither intuitive nor easy physically, to have the users look at the display while playing the game, as the players are constantly concentrating on the floor display and the other players. This informed our design that we should keep the game interface as simple as possible and provide game's feedback on common game space visible to all players.

Physicality issues of the virtual player roles

The Age Invaders platform involves the players in a physical game space arena focused on a room-sized game board with 45 tiles each representing a physical position the players can occupy. Physical players register their position in one square at a time since the size of the square is just large enough for one person standing in place. While occupying a square, it is reserved for their avatar in the virtual world enforced by the game logic.

The presence of the virtual player is felt on the physical game space by the evidence of their activities in the virtual game space including the placement of barriers and hearts or by changing the speed of the laser beams. The virtual player's activities were not easily understood by the physical players as being activity directed by the human player versus coming from the logic of the computer program.

Most players who had experienced the game play from the virtual player role expressed that they found the game play experience less enjoyable than the physical player role. This could have been for a number of reasons which might include the following:

- The physical players interact in a more social situation in which they see the other players.
- Interaction in the physical space involves natural conversation and body language.
- Interaction in the physical space adds the element of performing on-stage for others, while the virtual player does not receive the same feedback.
- The physical exertion of the virtual player is much less and involves small hand movements with the mouse and keyboard.

Game experience issue: social play is fun

Social factor or playing with people in the physical space is constantly identified by the elderly and children player as what makes the game fun, evident in the data from questionnaires, semi-structure interview and focus group discussion.

As discussed in the earlier category on virtual player's roles, players prefer to play in a more social situation in physical space where they can

see other players. They also enjoy the richness of verbal and non-verbal communication that happens in the physical space, whereas the virtual player is interacting with other players through the virtual world interface which lacks these communications.

The physical nature of play leads to higher incidence of touching or physical contact between the teams whereby the players will make use of their bodies to block each other. There is also high incidence of physical contact within the team as players would tap each other on the back in order to get their teammates' attention. At the end of the game, few team members high-five each other in order to congratulate themselves on doing well. The high level of physical contact among intergenerational players helps to build rapport between the different age groups and strengthen their social bonds.

We observed in the video recording that when there is laser approaching, the team player or even opposing team player (on several accounts) would alert the player to move away, to avoid being hit by the laser. When a bonus item appears on the platform, the team member will shout at the nearest player to collect it as soon as possible, before the opposing team players collect it. On several occasions when two players rushed to collect the item, the player who succeed expressed excitement using words like "Yes!", while we noticed the player who failed expressed disappointment. Further probing leads us to understand that the player was engaging in competition with

other players to collect the bonus item and to avoid the laser which would reduce their game life, which is identified as being fun and memorable.

The players also expressed high motivation to play with their family members on the system. During the interview and post-test questionnaire, the users were asked which family members they would play this game with. The users started to name their family members and why they would enjoy playing.

“My brother and sister, they like this kind of game!”, quoted a 12 years old girl.

“Grandparents, to build family ties”, said a 12 years old boy.

“Grandchildren, they like to run around,” quoted a 69 years old grandfather.

It is interesting to note that the elderly users are only motivated to play such physical games with their grandchildren or younger players, while the children users are motivated to play with either their siblings or grandparents.

Game experience issue: adjustable game difficulty makes the game fun for both elderly and children

The physical activity of the players in the game space involves moving the body amongst the 45 squares of the game board and using a small handheld controller to launch laser beams in the game space. The physical

interaction with the handheld controller is the same amongst the players, but there are significant differences in the physical experiences of the players' positional movements, which vary depending on the team of which the player is a member. For the child players, the movements must follow the indicators on the game board. The child is presented with two squares that are adjacent to their current position to which she can move. There is a timer that requires the advancement of steps each 3 seconds, after which, a health level is deducted. This adds the sense of urgency to the physical movements and can be adjusted to an appropriate timer speed by the virtual player. We have identified a footprint timer range of one to three seconds to be the most exciting for the young players. Most young players felt the game was challenging because they have to take care of a few tasks at the same time, for instance following the step patterns, avoiding the approaching laser beams and trying to launch one. It turned out that these extra challenges made the game physically more interesting and enjoyable to the young and less demanding for the older people as they have the freedom to move to any position as they do not need to follow any sequence of steps. This matches the physical effort to the desired amount of movement that the elderly prefers. Through the nature of the team competition, the adult is compelled to move into a position to take offensive action, but can easily reduce the amount of movement and play from a more defensive style.

Prior to the study, the older people expressed their interest in playing

games similar to DDR which promote their body movements as a form of exercise. However, they are hesitant to try DDR because of the fast paced nature of the dancing game, which is perceived as too demanding for their physical ability. All the elderly participants expressed that an entertainment platform that could allow them to play with children must have an adjustable game speed so that the game pace can be calibrated to suit both parties.

After playing the Age Invaders, when asked about the difficulty level in the game, all the elderly agreed that the game speed was fine. A few mentioned that the pace could be a little slower in order to play for a longer period of time. However, they emphasized that the game speed cannot be too slow, otherwise it would become boring.

4.1.2.4 Experiment Design Results

Based on the emerging themes on game design using grounded theory, the social competition and game difficulty have been identified as variables of interest to be studied in a controlled experiment. The details of this experiment are described in Section 3.8.1.3.

Game Experience Questionnaire

The GEQ was used to evaluate the players' game experience. Users are asked to indicate their feeling according to a scale of 0 - 4 as indicated in Table 4.4. Figure 4.13 shows a child player filling up the GEQ with

the help of a facilitator. Figure 4.14 shows an elderly player filling up the GEQ with the help of a facilitator. The visual cues in a form of graphical representation of the four game scenarios are used to help the users to recall different game scenarios.



Figure 4.13: Child player filling up GEQ with the help from a facilitator



Figure 4.14: Elderly player filling up GEQ with the help from a facilitator

Table 4.4: GEQ rating scale

not at all	slightly	moderately	fairly	extremely
0	1	2	3	4

Table 4.5: Alpha value of GEQ

Dimension	Cronbach's Alpha
Competence	.600
Immersion	.570
Flow	.712
Tension	.768
Challenge	.762
Negative Affect	.875
Positive Affect	.722

Cronbach's Alpha for each dimension is shown in Table 4.5. The α value is above 0.7 for 5 dimensions: Flow, Tension, Challenge, Negative Affect and Positive Affect, showing strong internal consistency. Hence, we only focus on these 5 dimensions for this study.

The inconsistency of the rating results in the competence and immersion dimensions were further studied by breaking down the users into elderly and children group. Cronbach's Alpha test was run separately for each group.

For Competence dimension, the α values for elderly and children are 0.453 and 0.707 respectively. For Immersion dimension, the α values for elderly and children are 0.170 and 0.793 respectively. This suggests that the elderly may not understand the questions, which could be due to their cultural differences. Few elderly players feedback that playing the game

Table 4.6: Game Experience Questionnaire Results

	IV ₁ : Social Competition			IV ₁ : Game Difficulty		
	Mean (Computer)	Mean (Human)	F	Mean (no balancing mechanism)	Mean (balancing mechanism)	F
Tension	0.65	0.37	3.03	0.49	0.53	0.08
Flow	2.80	3.09	5.47*	2.83	3.06	4.38*
Challenge	2.60	2.68	0.18	2.38	2.91	18.24**
Negative	0.53	0.21	6.27*	0.38	0.35	0.06
Positive	2.96	3.43	9.13**	3.13	3.26	0.98

* $p < 0.05$ ** $p < 0.01$

well does not mean that they are skillful. They do not see playing games as a skill. Many elderly players also could not comprehend the statement “I was interested in the game’s story”. Future questionnaires which target elderly should take into account these cultural differences in order to gain more insights.

GEQ Results

Two-way repeated measures ANOVA was conducted on the ratings given by the users for the five GEQ dimensions of each scenario. F values of each within-subject main effects are shown in Table 4.6. No significant two-way interaction effect was found ($p > 0.05$) on all dimensions.

Flow

A significant within-subjects main effect was found between those playing against computer and elderly/child opponent ($F(1,23) = 5.47, p < .05$). People reported higher levels of flow experience when playing against a

younger or older opponent ($m = 3.09$) than computer opponent ($m = 2.80$).

A significant within-subjects main effect was also found between those playing in non-balanced and dynamically balanced scenarios ($F(1,23) = 4.38$, $p < .05$). People reported higher levels of flow when playing in balanced scenario ($m = 3.06$) than non-balanced scenario ($m = 2.83$).

Challenge

A significant within-subjects main effect was found between those playing in non-balanced and balanced scenarios ($F(1,23) = 19.14$, $p < .01$). People reported higher levels of challenge when playing in balanced scenario ($m = 2.91$) than non-balanced scenario ($m = 2.38$).

Results in Figure 4.16 suggest that there is an interaction effect between balancing mechanism and age group on the number of matches won in a game. Further analysis was conducted on the dimension of challenge by running mixed design ANOVA for the dimension of challenge with social play and balancing as within subject variables and age group as between subject variable. Surprisingly, no interaction effect was found for balancing game difficulty and age group ($p > 0.05$) on challenge.

Positive Affect

A significant within-subjects main effect was found between those playing against computer and human opponent ($F(1,23) = 9.13$, $p < .01$). People reported higher levels of positive affect when playing against an elderly or child opponent ($m = 3.43$) than computer opponent ($m = 2.96$).

Correlation was run on the number of matches won and positive affect, to check that there are no extraneous variables. No significance was found ($p > 0.05$).

Negative Affect

A significant within-subjects main effect was found between those playing against computer and elderly or child opponent ($F(1,23) = 6.27$, $p < .05$). People reported higher levels of negative affect when playing against a computer opponent ($m = .53$) than human opponent ($m = .21$).

Correlation was run on the number of matches won and negative affect, to check that there are no extraneous variables. No significance was found ($p > 0.05$).

Gameplay Results

Effect of Social Competition on Speed

A significant within-subjects main effect was found between those playing against computer and human opponent ($F(1,23) = 4.41$, $p < .05$). The result indicates that players who played against an elderly or child player have a faster speed ($m=2.53$) compared to playing against the computer ($m=2.71$).

Effect of Balancing Game Difficulty on Number of Matches Won

Independent t-test was conducted on the number of matches won per game for all four scenarios for elderly and children players. Figure 4.15 displays the average number of matches won for each scenario.

No of Matches Won across 4 scenarios

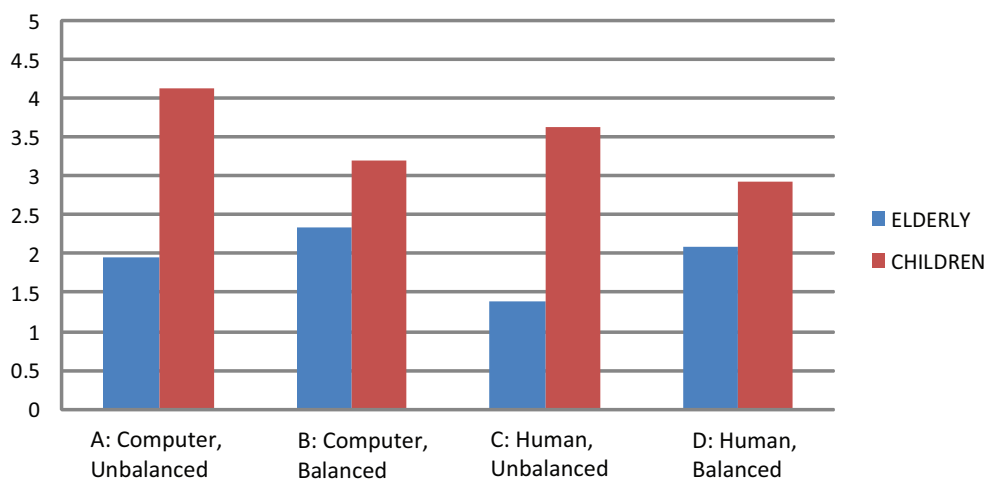


Figure 4.15: Average number of matches won for each game scenario

As expected, results showed that the difference between the matches won for these two groups are statistically significant across all four scenarios. The t-test results for A, B, C, D are $(t(19.78) = -4.31, p < 0.01)$, $(t(19.17) = -2.34, p < 0.05)$, $(t(22) = -4.46, p < 0.01)$, $(t(22) = -2.78, p < 0.05)$ respectively. This shows that there is indeed a gap in the ability between the elderly and children.

Mixed design ANOVA was then run on the total number of matches won with social play and balancing as within subject variables and age group as a between subject variable.

The results showed a significant interaction effect between the balancing game difficulty and age group ($F(1,22) = 33.03, p < .01$). The presence of balancing mechanism reduces the number of matches won by children and

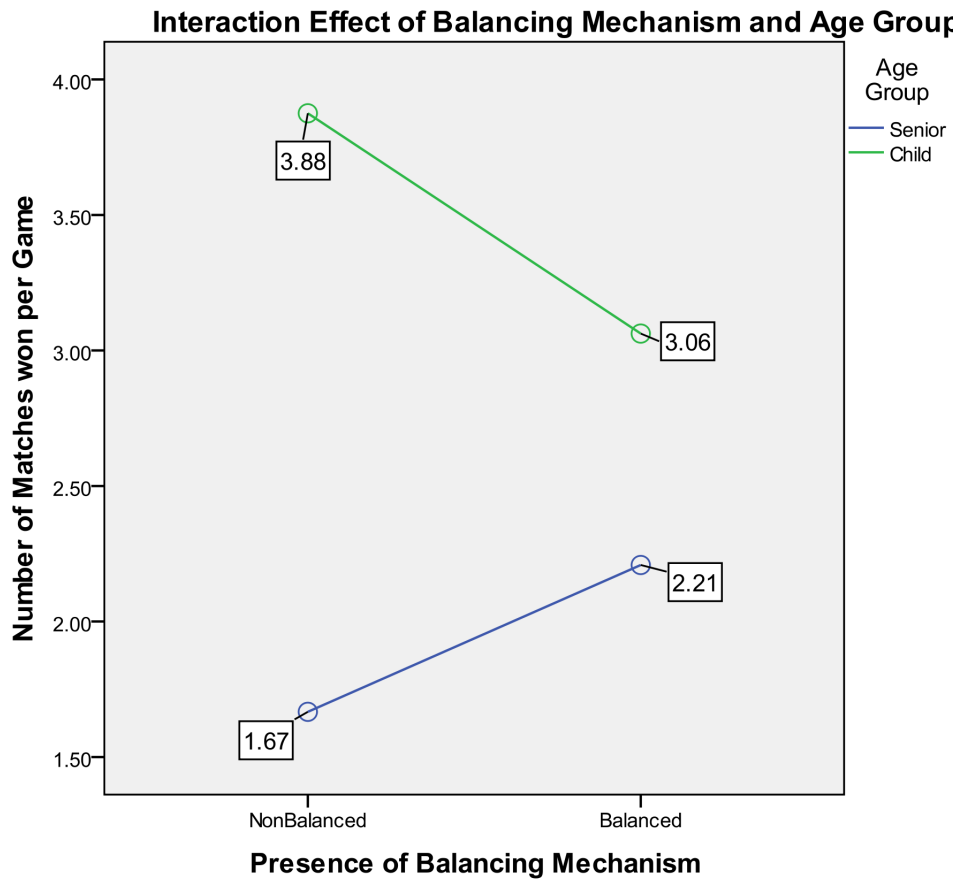


Figure 4.16: Interaction effect of balancing and player's ability

increases the matches won by elderly as shown in Figure 4.16.

Discussion

Players experience higher flow when playing with elderly or child opponent and in dynamically balanced game

The result suggests that social competition causes the players to be more competitive as they try harder to win the game by playing faster. As a result, the players are more absorbed in the game, hence higher level of flow is reported.

“Playing with kid is more enjoyable than with computer”, an elderly player remarked.

“More focused when playing with kids than with computer”, an elderly player said.

A child player commented, “I feel more absorb when playing with the elderly than computer, and when playing in a balanced situation than a non-balanced”

In a balanced scenario, the difficulty of the game is adjusted according to the players’ ability. According to flow theory [17], flow exists when there is a match between skill and challenge for each player. Thus, higher flow ratings reported for balanced scenarios indicates that our balancing mechanism is adequate in providing the appropriate amount of difficulty to the user than compared to a non-balanced case.

Players experience higher challenge when playing in dynamically balanced game regardless of their age group

The observation that children felt more challenge in dynamically balanced game scenarios corresponds with the findings in Figure 4.16 which indicates that children win less when the balancing mechanism is present.

However, the fact that elderly find dynamically balanced games more challenging despite winning more when balancing mechanism is an interesting finding.

One possible explanation is that increase in perceived challenge may come about because victory now seem more attainable to elderly players which in turn motivated them to put in more effort.

Players experience higher positive affect and lower negative affect when playing with elderly or child opponent

As positive affect is associated with emotions related to gaming achievements, playing with elderly or child opponent could possibly induce more sense of achievement as winning a human opponent in reality is more emotionally rewarding than winning against the computer.

Moreover, the physical interactions between elderly or child players add more challenge to the game than the playing with computers in forms such as obstructing and dynamic strategies. This is also supported by the earlier result that players generally find greater challenge in scenarios with elderly or child player. As challenge is higher, the sense of accomplishment will be higher thus giving rise to a greater positive affect.

On the other hand, negative affect comprises a compilation of negative feelings such as regret, lack of focus, shame and boredom [76] This result suggests that users generally find playing with human opponent less boring than playing with computer. This also corresponds with the observation on positive affect, thereby further supporting that the presence of a elderly or child opponent generates more interest in a game.

“Playing by oneself with computer is more boring”, commented an elderly participant.

This suggest that it is less interesting to play with computer opponent than with child opponent.

Players are more competitive when playing with elderly or child opponent versus computer opponent

When playing against human opponent, there are constraints of physical space, for example physical blocking and view occlusion, which in theory would slow down the playing speed. However the result shows that they are playing faster when playing against human opponent than when playing against virtual player. This indicates that they try harder to win the game, which suggests that the presence of social play prompts the players to be more competitive.

“When my opponent moves faster, I will move faster”, said a few participants.

Explicit dynamic balancing narrows the win-lose gap

Explicit dynamic balancing reduces the number of matches won by children and increases the number of matches won by elderly. With the balancing mechanism, children have more difficulty to win a game, while the elderly were given more chances to win. This shows that the balancing

mechanism succeeds in bridging the gap between players with different levels of ability.

“[Explicit dynamic balancing] is a handicap, it fills the gap between the skills of the two players in the game”, quoted one of the elderly player.

Balancing game difficulty is fair

Majority (70.8%) of users think that explicit dynamic game balancing is fair.

A few users mentioned that, “If you are good, you should do more!”

“Because if a person keep winning, it’s not fair,” commented a child.

“[Balancing] is fair, especially when playing with children. It gives more opportunity to win,” said one of the elderly.

A few children participants gave feedback that the balancing mechanism is unfair but said that they like it nonetheless because it makes the game more challenging. Players forgot about their age differences during game play

50% of the 24 users reported that they forgot about the age difference when they are playing the games with a human opponent. It could be that

because they are so absorbed in the game that they are taking the other player as their opponent without considering the age differences.

“It’s as if I have become a child again. I adopt a child’s mentality. When playing against the child, it feels as if I have become younger,” commented one of the elderly participants.

“At the beginning, I’ll be aware [of the age difference]. But when you really get into the game, you’ll forget about the age difference and just want to win,” remarked an elderly participant.

“[My opponent] is very competitive and it does not cross my mind that I am playing with an elderly,” said one child participant.

The balancing mechanism automatically balances the differences between two players, regardless of their age. If the elderly player is faster, the balancing mechanism would also impose more challenge on him or her.

4.2 Cultural Play

4.2.1 Technical Results

To evaluate the performance of our system, we carried out glass-box and black-box evaluation [73]. Glass-box evaluation attempts to look inside the system and measures how well each module performs while black-box evaluation attempts to measure how well the system performs as a whole.

Table 4.7: Keywords retrieval accuracy

Total number of keywords	Number of keywords matched	Accuracy (Number of keywords matched/Total number of keywords)
266	236	88.72%

We carried out the glass-box evaluation by examining each system module carefully. For black-box evaluation, the users gave their rating on relevance and enjoyment for each input-output chat entries.

4.2.1.1 Glass-box Evaluation

The evaluation set is randomly selected from one of the five Confucius scholar’s data set.

Keyword identification

For each of the 108 input sentence(s), the scholar has provided two to three keywords. Total number of keywords provided by the scholar is 266. Each sentence is entered into our system and our system identified keywords are compared to the ones provided by the scholars. As shown in Table 4.7, the total number of system identified keywords that matches the keywords provided by the scholar is 236. Therefore the accuracy of keyword identification is 88.72%.

Topics Identification

Total number of topics provided by the scholar is 265. Each sentence is

Table 4.8: Topics retrieval accuracy

Total number of topics	Number of topics matched	Accuracy (Number of topics matched/Total number of topics)
266	216	81.20%

Table 4.9: k-NN method retrieval accuracy improvement

	Total number of output entries provided	Number of output entries matched	Accuracy
k-NN (k = 3)	108	46	42.59%
Set 1	108	36	33.33%
Set 2	108	35	32.41%
Set 3	108	26	24.07%
Set 4	108	35	32.41%

entered into our system and our system identified topics are compared to the ones provided by the scholars. As shown in Table 4.8, the total number of topics identified by the system that matches the topics provided by the scholar is 216. Therefore the accuracy of keyword identification is 81.20%.

Confucius Entry Identification

Out of the 5 sets of input-output data provided by the Confucius scholars, one set is randomly selected for evaluation. The four sets were used for k-NN training. The Confucius entries selected using k-NN and one of the four individual sets are each compared to the Confucius entries selected in the evaluation set. The result is shown in the Table 4.9.

With k-NN method, an accuracy improvement of 39.39% was observed

Table 4.10: User rating on the enjoyment of Confucius output

Rating	Frequency	Percentage
1	53	6.8
2	49	6.3
3	106	13.5
4	158	20.2
5	417	53.3
Total	783	100.0

when compared with average performance of Set 1 to 4. Comparing to the worst case Set 3, an improvement of 76.92% was observed.

4.2.1.2 Black-box Evaluation

For black-box evaluation, the user gave feedback on their enjoyment and relevance rating of each of virtual Confucius response to the input sentence or question. For each input-output pair, the user can rate from 1 to 5, 1 being strongly disagree, and 5 being strongly agree. For the question, “I enjoy the Confucius’s response”, the users rating is shown in Figure 4.17 and Table 4.10. For the question, “The Confucius’s response is relevant to my input sentence”, the users rating is shown in Figure 4.18 and Table 4.11. Frequency refers to the number of input-output pair being rated for that particular rating number. The results shows that users rated highly on their enjoyment and relevance of the Confucius’s chat reply.

There is a positive correlation between relevance and enjoyment ($r(778) = .673, p < .01$), indicating that as the user ratings for relevance increase,

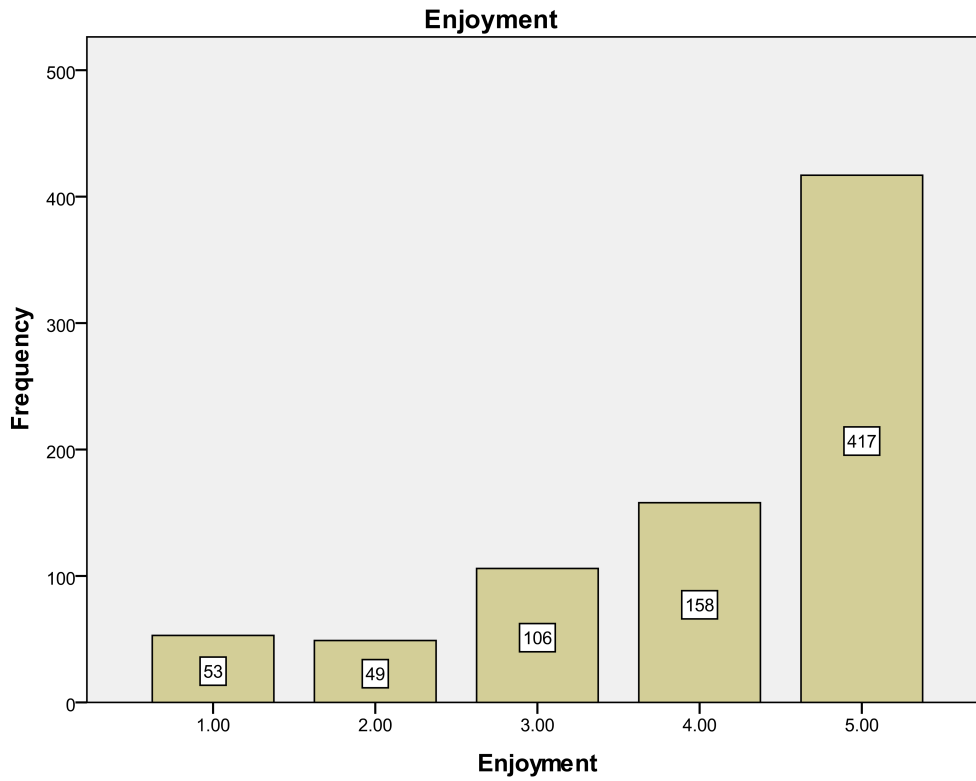


Figure 4.17: User rating on the enjoyment of Confucius output

Table 4.11: User rating on the relevance of Confucius output

Rating	Frequency	Percentage
1	66	8.4
2	45	5.7
3	117	14.8
4	168	21.3
5	393	49.8
Total	789	100.0

the enjoyment ratings also increases.

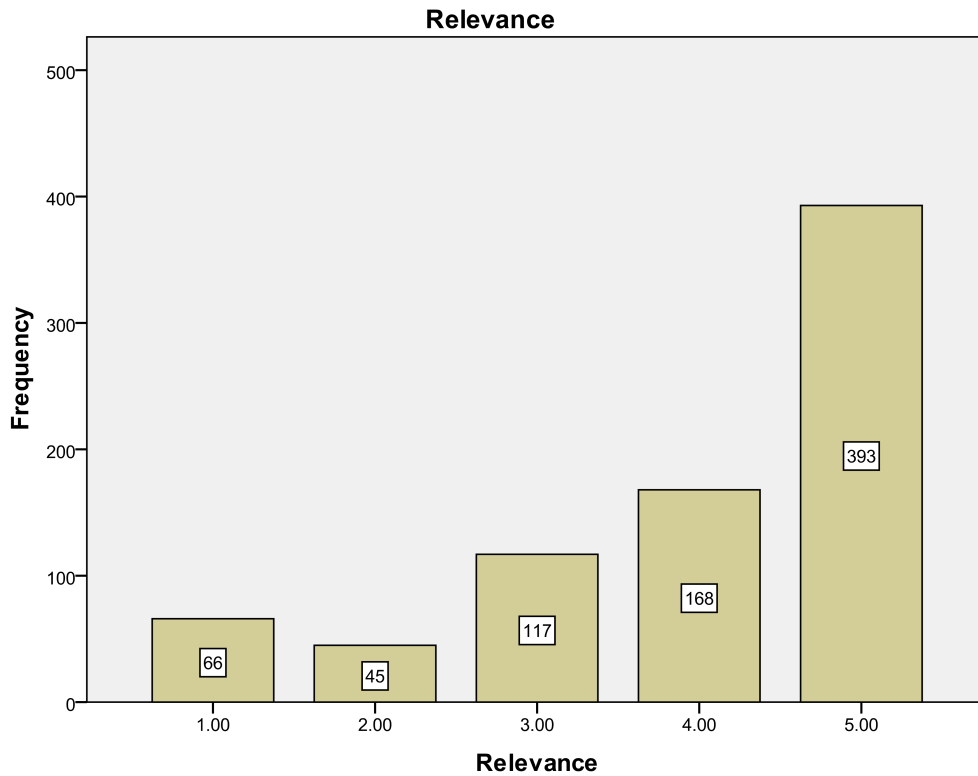


Figure 4.18: User rating on the relevance of Confucius output

4.2.1.3 Example of input-output retrieval

The example below shows the walk-through of a correctly retrieved system output which matches the expert’s (Confucius scholar) given output, based on the input-output data set provided by a Confucius scholar, as described in Section 3.5.5. In this example as shown in Figure 4.19, the input system to the system is “What would cause the instability of a family and how should we stay united?”. The system selects the keywords of the input sentence using two methods, headwords and inverse term frequency. The sentence is first fed into a parser to get the grammatical structure of the

sentence. The last noun of each noun phrase is selected as headword of the sentence. Usually they are the topic the user is talking about. However, sometimes there are no nouns in the user input, or there are some important words that are not nouns. Therefore, we employ another method called inverse term frequency to find the important words. The words with higher inverse term frequency value is considered more important in the sentence. Furthermore, the input sentence is passed through a Word Sense Disambiguation (WSD) module, so that we not only know what are the keywords of the input, but also the meaning of these words in the context. The output of WSD module is in the format `word#parts of speech#sense number`. For example, `instability#n#3` is the noun sense number three of the word `instability`, which is a lack of balance or a state of disequilibrium; `united#a#1` is the adjective sense number one of the word `united`, which is characterized by unity or joined into a single entity. The selected keywords with their corresponding senses in the sentence are `instability#n#3`, `family#n#2`, `united#a#`. The details of how the keywords are selected is presented in Section 3.7.2.1. Based on the keywords, the system identifies the topics based on the semantic similarity of the keywords and topics as described in Section 3.7.2.2. In this example, the system is able to correctly determine the topics based on the input sentence. The topics identified are 22 and 9 which correspond to family and harmony topics respectively in Table 3.10. The system then find the three most relevant database entries,

based on the closest distant, as described in Section 3.7.2.3section. In this case, the three closest entries belong to class 1283, 1970 and 1283. Based on the majority vote from the three closest neighbors, 1283 is the entry that will be output. The number 1283 refers to the index of the entry in the database. In this case, the output selected by the system matches the output given by the expert, “A family must first destroys itself before others can destroy it.”

Expert input:

What would cause the instability of a family and how should we stay united?

The selected headwords are:

[instability, family]

The selected keywords using inverse term frequency:

[united]

All the keywords selected are:

[instability#n#3, family#n#2, united#a#1]

Topics selected are:

[22, 9]

Top three entries selected using k-NN:

[1283, 1970, 1283]

System output:

1283 A family must first destroys itself before others can destroy it.

Expert output:

1283 A family must first destroys itself before others can destroy it.

Figure 4.19: Confucius Chat input-output retrieval example 1

In another example as shown in Figure 4.20, the system output selected is different from the output given by the expert. Based on the expert input sentence, the keywords selected using headwords and inverse term frequency with their corresponding senses are *action#n#1*, *son#n#1*, *filial#a#1*. The topics identified are 8, 2 and 19 which correspond to *conduct*, *children*, *filial* topics respectively in Table 3.10. The top three closest entries selected using k-nearest neighbor belong to class 26, 1612 and 186. Since there is an equal vote, the system will randomly choose one entry to be output, in this case, entry 1612 was selected. Note that the three entries selected using k-nearest neighbor were the closest match with the input sentence's topics combination, based on the classification by four Confucius scholars. The output provided by the evaluation expert is entry 186, which is different from the system selected output. Although the output is considered incorrectly retrieved for the evaluation process, it is noted that the system output is reasonable as a reply to the input sentence.

Expert input:
What kind of action should a son uphold for him to be considered filial?

The selected headwords are:
[action, son]

The selected keywords using inverse term frequency:
[filial]

All the keywords selected are:
[action#n#1, son #n#1, filial#a#1]

Topics selected are:
[8, 2, 19]

Top three entries selected using k-NN:
[36, 1612, 186]

System output:
1612 A filial son does not transgress what is due from him in all the sphere beyond himself.

Expert output:
186 If the son for three years does not alter from the way of his father, he may be called filial.

Figure 4.20: Confucius Chat input-output retrieval example 2

4.2.2 User Study Results

4.2.2.1 Pilot Study

We conducted a study with 6 pairs of Singapore Chinese parent and child (12 users) to get their feedback on using our system. The details of this study are described in Section 3.8.2.1. Figure 4.21 and Figure 4.22 show a

parent and child pair having fun using Confucius Chat system.

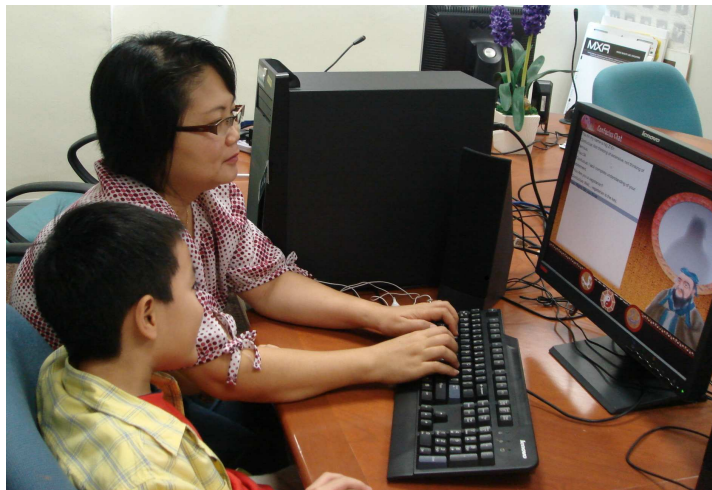


Figure 4.21: Parent and child using Confucius Chat during pilot study



Figure 4.22: Parent and child having fun with Confucius Chat

Figure 4.23 shows two children using Confucius Chat.



Figure 4.23: Two children using Confucius Chat during pilot study

The results of the study are summarized in Table 4.12. Question 1 seeks to evaluate the user's enjoyment of interacting with Confucius Chat. The users gave overwhelmingly positive response to their experience of interacting with our systems. 83.3% of children and parents agreed that they enjoy using Confucius Chat system. Questions 2, 3, and 4 seek to understand the user's enjoyment of interacting with the systems alone, with their peer and with another younger or older user (intergeneration). Fifty percent of the parents either neutral or disagreed that they enjoyed using the systems alone, while 66.7% of the children disagreed that they enjoyed using the systems alone. Most of the users preferred to play Confucius Chat together with another person. Of the parents, 100% agreed that using Confucius

Chat with their children was enjoyable, and 50% of them agreed that using the system with their spouse was enjoyable. Of the children, 83.3% agreed that they enjoyed using the system with their peers and 66.7% of them agreed that they enjoyed using the system with their parents. However, only 33.3% of the children agreed that using the system alone is enjoyable.

Questions 5, 6 and 7 seek to evaluate the user's perception of the systems in improving intergenerational interaction and their readiness to recommend this media to their friends and family members. Hundred percent of the parents and 83.3% of the children agreed that Confucius Chat can be used to improve interaction among young and old people. Of the children, 100% would recommend this media to their friends and family members, while 66.6% of the parents would recommend this media to their friends and 50% of them would recommend this media to their family members. Rationale for lower rating from parents with regard to recommending this media to the children was due to their concern that the philosophies and teachings are too complex and younger children may not comprehend them. However, the children did not have such concern and they were excited about their interactions with Confucius Chat.

4.2.2.2 Punggol Study

We carried a user study during a community event in a local residential estate, Punggol, in Singapore. The details of this study are described in

Table 4.12: Children and Parents feedback after using Confucius Chat

		Disagree		Netural		Agree	
		C(%)	P(%)	C(%)	P(%)	C(%)	P(%)
1	I play digital/computer games	16.7	16.7	33.3	16.7	50	66.7
2	I enjoy using this application alone, interacting directly with Confucius Computer	66.7	33.3	0	16.7	33.3	50
3	I enjoy using this application together with my peers	0	16.7	16.7	33.3	83.3	50
4	I enjoy using this application together with older (younger) players	16.7	0	16.7	0	66.7	100
5	Can Confucius Computer used to improve interaction among young and old people?	16.7	0	0	0	83.3	100
6	Would you recommend this media to your friends?	0	16.7	0	16.7	100	66.6
7	Would you recommend this media to your family members?	0	16.7	0	33.3	100	50

Sample size = 12

6 parents (aged 38-52) and 6 children (aged 7 - 11)

Section 3.8.2.2. Figure 4.24 shows a child using the system alone and Figure 4.25 shows a parent and child using the system together.

The results for the pre-test questionnaire are shown in Table 4.13. Question 1 seeks to understand user’s English comprehension as this may affect their understanding of the virtual Confucius’s output. Before the user took part in the study, they are advised to have basic understanding of English language, as this is the medium used in the interaction. More than 60% of the users agreed or strongly agreed that they have good English comprehension. In question 2, more than 60% of the users reported agree or



Figure 4.24: A child using Confucius Chat during Punggol study



Figure 4.25: Parent and child using Confucius Chat during Punggol study

strongly agree that they are confident in using a chat system. 59% of users agreed or strongly agreed that they are interested to learn about Confucius philosophy and teaching in question 3. Question 4 seeks to understanding the motivation of the users in discussing traditional values with their parent or child. 65.2% of the users agreed or strongly agreed to this statement.

Figure 4.26 shows a parent and child filling up the post test questionnaire. The results of post test questionnaire are summarized in Table 4.14. Questions 1 and 2 measure the affective aspects of the users' interaction

Table 4.13: Punggol Study Pre-test questionnaire result

	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)
1. I have good English comprehension skills (e.g. can understand sentences without problems).	2.9	8.7	26.1	37.7	24.6
2. I am confident that I can use a chat system (e.g. MSN, Facebook chat)	8.7	10.1	18.8	30.4	31.9
3. I am interested to learn about Confucius philosophy and teaching	1.4	7.2	31.9	36.2	23.2
4. I am interested to discuss traditional values about family (filial piety, parental love, etc) with my parent/child.	1.4	2.9	30.4	40.6	24.6



Figure 4.26: Parent and child filling up the post test questionnaire

experience. More than 50% of the users agree and strongly agree that they enjoy using the system and learning cultural values and teachings using the system is fun. Only less than 10% of the users disagreed or strongly disagreed that their experience is fun and enjoyable.

Questions 3 and 4 measure the relevance of virtual Confucius output. 40.5% of the users agreed or strongly agreed to question 3, “Confucius Chat replies are relevant”, while 56.5% of the users agreed or strongly agreed to question 4, “Confucius Chat replies are meaningful”. Only less than 15% of the users disagreed or strongly disagreed with the two questions.

Question 5 measures user’s engagement with the system. 49.3% of the users agreed or strongly agreed to this question, “I am absorbed or engaged in discussion using Confucius Chat”. 11.5% of the users disagreed or strongly disagreed with this question.

Questions 6 and 7 seek to evaluate the perceived usefulness of the system in exploring cultural values and improving communication between parent and child. More than 60% of the users agreed or strongly agreed to both the questions, “Confucius Chat is useful for parent and child in discussing family values”, and “Confucius Chat could improve communication between parent and child”.

Question 8 measures the motivation of the user in learning eastern cultural values after interaction with the system. 59.4% of the users agreed or strongly agreed to the question, “After using Confucius Chat, I am motivated to learn more about eastern culture”.

During the interview, few parents reported that children in general, are increasingly indifferent toward their own culture and the indigenous practices around them, while most of them and their elderly are still steeped in

Table 4.14: Punggol Study Post-test questionnaire result

	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)
1. I enjoy using Confucius Chat	1.4	5.8	33.3	34.8	24.6
2. Learning cultural values and teachings using Confucius Chat is fun	2.9	7.2	33.3	24.6	31.9
3. Confucius Chat replies are relevant	4.3	10.1	44.9	24.6	15.9
4. Confucius Chat replies are meaningful	4.3	10.1	29.0	27.5	29.0
5. I am absorbed/engaged in discussion using Confucius Chat	4.3	7.2	39.1	31.9	17.4
6. Confucius Chat is useful for parent and child in discussing family values	1.4	7.2	26.1	34.8	30.4
7. Confucius Chat could improve communication between parent and child	1.4	10.1	23.2	31.9	33.3
8. After using Confucius Chat, I am motivated to learn more about eastern culture.	1.4	11.6	27.5	31.9	27.5

the traditional eastern pattern of thinking and being. Many parents agreed on the importance of children understanding traditional cultural values, and that the learning activity should be regular for it to be effective. Among the traditional values that the parents felt were important are family values, ethics and traditional eastern values. However when prompted how are they currently communicating these values with their children, most of them did not do this as a structured or dedicated activity. Many of them mentioned

that they verbally discuss with their children on those topics, as and when they felt the need. Few reported using books, television, Internet and educational software. Many children mentioned that they enjoy learning those cultural values but prefer the activity to be more interactive. Many felt the media that they are currently using are boring, as they could not provide input or influence the content, and the same activity cannot be repeated over time. Few children suggested integrating the content into games or virtual characters which they could talk to. They mentioned that learning cultural values using Confucius Chat system is fun.

4.2.2.3 Emerging Themes

As the data coding process continued, the themes developed into the following three categories. Issues that were reported by user statements and supported by additional observation are now presented.

Interest in Confucius as a point-of-entry into learning

Users have a tendency to treat Confucius as a social actor. They observe social etiquette with Confucius and exchange social greetings e.g. hello, thanks, bye etc. They also try to find out about Confucius as a person by understanding his background through asking him question about his name, his age, his family etc. In addition, they engaged in playful casual conversation with virtual Confucius. These observations are consistent with previous studies on conversation agents [19] [52]. Being interested in Confu-

cius as a social actor motivates users to ask Confucius questions and further their interactions with Confucius. Each interaction with Confucius presents an opportunity for virtual Confucius to introduce users to Confucian values. For example, the questions about Confucius's personal life and background serve as a point of entry to learn about Confucius values. In the conversation log below, the user (8 years-old female) enquires after the age which Confucius began his studies. This question serves as a point of entry for her to learn Confucius' perspective on studying.

user8 *how old are you*

Confucius *I am about 2500 years old*

user8 *how old when you are die*

Confucius *To put the people to death without having instructed them - this is called cruelty.*

user8 *how old you when study*

Confucius *My disciples find that having exerted all their ability to study my doctrines, there seems something to stand right up before them; though they wish to follow and lay hold of it, they really find no way to do so.*

It is evident that children tend to be more playful with the system. Children who used Confucius Chat tend to ask more casual questions and the interaction with the system is markedly more light-hearted in tone. The

following chat-log shows a typical child's (user 14, male child) light-hearted exchange with Confucius.

user14 *i am a boy*

Confucius *A little kid?*

user14 *i am a man*

Confucius *Thanks for telling me your gender. You are a man.*

user14 *i am superman*

Confucius *How are you, superman.*

We also observed that when children use the system, they try to ask questions that test the limit of the system, for example asking the system to make a judgment or prediction on people or things of their interest. Their questions are not necessarily related to cultural values and it appears that the main focus of the interaction was for entertainment purposes. The following exchange is taken from the chat log of a pair of 12 year-old boys.

User22 *Is mrs lim a kind teacher*

Confucius *Jade, when struck, yield a note clear and prolonged, yet it terminates abruptly. This appears to a gentleman like music.*

user22 *Lol*

Confucius *I'm glad you find this amusing.*

user22 *is mr wee a fierce teacher*

Confucius *When I walk along with two others, there are bound to be something I can learn from them.*

On the other hand, users engaged in serious conversation with virtual Confucius to get his advice on family interpersonal relationship, for example “how to be filial”, “conflict between siblings” and “how to serve parents”. A child mentioned, “When I get scolding from my mother, I can tell Confucius!” This also shows that they perceive Confucius to be equipped with the social skills necessary to deal with complex social situations. In the following example, the child is experiencing frustration because her parents scold her. She then tries to ask the system for help in resolving tension which exists between her parents and her.

User 1 *my sister always share things with me but my par-
ents will scold me some time*

Confucius *If you wound your parents, you are wounding your
own root.*

User1 *can you help me*

Confucius *When I walk along with two others, there are bound
to be something I can learn from them.*

In this case, the interaction again serves as a point of entry for user to learn about Confucian values. The statement “if you wound your parents, you are wounding your own root” is merely a statement which suggests only that one should not hurt one’s own parents because it is like hurting a part of yourself. However, when the child triggered the response, the statement is put into the context of question and the interpretation becomes more nuanced. Based on the question, the interpretation of the statement becomes something like “Even if I am sad that I was scolded by my parents, I should not do anything to hurt them because it would be like hurting myself. I need to find another way to resolve the problem instead of getting upset or doing something that will hurt my parents”. The dialogical nature of the interaction with Confucius motivates users to reflect upon the meaning of the classical text of Analects in order to contextualise it into their own context. As users reflect upon Confucius output and try to relate it back

to their own context, the users are internalizing Confucius' teachings which make for more effective learning.

Beyond interpersonal relationships, children and parents also consult Confucius about other more general issues. The topics range from being academic in nature such as "how to do well in studies" and "how to be smarter" to questions dealing with ethics such as "what is evil". The types of questions that emerge suggest that the topics users talk about are strongly influenced by the reputation of Confucius. Confucius' philosophy emphasises strongly on social relationships within a family, morality and education.

The combination of Confucius' reputation as well as users' tendency to treat conversation agents as social agents motivates users interact with virtual Confucius either by asking him for advice or engage in casual conversation. Every interaction presents an opportunity for Confucius Chat system to impart traditional cultural values and Confucius' teachings. The philosophical output of Confucius is thought-provoking and this encourages further interaction as demonstrated in the example below:

user13 *How do you deal with people who are rude to you*

Confucius *When punishments are not properly awarded, the
people do not know how to conduct themselves.*

user13 *when is punishment too much*

Confucius *If good men were to govern a country in succession
for a hundred years, they would be able to dispense
with capital punishments.*

The parent-child pair has triggered a response “When punishments are not properly awarded, the people do not know how to conduct themselves” and was apparently intrigued by it. This led to his second question, “when is punishment too much?” By sustaining users’ interest, Confucius Chat is able to extend interaction and prolong engagement with the user. Further queries about Confucius’ original response will also lead to a better understanding of the values which Confucius expounds.

In post-test interviews, children have consistently expressed their preference for using Confucius chat system to learn about traditional values over books or other media. Most children find the virtual Confucius’s output entertaining. “The chat answers very funny”, said one child. Another contributing factor for their enjoyment is that the chat system is interactive. “Because we can ask any question”, and “faster to get answer compared to other media”, commented two different children. Parents also expressed

their view that the interactive element of Confucius Chat makes it a more interesting, if not effective way for children to learn about traditional cultural values. According to one mother, “Confucius Chat is better as there is two-party communication.” Another 38 year old mother acknowledges that new media is more entertaining and said “New media is more engaging for children.” All these user feedback suggests that interactivity and entertaining factors afforded by Confucius system makes it more appealing to the users who in turn are motivated to prolong their engagement with the system.

Social Interaction Issue

When parent and child use the system together, we observed the learning of cultural values takes place mostly between parent and child instead of between user and system. Parents act as a facilitator of knowledge between Confucius and the child by offering suggestions to children as to what questions to ask. Parents also make use of their understanding of the reply to teach the child to interpret and contextualise Confucius replies and that forms the basis of the interaction between parent and child.

In addition, parents also try to guide children by reading out loud Confucius’ replies together with the child. This helps to structure the activity as well as focus children’s attention on the educational aspect of interacting with Confucius Chat. The following chat log comes from a daughter-father pair. The pair consists of a 9 year-old daughter and a 39 year-old father.

The conversation tone is serious and the focus of the interaction appears to be on learning about Confucius values.

user11 *tell me more about filial piety*

Confucius *If the son for three years does not alter from the way of his father, he may be called filial.*

user11 *how to be filial*

Confucius *King Yu displays the utmost filial piety towards the spirits.*

The parent-child pair began with a general question about filial piety and based on the response, the parent suggested the follow-up question which is more focused and was directed at understanding the type of behaviour which is construed as being filial. This is an example whereby the social interaction between parent and child leads to better interaction with the system that is more beneficial for learning and understanding cultural values because the learning becomes consolidated and is much more in-depth.

Confucius Chat system facilitates transmission of cultural values as well as social interaction between the two human users involved. Parents recognised that Confucius is able to serve as a bridge between generations for them to discuss about important cultural values and values Confucius because the discussion about cultural values serves dual purposes of learning as well as social interaction.

“Confucius computer could be used to improve interaction among young and old people. The old people have more knowledge about Confucius and young children will ask them during the interaction.” - Parent

Based on the user feedback, children are equally partial towards using it with an adult family member or with children. They value the interaction with the system because they find it “fun” and the desire to share this fun with another person serves as the driving force for using the system with another user.

“I think grandpa will also like to use this. [We] can play together when I go over [to his place].” - Child

Thus, it appears that social interaction with an adult family member is a strong motivation for children to continue their interaction with Confucius and thus increasing their exposure to traditional cultural value. As children gain more understanding of Confucius values, they are also gaining more understanding of the values that their parents and grandparents hold dear. Thus, as they become more aware of Confucius values, they are being more aware of the values that guide their parents and grandparents actions and this increase in understanding of other family members will benefit them in future family interactions.

Content/knowledge comprehension issue

Through the course of our study, we found that children especially the younger ones have more difficulty understanding Confucius' output. This problem is further exacerbated by children's tendency to make spelling or grammatical errors in their input, thus increasing the chances of error in Confucius output. However, this does not necessarily deter them from enjoying interacting with the system. While some children displayed frustration/annoyance at the philosophical reply of Confucius, most children find the philosophical replies amusing. The excerpt below is taken from the chat log of a pair of 11 year-old females who expressed their amusement at the exchange even though they did not understand Confucius' reply.

user5 *will i pass my PSLE with good grades?*

Confucius *If in his words, the ruler does not go beyond what should be said, nor in his actions what should be a model, then the people, without being commanded, will revere and honour him.*

user5 *Lol*

Confucius *I'm glad you find this amusing.*

While it is good that children were not deterred by Confucius' philosophical output, it limits the effectiveness of Confucius Chat if the user is unable to understand the output. Parents recognised the complexity of Confucius output and children's limited cognitive ability and voiced similar

concern over the effectiveness of the system to teach this younger group of children traditional value.

“I feel that is too difficult for young children below 9 years old. Confucius Chat is probably be more suitable for upper primary or secondary students.” - Parent

“I will only recommend to my family members with elder child because is good to teach the child with ancient culture.” - Parent

These quotes illustrate the need for the Chat system to be able to recognise whether the user is a child and adapt its more of output according to less complex sentences in order for younger children to benefit from Confucius’ teachings. While younger children were observed to encounter more difficulty to make sense of Confucius output, we also observe some users in the parent age group who could not understand Confucius’ output. This was attributed to an insufficient knowledge of Confucius values which would serve as a basis to interpret Confucius’ replies. There was also distinct difference between the way parents with higher level of pre-knowledge and parents with lower level of pre-knowledge interact with Confucius Chat. Parents with higher level of pre-knowledge tend to be able to engage in more meaningful conversation with the Confucius and asked Confucius specific questions. On the other hand, parents with lower level of pre-knowledge tend to ask more open-ended questions or choose to engage Confucius on a

more casual basis such as making small talk. Similarly, it would be beneficial for the Chat system to be able to recognise the knowledge level of the user and adapt its output according in order for the user to benefit from the interaction.

4.3 Cross Case Analysis

Emerging themes from both physical play and cultural play cases were cross analysed to expand and generalize the theories on intergenerational play systems. The themes developed into the following three categories are supported by data from the two case studies.

Play provides an opportunity for intergenerational communication

The results from both physical and cultural play case studies suggest that intergenerational communication is sustained by the fun afforded by such play systems. Verbal language, paralanguage and kinesics communication [77] occurs frequently between the intergenerational users when they are engaged in social play using our systems.

The verbal language communication between the two generations occur to improve the player's understanding of the play situation. For instance, in physical play system, the verbal exchange of information between the elderly and younger player for the purpose of alerting the younger players to

the possibilities of danger in their environment. Figure 4.27 shows how verbal communication in physical play system can play the role of coordinating the actions of the players and to encourage the other players. Similarly, the verbal communication between the two generations when using the cultural play system is to deepen the child's understanding of the Confucius output and promote discussion on events or incidents that happens in their family. As seen in Figure 4.28, the child was engaging with her father in a private discussion, based on virtual Confucius's reply. This form of verbal communication is valuable as it facilitates the learning process of the young and closer interaction between the parents and children.

Paralanguage communication between parents and children engaging in cultural play are in the forms of eye contact, facial expression and speech mannerism (e.g. exaggerated slow speech, reading out loud). For instance, the parents and children would read out loud the virtual Confucius's reply together. Sometimes they would laugh at virtual Confucius's replies. Paralanguage communication occurs in physical play system, in the form of independent sounds produced when winning or losing, such as exclamation, cheer, booing etc. There is also rich eye contact and facial expression between the players.

In the physical play case study, we observe that the bulk of the communication occurs on the kinesics level. The more physical nature of play also leads to higher incidence of body contact between the teams whereby the



Figure 4.27: Physical play system facilitates verbal communication

players will make use of their bodies to block each other.

“A few times I purposely block the elderly,” said one of the child participants.

“Human opponent will take up space, so I must find a way to access the space and outsmart my opponent,” replied one of the elderly players when asked about his strategy when playing against a child.

There is also high incidence of body contact within the team, as players would tap each other on the back in order to get their teammates’ attention.



Figure 4.28: Cultural play system facilitates verbal communication

At the end of the game, the team members may high-five each other in order to congratulate themselves on doing well. For instance, as shown in Figure 4.29, the children gave each other a high-five and cheered after winning a game. The high level of physical contact among intergenerational players helps to build rapport between the different age groups and strengthen their social bonds, thereby providing extra reward, apart from winning the game.

Intergenerational users prefer to engage in social play

The emerging themes from both case studies confirm that the intergenerational users prefer to engage in play activity with another person in the same physical space, as compared to being alone.

The results from the physical play studies suggest that the play expe-



Figure 4.29: Players cheering after winning a game

rience is more enjoyable when the two players are collocated in the same physical space. Participants of the physical play system played both the virtual player role as well as the physical player role. Players unanimously concluded that while the virtual player role is enjoyable, overall, the lack of sense of connectedness and the lack of ability to directly take part in the gameplay was not as enjoyable. Through the follow-up experiment done with the physical play system, we validated the fact that both elderly and children find it more fun to play with each other. Similarly, the results from the cultural play studies suggest that the parents and children users

both reported the play experience is more enjoyable when using the system together as compared to using it alone.

While both children and adults (parents and grandparents) prefer to engage in social play, their motivations are different: children play for the sake of having fun whereas older adults turn to play as a way to connect with children. Children's motivation for play is due to the fun nature of the activity, which more enjoyment is derived with the presence of another person. The adults' motivation for play would be best explained by the people factor, where the players use play as mechanism for social experiences.

Elderly users responded that it does not matter what kind of play system it is as long as they can play with their grandchildren. This divergence is more prominent in cultural play system where we observed that the adults were somewhat disinterested in using cultural play system alone and showed more outward enjoyment when they used the system with another child. The survey results from the cultural play study showed that although adults viewed the cultural play system as being strongly suitable for intergenerational usage, they are only interested to use it with children. This is in line with the feedback gathered from the elderly participants of the physical play system who said that that they cannot see themselves using the physical play system with their peers and are only motivated to use the system with their grandchildren.

On the other hand, regardless of the type of play, children are driven

primarily by the fun factor as their reason to use the play systems again. However, based on the user feedback on both case studies, children are equally partial towards engaging in a play activity with an adult family member or with children. They value the interaction with the system because they find it “fun” and have a desire to share this fun with another person serves as the driving force for using the system with another user. These diverging motivations should be taken into consideration before embarking on the design of an intergenerational play system. The kind of play which the system affords should be designed first and foremost for the children. In order to meet the needs of the older age group for social experiences, the gameplay mechanics should involve a large degree of social interaction, for example competition or discussion. Nonetheless, the two age groups’ diverging motivations converge to the same activity of play and it is in the activity of play that two age groups can be brought together to enjoy themselves and open the opportunity for communication with each other.

User experience is enhanced when the system matches the ability of the user

Mihaly Csikszentmihalyi’s Flow Theory [17] suggests that a person is more likely to get into a state of flow when there is a balance between challenge and ability. Thus, the difficulty of the system output should match the ability of the user in order to create a better user experience.

A better user experience is created when there is a balanced difficulty of the play. This is first reflected in the user requirements we gathered from the elderly participants in the physical play study who specified that they were worried that game pace of a physical play game. They stressed before and after the study that the game pace must not be too fast or they would not be able to follow but it must not be too slow either or they would get bored. After the elderly participants played the physical play system, which was specially designed to be slower and easier for the elderly, the elderly unanimously agreed that the game was fun and expressed their desire to play again. The field observations of the cultural play system provides hints as to what would happen to the user experience if care is not taken to match the system output to the ability of the user. In the usage of cultural play system, we observed that users are more likely to experience frustration when there is a mismatch between the output and their ability, for instance, they are unable to interpret the meaning of Confucius output.

A better user experience is created when there is a balance the difficulty of the output between the users. As intergenerational play systems are catered for age groups that are situated at different ends of the age spectrum, there is a disparate ability gap which exists between these two age groups in terms of cognitive as well as physical play ability. In physical play activities, the young is more advantaged than the old and the situation is reversed in cultural play or types of play that requires greater cognitive

ability. The need to balance difficulty between the users, is further explored in the experiment done using physical play system. The results validated the need for play systems to balance the difficulty given to each user by means of dynamic balancing. The results showed that players who engaged with a play system that adopts dynamic balancing have a more positive game experience, compared to engaging with a play system that does not employ any balancing.

Designing intergenerational play should take into consideration the differences in the abilities of the users. Instead of building systems with different pre-set difficulty levels, it would be more effective to design a system that can recognise the skill level of different users who are using the system together, then balances the interaction between them.

Chapter 5

Conclusion

Chapter 1 outlined the exploratory domain and the problem statement for this dissertation. The research question of this dissertation is, “How do we design novel interactive physical and cultural play systems that facilitate intergenerational communication?”. Play has many proven benefits for intergenerational communication. However, prior literature and our own initial survey with Singapore local grandparents, parents and children reviewed that there is currently limited digital play and entertainment system which is designed for their simultaneous consumption, despite their eagerness to participate in those activities together. Therefore, we are motivated to design novel interactive media that could mediate intergenerational communication through physical and cultural play. We are motivated to design physical play systems that allow the intergenerational users to simultaneously engage in a fun and leisure activity, using natural human movements, which is currently not supported by most games or entertainment devices.

In addition, as children today possess a high level of digital literacy, we are motivated to design new form of cultural play system, where users can explore cultural values and teachings through digital media. There are three research contributions in this dissertation: novel design and engineering of a physical play system, which allows grandparents, parents and children to simultaneously engage in games physically and through a virtual game world; novel design and engineering of a cultural play system which allows grandparents, parents and children to explore cultural values through a virtual chat agent, modeled after Confucius knowledge and teachings; uncover design principles from user studies of the two systems developed, to inform future researchers interested in designing better media experiences for an intergenerational audience.

Chapter 2 presents the definitions for the two forms of intergenerational play, physical play and cultural play, explored in this dissertation. Physical play is defined as engaging in a play activity which involves motor skills, while cultural play is defined as engaging in a play activity which allows the user to experience the core aspects of his or her culture. The contribution of our research is elaborated and comparison is made to highlight the similarities and differences of our research and those in the literature review. Previous entertainment systems address the differences of elderly and children by designing different roles for them. Our physical play research explores the potential for symmetrical interaction between seniors

and children, by putting them on the same playing field. By uniquely detecting each player's position of the floor game board in real time, the system allows the users to use full body movements to play the game, while the balancing mechanism was employed to address the ability gap between these two groups of players. Furthermore, the system affords rich verbal and non-verbal communication between the elderly and children players in the physical game space, without constraining them to a LCD monitor or TV screen in typical gaming systems. In addition, the system also offers the possibility of real and virtual game play, where parents can join the game remotely through the Internet. Our cultural play system employs natural language processing methods to analyse the user's input sentence, for example the keywords, the sense of the keywords, and their corresponding topics. At the same time, the system models Confucius knowledge and teaching. In this way, the system allows users to have natural language chat with a virtual Confucius while exploring the cultural values together with a parent or child. In addition, literature review on user play experience and variables that would influence the user's experience are presented. Finally, the theoretical framework for studying the user experience, which is based upon Game Experience Questionnaire, is reviewed.

In Chapter 3, multiple-case study approach used in this research is presented. Two cases of intergenerational play, physical play and cultural play were designed and studied in this dissertation. Design-oriented Research ap-

proach was employed in this research, to develop the research prototypes, while involving the intergenerational users throughout the design process. In this research, the development of the two different play systems were a means to test and uncover underlying design principles that would be useful in designing play systems meant for intergenerational use. We set out to design the system, which is not a simple productivity application, but a system that is an open platform encouraging interaction and promoting fun social play. The design steps we followed include the following: problem identification, problem exploration, setting the design goals, design requirements of prototype, research user needs, research context of use, design idea generation, prototype creation, and usability studies. Each iteration returned to the beginning and followed a subset of the design cycle in attempts to understand the user better or to overcome a technical challenge. In creating the prototypes, various technologies, their cost, availability, feasibility, implementation and performance are evaluated carefully. The objective is to discover novel use of technology to create new interaction experience. In the physical play case, an interactive floor system was developed to allow grandparents and grandchildren to play the games by physically moving their bodies on the platform. Input devices of the system include Bluetooth Controllers for triggering events in the game, Bluetooth Slippers with embedded RFID readers for tracking the position of the players, and control parameters from the online player virtual clients. Output devices of the

system are the 45 LED panels on the floor platform, each having 256 Ultra Bright LEDs, for displaying the objects and events of the game, lanyard style Bluetooth Displays for displaying individual player's events, and a 3D online player virtual client for displaying the virtual world of the game. As the players move on the floor platform, their coordinates are tracked and translated to the virtual world in real time, creating a seamless link between physical and virtual worlds. The parents who play as virtual players can change the game parameters in real time to balance the gameplay between grandparents and grandchildren.

In the cultural play case, a virtual Confucius chat agent, which was modeled after Confucius knowledge and teachings was created to allow users to have a natural language chat with virtual Confucius while exploring cultural values. To improve the retrieval accuracy of our system, k-nearest neighbor (k-NN) algorithm was employed. Five Confucius scholars were engaged to provide input-output data-sets for the training and evaluation of the system. A total of 432 vectors, 4 each to describe a database entry, are obtained. To use k-NN algorithm, k value which yields the best performance is obtained using a k-fold cross validation method. Each database entry is treated as a unique class, described by a set of vectors manually assigned by Confucius scholars. When a new input sentence is entered to the system, natural language processing methods are employed to determine the keywords and corresponding topics in the sentence. k-nearest neighbor

algorithm will then determine the most relevant class the input sentence belongs to, based on the similarity of the input sentence topics and the vectors describing each database entries. The database entry corresponds to the selected class will be output. The software engineering details to build the system prototypes are presented. Subsequently, in depths user studies and experiment were carried out to identify and validate usability and interaction issues and to uncover possible design principles. The methods for carrying out user studies for the two cases are also elaborated. We have conducted two user studies for physical play, first with a group of 49 polytechnic students, and later with 20 elderly and children. On the other hand, two user studies were carried for the cultural play system, with 12 parents and children in the first study and 83 parents and children in the second study. Grounded theory was used to analyse the data for emerging themes. In the physical play case, experiment design was carried out to further enhance the results.

In Chapter 4, the technical performance of both physical and cultural play systems are evaluated. For physical play system, in terms of network performance between the game server and LED panel, the new firmware (movement and flashing of images are automated by LED PIC micro-controller) outperformed the old firmware (Game server sending image flashing or animation instruction manually to LED PIC micro-controller) for animating images. In terms of performance for a flashing image over a period of 30

seconds, a total of 6.3kB were sent for the old firmware implementation. On the other hand, the new firmware only sent 94 bytes to achieve a flashing image over a period of 30 seconds and turn it off. For the case of a moving image, a total of 1.92kB were sent to achieve an animation of moving an image from one end of the LED Panel to the other end for the old firmware. However, the new firmware only required 96 bytes to achieve a moving image from one end of the screen to the other. We have tested the final firmware of the LED panels for a moving laser. The laser can advance by one pixel every 20ms. This refresh rate is more than enough to handle fast moving images in action based game like Age Invaders, where the average laser speed for elderly is 36ms and for children is 62ms. System accuracy and response test was carried out with 10 university students. The system is able to register the user's position with an accuracy of 91.5%, at one second per new position interval. The participants were also asked to rate their perceived system position registration's response time, based on how fast the square border lighted up upon entering a new position on the floor blocks. 90% of the participants responded that the system position registration response time is fast or real time.

To evaluate the performance of the cultural play system, glass-box and black-box evaluations were carried out. Glass-box evaluation attempts to look inside the system and measures how well each module performs while black-box evaluation attempts to measure how well the system performs as

a whole. Glass-box evaluation was carried out by examining each system module carefully. Black-box evaluation is based on the user rating on the relevance and enjoyment for each input-output chat entries. For the glass-box evaluation, the system is able to identify the keywords and topics with an accuracy of 88.72% and 81.20% respectively. Based on the input sentence provided by a Confucius scholar, the system selected output is compared to the Confucius scholar output. An accuracy of 42.59% was obtained using k-NN method. There is an accuracy improvement of 39.39% when compared with the average performance of individual scholar's classification. For black-box evaluation, more than 70% of the users gave rating of 4 (agree) or 5 (strongly agree) for the enjoyment and relevance of virtual Confucius's response to their input sentence or question. There is a positive correlation between relevance and enjoyment ($r(778) = .673, p < 0.01$), indicating that as the user ratings for relevance increase, the enjoyment ratings also increases.

The user study data gathered in physical and cultural play cases were first subjected to analysis separately using grounded theory. After analysing both cases separately, a cross-case analysis was carried out whereby the findings of two individual cases were compared and contrasted. There are three emerging themes: Play provides an opportunity for intergenerational communication; Intergenerational users prefer to engage in social play; User experience is enhanced when the system matches the ability of the user.

The results from both physical and cultural play case studies suggest that intergenerational communication is sustained by the fun afforded by such play systems. Verbal language, paralanguage and kinesics communication occurs frequently between the intergenerational users when they are engaged in social play using our systems. The emerging themes from both case studies confirm that the intergenerational users prefer to engage in play activity with another person in the same physical space, as compared to being alone. However, their motivations are different: children play for the sake of having fun whereas adults (parents and grandparents) turn to play as a way to connect with children. In addition, the emerging themes suggest that a better user experience is created when there is a balance the difficulty of the output between the users. As intergenerational play systems are catered for age groups that are situated at the different ends of the age spectrum, there is a disparate ability gap which exists between these two age groups in terms of cognitive as well as physical play ability. In physical play activities, the young is more advantaged than the old and the situation is reversed in cultural play or types of play that requires greater cognitive ability. The need to balance difficulty between the users, is further explored in the experiment done using physical play system. The results validated the need for play systems to balance the difficulty given to each user by means of dynamic balancing. The results showed that players who engaged with a play system that adopts dynamic balancing have a more

positive game experience, compared to engaging with a play system that does not employ any balancing.

The kind of play which the system affords should be designed first and foremost for the children. In order to meet the needs of the older age group for social experiences, the gameplay mechanics should involve a large degree of social interaction, for example competition or discussion. Designing intergenerational play should also take into consideration the differences in the abilities of the users. Instead of building systems with different preset difficulty levels, it would be more effective to design a system that can recognise the skill level of different users who are using the system together, then balances the interaction between them.

In this research, three age groups, grandparents, parents and children, are brought together to enjoy themselves in the physical and cultural play systems. Our results show that when play is carefully designed, by catering to the needs of the users, it can offer rich intergenerational communication opportunities. It is hoped that this research would lead to exploration of more innovative design of technology, to connect intergenerational users through play. Currently, the Confucius Chat system has been extended into a mobile application, iSage (Figure 5.1), which offers users advice, based on various philosophers and knowledge base. In this application, the users can choose to ask the virtual Sage on topics ranging from love, fate and many more to be expanded in the future. The topic knowledge databases were

obtained from various sources. Based on the algorithm of Confucius Chat system, iSage allows user to interact with the application using natural language chat. The iSage application has been deployed on the Android Market (<https://market.android.com/details?id=com.mixedreality>).



Figure 5.1: Confucius Chat Mobile App

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Appendix A

Schematic and PCB of Bluetooth Controller

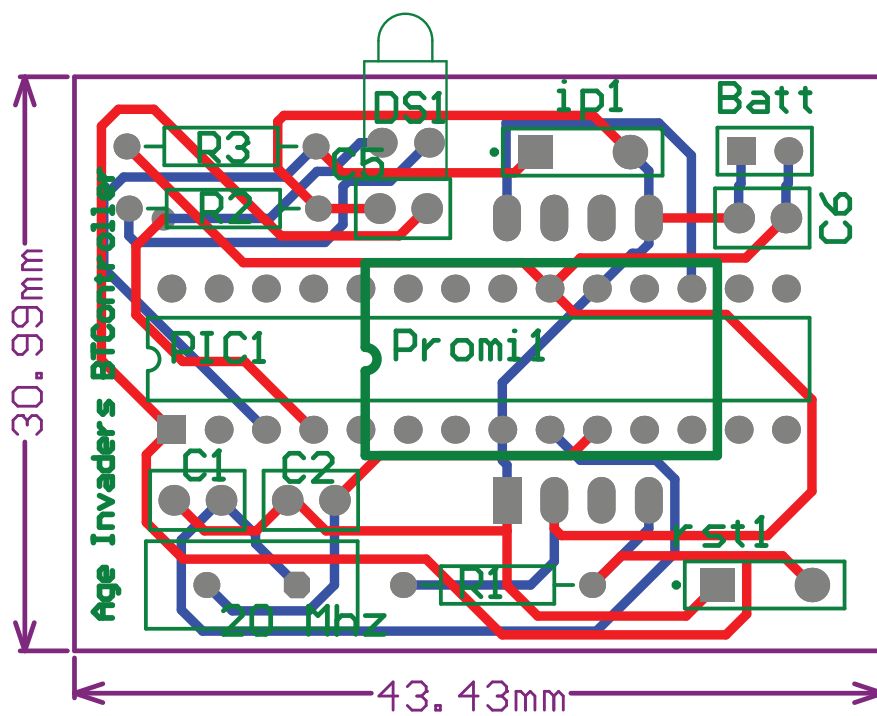
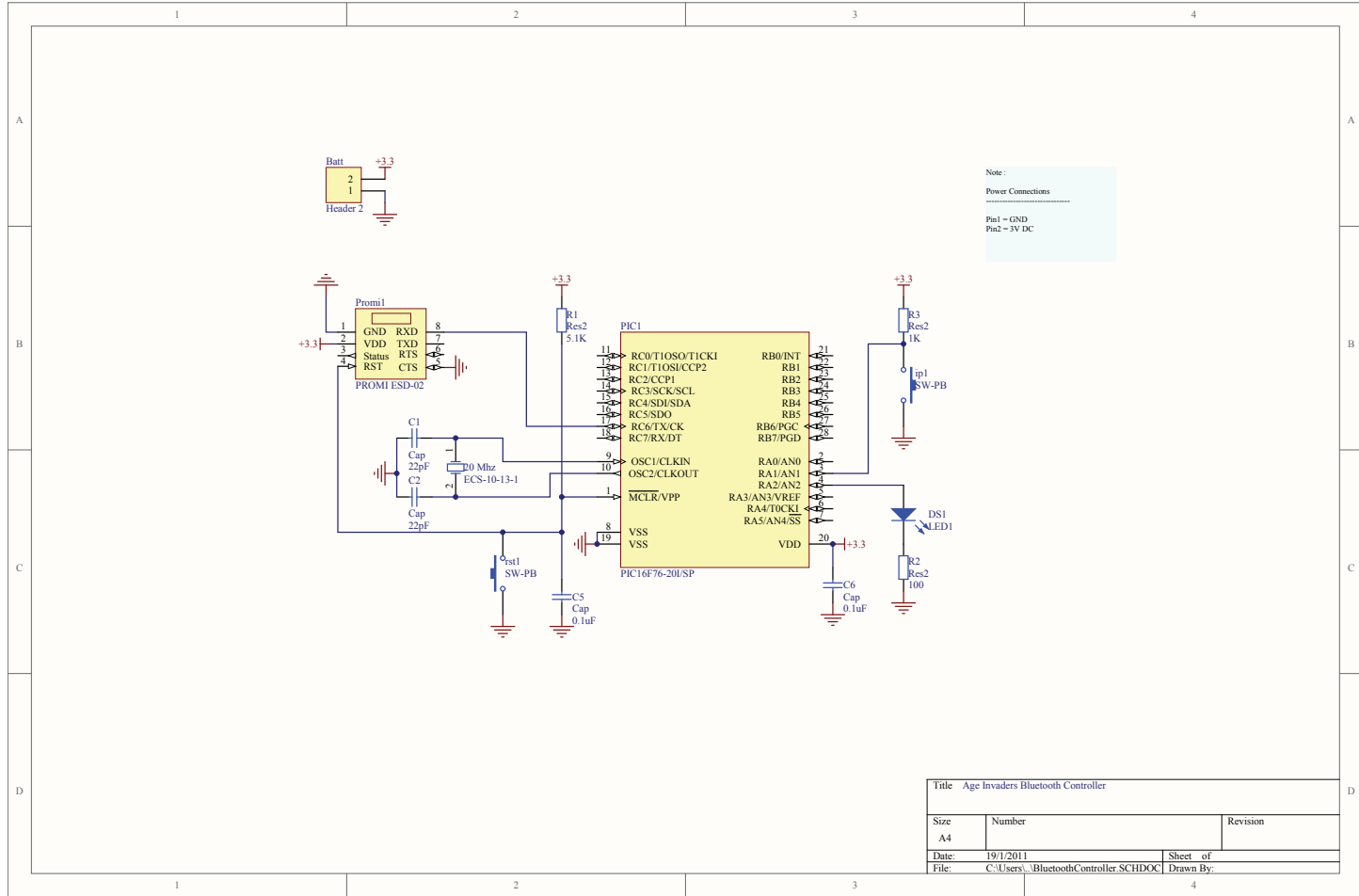


Figure A.1: PCB of Bluetooth Controller

Figure A.2: Schematic View of Bluetooth Controller



Appendix B

Schematic and PCB of Bluetooth Display

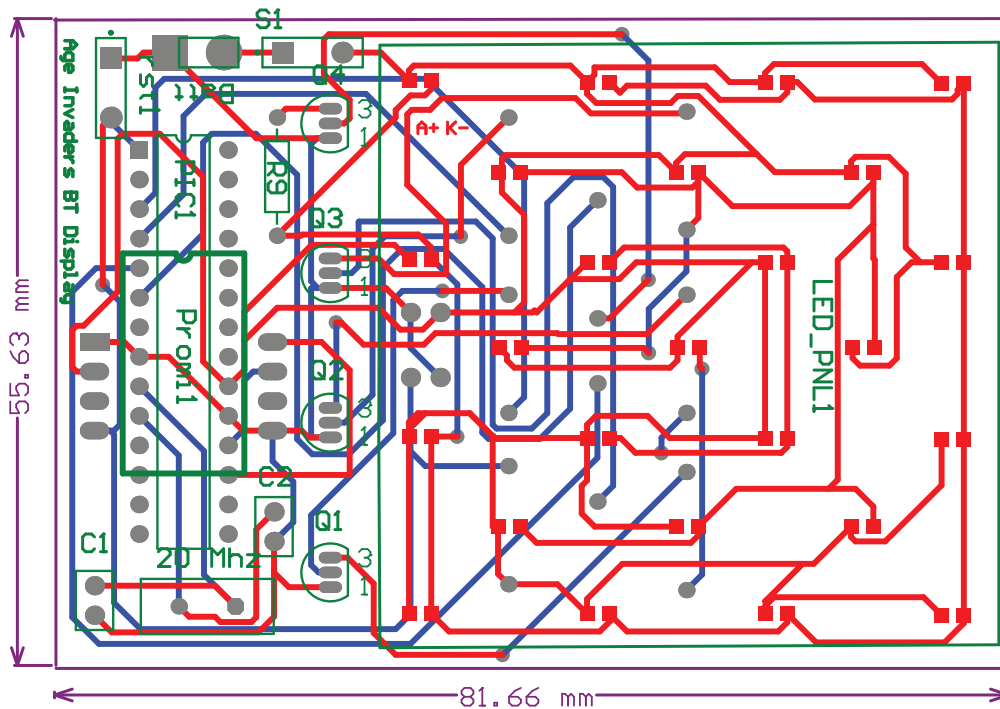


Figure B.1: PCB of Bluetooth Display

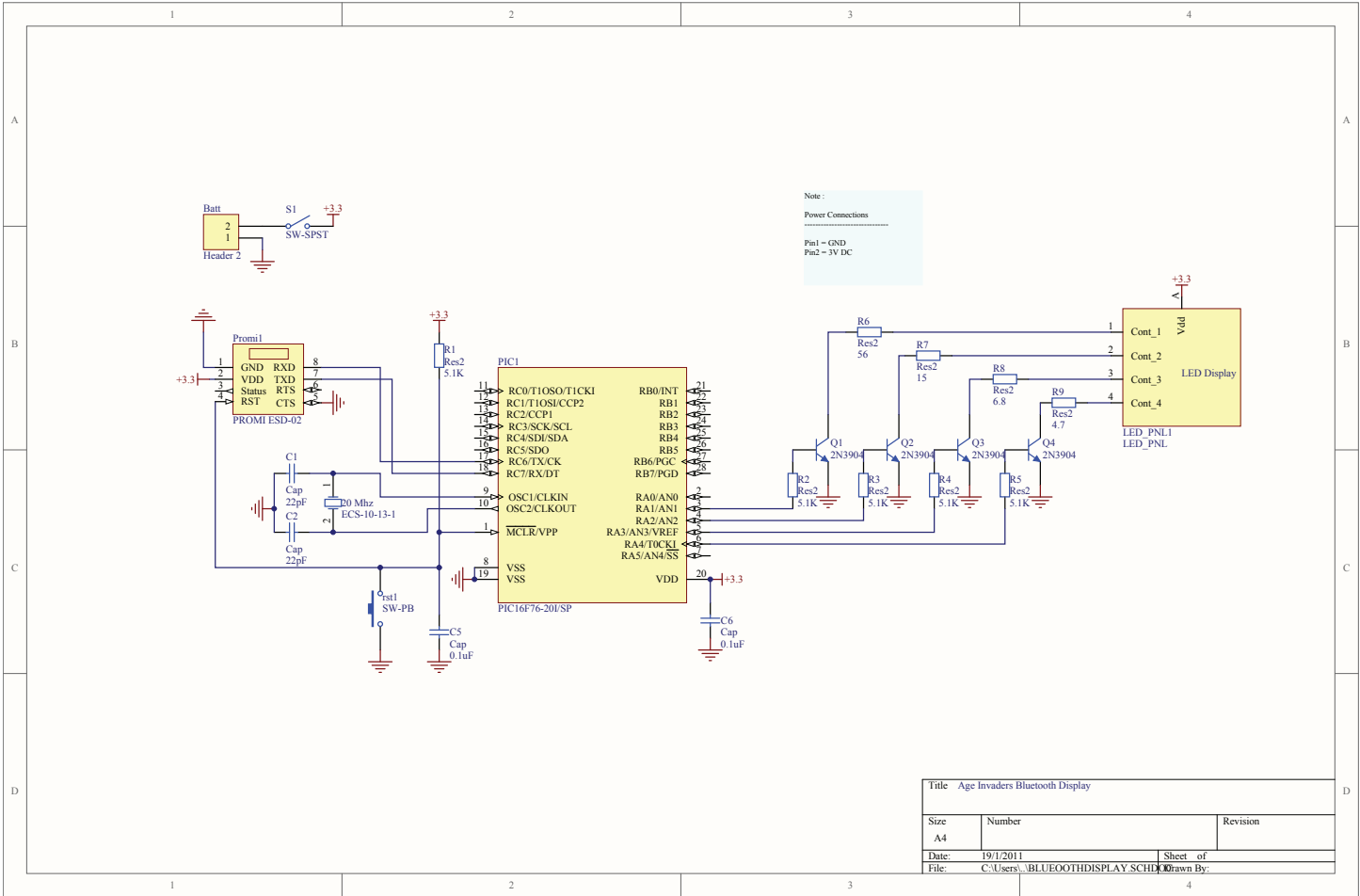


Figure B.2: Schematic View of Bluetooth Display

Appendix C

Schematic and PCB of Bluetooth

Slipper

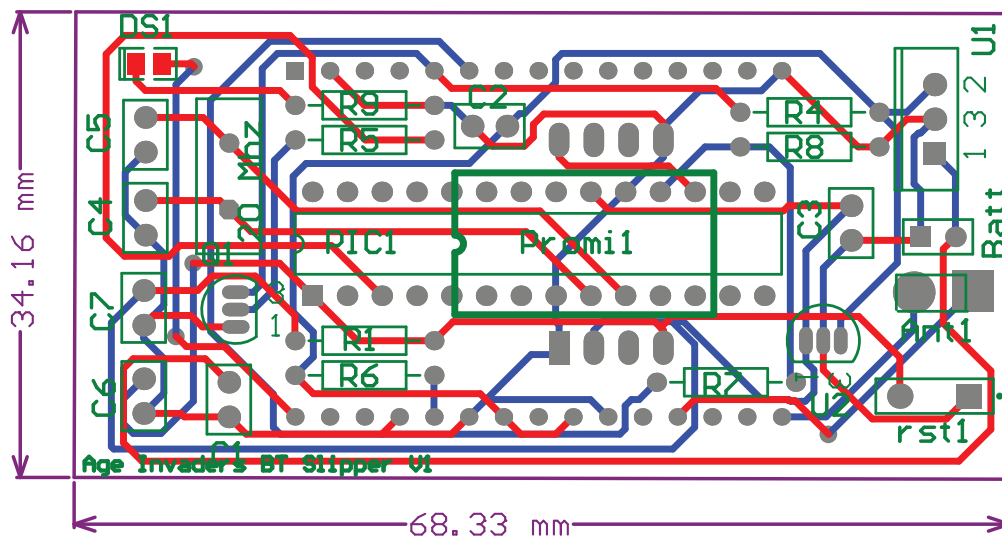
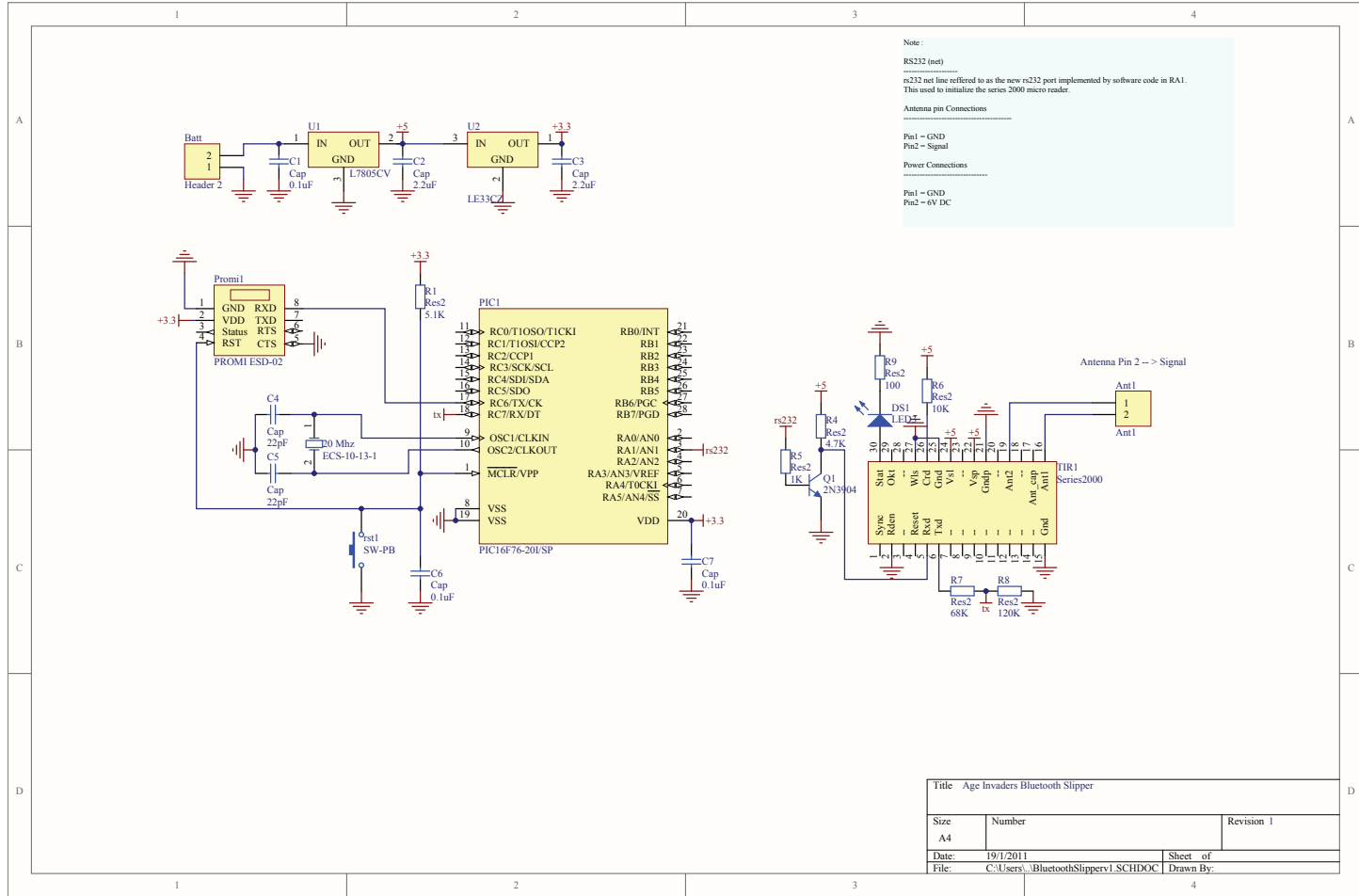


Figure C.1: PCB of Bluetooth Slipper

Figure C.2: Schematic View of Bluetooth Slipper



Appendix D

Schematic and PCB of New Bluetooth Slipper

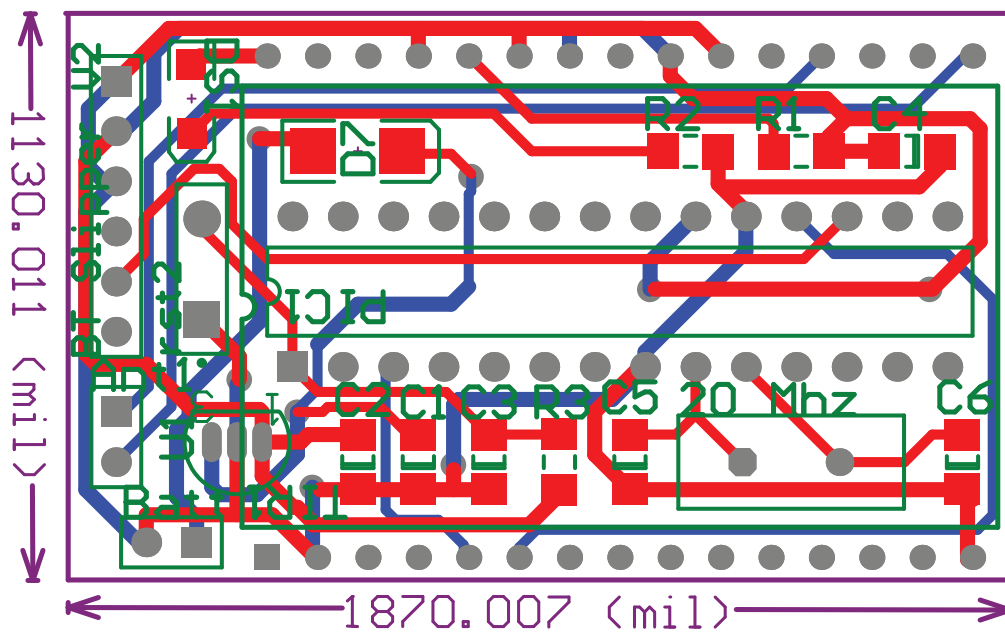


Figure D.1: PCB of New Bluetooth Slipper

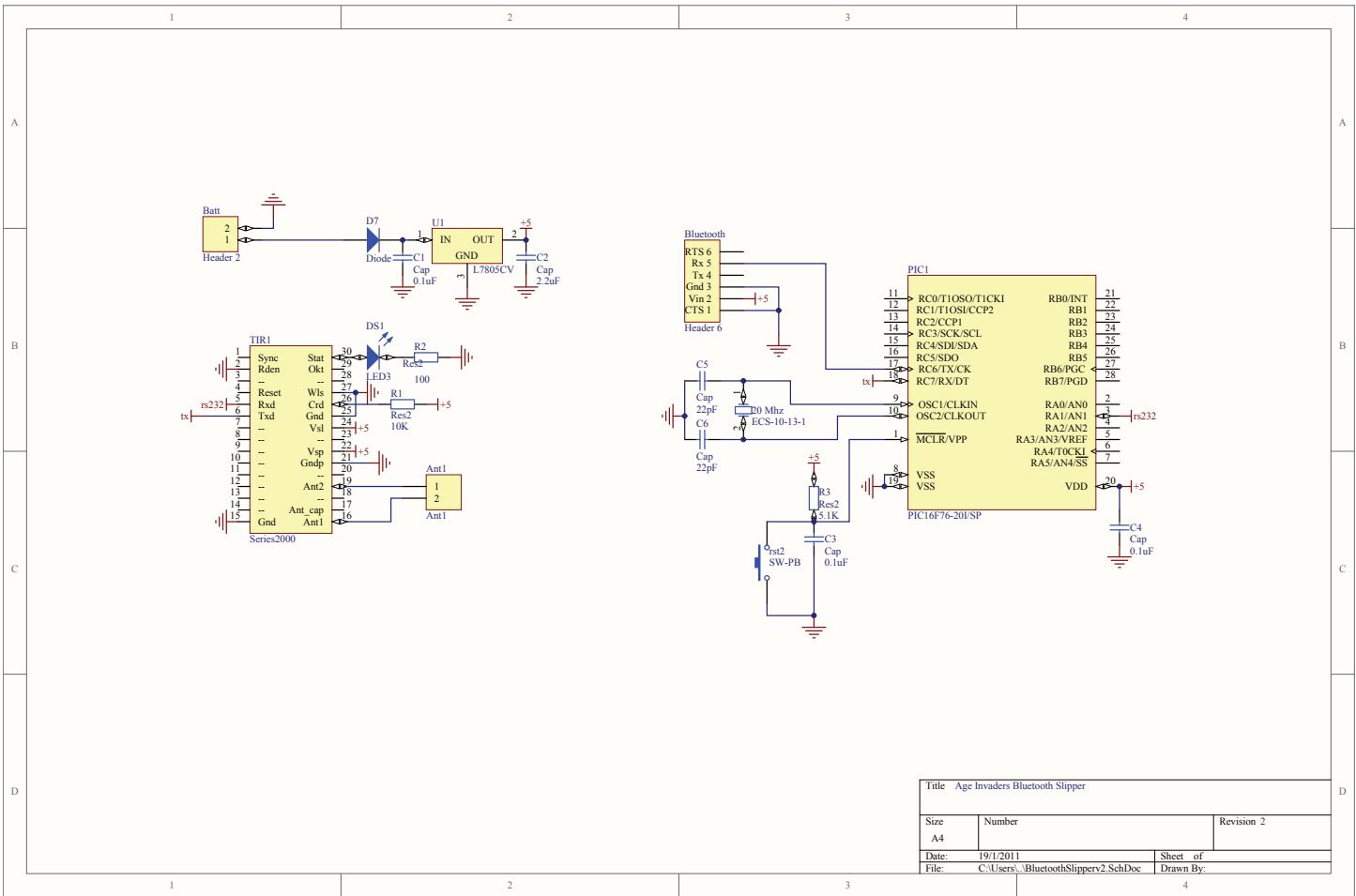


Figure D.2: Schematic View of New Bluetooth Slipper

Appendix E

Schematic and PCB of LED Panel Controller

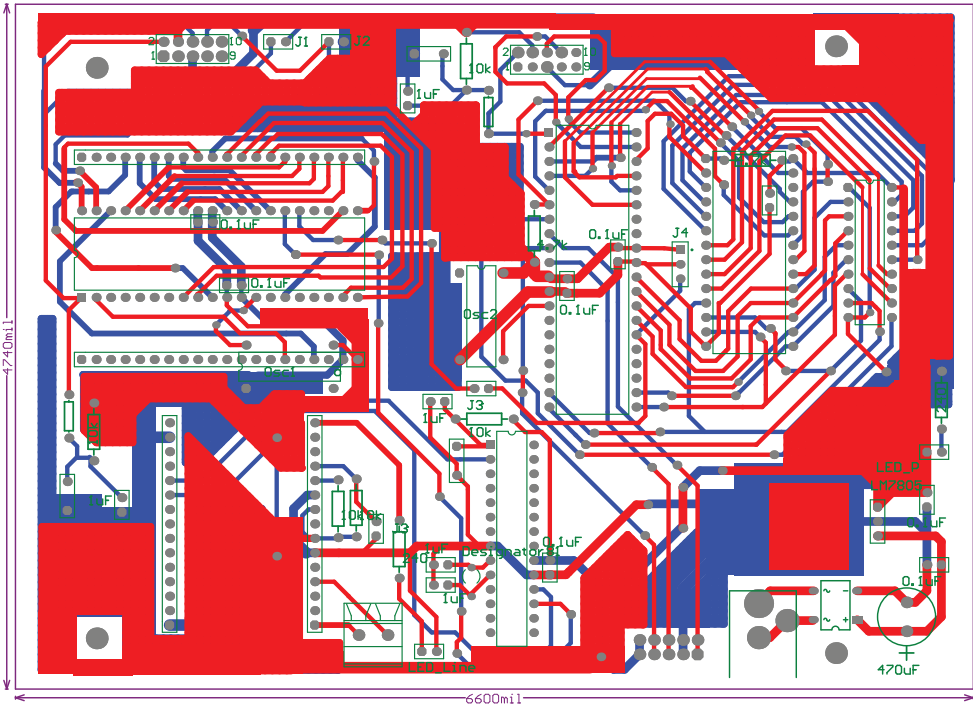


Figure E.1: PCB of LED Panel Controller

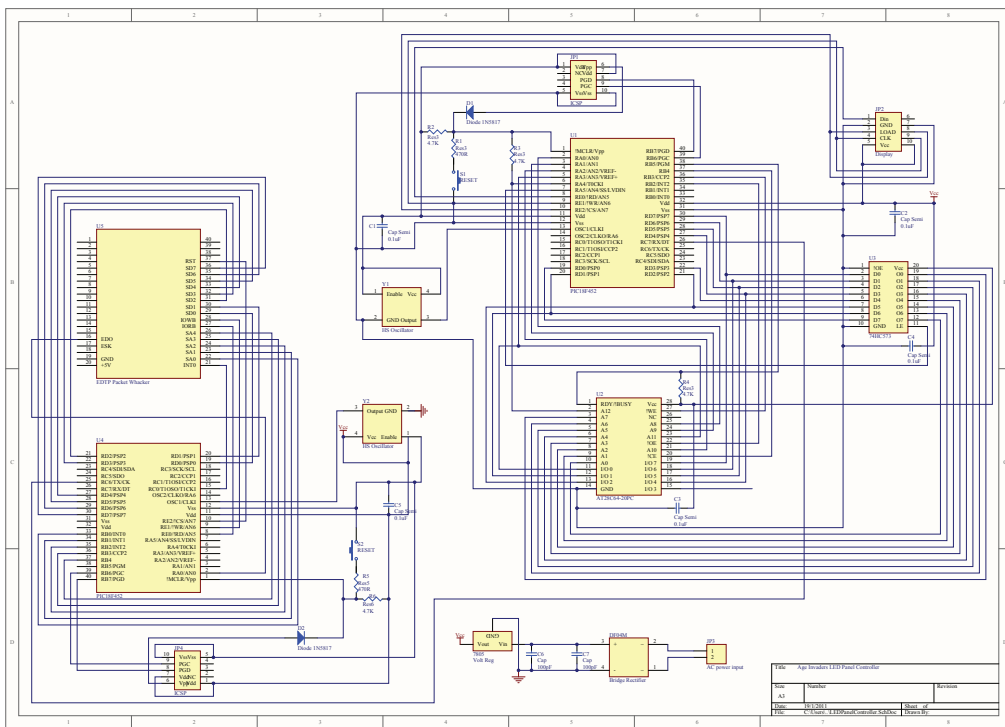


Figure E.2: Schematic View of LED Panel Controller

Appendix F

Schematic and PCB of LED Panel

Display

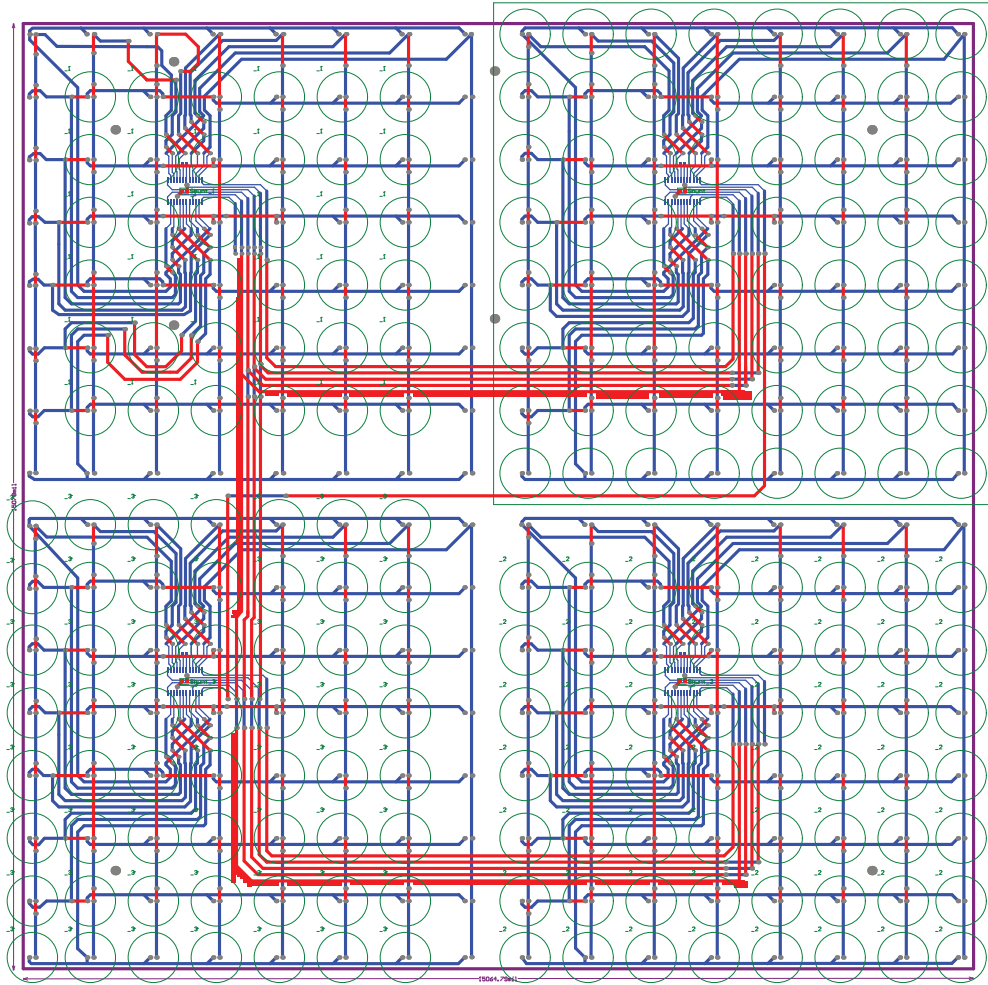


Figure F.1: PCB of LED Panel Display

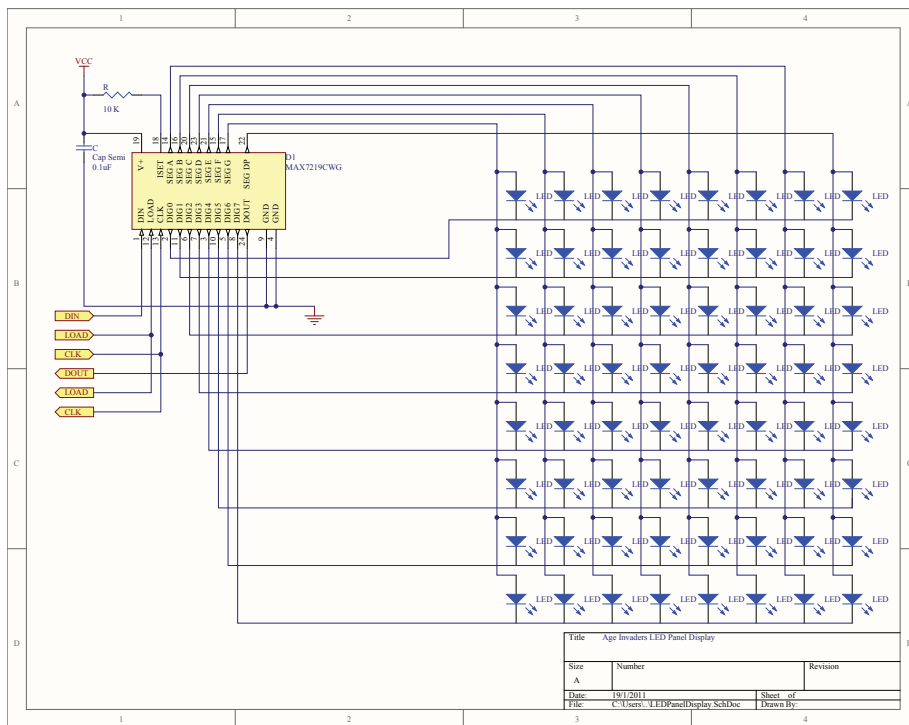


Figure F.2: Schematic View of LED Panel Display