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Gesture controlled user interface for elderly people

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Abstract

Global population aging has become a serious issue, which gains increasing attentions all over the world. More and more researches about elderly people were conducted, especially about senior´s interaction with computer. Hence, the goal of this research is to identify usability and accessibility issues faced by elderly people and provide a usable and accessible gesture controlled user interface (GCUI) for them. Moreover, this thesis provided some suggestion of accessibility guidelines for GCUI. Meanwhile, the problem of aging is particularly significant in China, which is one of the world´s most populous countries. Considering this problem, this study was performed over Chinese elderly participants. Due to the wide gap between younger designer´s experience and experiences of the older users, it is important for designers and developers to increase the awareness of the characteristics of elderly people. Hence, the user-center design approach was used in the process of design and development. User testing, interview and accessibility testing were used to identify the usability and accessibility of prototype of GCUI in different stages. The result of usability testing confirmed that the prototype of GCUI is easy for elderly people to learn and understand. Furthermore, the result of accessibility testing indicated that this prototype of GCUI partially meet the accessible requirement. However, there are some limitations in this thesis. For instance, user experience is dependent on the accuracy of hand gesture detection and recognition. The program lacks audio feedback and does not support assistive technology. All in all, GCUI can provide a new opportunity for elderly people to interact with computer.

Keywords: Hand gesture, Gesture controlled user interface, elderly people, Interaction with computer

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1 Introduction

As many countries gradually step into the aging society, more and more researches about elderly people were conducted, especially about the interaction with computer for seniors. With the widespread popularity of computer in the modern society, information technology is being continuously incorporated into daily lives of elderly people. Thus, they will probably turn out to be a large potential user group. For the majority of the population, the access to the computer is by mouse and keyboard. There have been many studies about elderly people´s needs with respect to their interaction with computer by mouse and keyboard. As has been concluded, it is difficult for seniors to learn how to operate mouse and keyboard, since it requires high eye-hand coordination and more cognitive effort (Vigouroux, Rumeau, Vella, & Vellas, 2009). Meanwhile, the idea of gesture control of computer provides an alternative to the traditional input of keyboard and mouse. Compared to the use of mouse and keyboard, gesture control provides a more intuitive way of interaction (Chen, 2013). The topic about elders using gesture as input to interact with computer has been addressed by many studies recently. Gesture-based interfaces for computers are considered to be more natural and intuitive (S. S. Rautaray & Agrawal, 2015). While gesture can be achieved by the any part of body, hand gesture is the most effective manner of interaction input to the computer (Erol, Bebis, Nicolescu, Boyle, & Twombly, 2007). Hand can perform a variety of gestures. The trajectory and direction of movement by hand are widely ranged compared to movement by other parts of the body. Moreover, gesture control user interfaces (GCUI) have been studied for over 30 years (Bhuiyan & Picking, 2009). It becomes a hot topic that is connected with the problem of aging society. In the past five years, the majority of those GCUI studies focus on the elderly users. However, limited studies can be found on the usability and accessibility of GCUI for elderly people. Therefore, this study focuses on identifying the usability and accessibility problems faced by elderly users in interacting with computer and provide a usable and accessible GCUI for them.

In order to achieve the goal of this thesis, the author intended to design and develop a prototype of GCUI regarding three aspects.

First of all, the device for operating GCUI should be ubiquitous. In those previous studies, they used some extra devices or sensors such as Microsoft Kinect, sensor gloves and so on. However, some of those devices are expensive and not commonly used in our daily lives. Compared with those extra devices and sensors, the usage of desktop with external camera or laptop with build-in camera is more wide and common. Hence, this study tried to use computer with build-in camera as the device to capture the hand images for gesture detection and recognition.

The second aspect is the selection of hand gestures. The hand gestures should be easy to learn and remember so as to qualify a reasonable usability and accessibility of the GCUI. Thus, the author attempted to use the most simple hand gestures to achieve most operations.

Thirdly, the functions of GCUI should fulfill the demands of users. There are several applications or interfaces aimed at improving the elderly people´s social participation. For instance, the communication software and e-mail applications can help elderly people contact with their family and friends; electronic newspaper applications can provide daily information; e-health applications can help them better manage their body and so on. However, there are so many applications on the market. How can elderly people decide which application they need and is suitable for them? Will they get confused and bored by switching between different applications to obtain different information? Moreover, different applications may have different operations routines that need to remember. And this will increases the difficulty of application´s learnability. Meanwhile, as Marek said in his article, there are many age-related changes among elderly people such as the gradual decrease of vision, hearing, motor skills and the deterioration of the cognitive skills. Those changes affect the use of computer for elderly (Van De Watering, 2005). Hence, if the GCUI can integrate all the functions in these applications, it will then provide a better way for elderly users to obtain information.

In addition, W.Chen addressed that there remains some significant challenges for gesture interface to overcome. Due to the wide gap between younger designer´s experience and experiences of the older users, it is important for designers and developers to increase the awareness of the characteristics of elderly people. Hence, the user-center design approach should be used in the process of design and development (Chen, 2013).

All in all, the goal of this research is to identify usability and accessibility issues faced by elderly people and provide a usable and accessible GCUI for them. To achieve this goal, focus group was used to gather the demands of elderly users. And the author used user testing and interview to improve the usability and accessibility of GCUI. In the end, a comparative study was conducted in order to perform a more thorough analysis on the usability and accessibility of GCUI.

1.1 Background

Global population aging has become a serious issue, which gains more and more attentions all over the world. According to data from the United Nations, whereas 5.2 percent of the population was over 65 in the year 1950, this percentage is projected to grow to 15.9 percent in 2050, to 27.5 percent by 2150, and to 32.3 percent by 2300 (Ronald M. Baecker 2012). Meanwhile, the problem of aging is particularly significant in China, which is one of the world´s most populous countries. According to data from the National Bureau of Statistics of China, those who aged over 65 numbered 63,680,000, which was 5.56% of the total population in China in 1990. In 2000, it had risen to 88,210,000, i.e. 6.95%. And it increased to 137,550,000, i.e., 10.05% at the end of 2014. Moreover, the development of medicine makes it possible for people to live longer. The proportion of elderly people has reached in an unprecedented peak and will increase steadily in the future (Chen, 2013).

As for the definition of elderly people, there are two views at present. According to the United State, they identified 65 as the beginning of the old age. This standard is widely used in developed centuries based on the average life expectancy. Another one that is generally adopted by UN, is that people who are over 60 and 60 years old are referred as the old generation. Most of the developing countries use 60 as the starting point of the old age. Because the average life expectancy in developing countries is lower than the developed countries. Furthermore, the 60-year-old is the exactly border of the working age in China. And it is taking into account the definition of Chinese elderly users (Yao, Qiu, Huang, Du, & Ma, 2011). Hence, this 60 standard was used in this thesis when elderly people are referred.

In addition, a survey shows that 70% of those elderly people who suffered from mental disease are lack of psychological care, for instance, the ´empty nest ´ phenomenon (Yao et al., 2011). Several studies described ´empty nest syndrome´ as parents express the feeling with depression and loneliness because of the children´s departure from home (Long & Martin, 2000). And the loneliness does increase with the age, because of the increasing of physical impairments and decreasing of social integration (Tomaka, Thompson, & Palacios, 2006). Thus, improving the social integration and psychological care may be helpful to reduce the loneliness for elderly people.

Moreover, with the rapid development of social network and ubiquitous computing, many studies are devoted to improving elderly people´s mental satisfaction by letting them interacting with computer. Nevertheless, the percentage of elderly online users is still quite small. Compared to the younger online users (81%), the percentage of elder adults who are involved in social network is around 34% by 2012 (Arfaa & Wang, 2014). The elder user group still represents a small demographic in social network access. Several studies focus on addressing the technical and physical obstacles faced by elderly people. Those obstacles can demonstrate why senior users are lack of motivation to participate. From the technical aspects, the complexity of computer has been mentioned many times. Elderly people need to spend a lot of time on learning how to use the system. It is easy to image that a normal webpage could be difficult for elders to access, by using mouse and keyboard. Meanwhile, the age-related limitations also affect the accessibility of computer for elderly people, for instance, the physical and cognitive impairment.

As shown in the figure 1.1, the percentage of Chinese elderly online users increased from 0.7% to 1.8% as in the end of 2012. However, compared to the others group, elderly people only represent a small part.

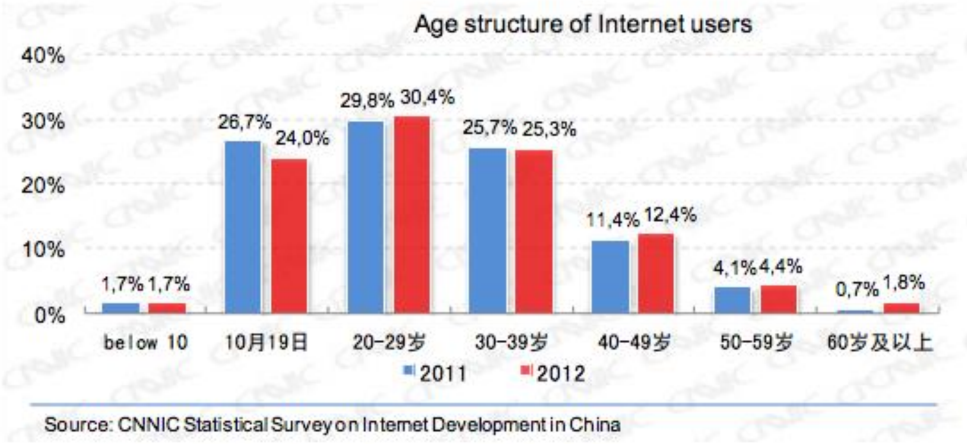


Figure 1.1 Age structure of Internet Chinese users

As for Chinese elderly people, there may be more barriers such as knowledge barriers (for instance, limited knowledge, as they were born in the time of war), economic barriers (especially in rural area in China), psychological barriers and so on. Those barriers hinder their access to computers and Internet.

Furthermore, there is currently lack of social concern for elderly people using computer in China. People have been working on solving the usability and accessibility problems and design tools to help elders live healthier and safer more than 20 years in western countries (Jia & Choe, 2013). Moreover, many countries have published relative legislation or policy regarding to accessibility. For instance, Morten mentioned as following:

In 2013, the Norwegian government passed the new regulations regarding the Universal Design of Information and Communication Technology (ICT) which mandates that all websites must meet a minimum accessibility standard of Web Content Accessibility Guidelines (WCAG) 2.0, level AA. The new law takes effect on July 1st 2014 for new web solutions and all existing / grandfathered web solutions must meet the same requirements by January 1st 2021(Rand-Hendriksen, 2014).

However, the similar legislation is not yet available in China nowadays. In comparison, the accessibility and usability of interaction with computer for elderly people is a quite new topic in China. Hence, this thesis picked China as the research base to identify the usability and accessibility issues of existing GCUI faced by elderly people. A usable and accessible GCUI for Chinese elderly people is also designed and tested in the process. According to the Center of Universal Design at North Carolina State University, universal design is the design of product and environment used by all the people without the need of any adaptation and specialized design(The center of Universal Design). In other words, universal-designed products should be easy used and benefited for the people of all the age and abilities. Considering the purpose of this study, the universal design should be referred as the design principles during the process.

1.2 Purposes

One purpose of this study is to identify the usability and accessibility obstacles of interacting with computer face by elderly people. Through learning the previous study and interviewing some elderly online users, the author gets a better understanding of obstacles faced by elderly people.

Another purpose of the project is to help elderly people access the computer more easily. Therefore, how to provide a natural GCUI is another focus of the project. A prototype of GCUI, named as Extremely Brief Application for Elderly People (EBAPP), is designed throughout the project for this purpose. By using this application, elderly people can access information about news and weather forecast as well as communicate with their family.

In addition, the project aims to provide some suggestions about the accessibility guidelines of for the design of GCUI.

1.3 Concept clarification

- Human-Computer Interaction (HCI)

  Human-computer interaction is a concept that concerns the study, design and uses of the interaction patterns between the user and computer. As for the user, they are more concerned about the functionality and the entire experience of the interaction with computer (Te'eni, Carey, & Zhang, 2005).

- Information Communication Technology

  Information Communication Technology combines the information technology and communication technology together. In general, it is often used as an extended synonym for information technology. But it becomes a more specific term for the integration of telecommunication and computer which enables users to access, store, transmit, and manipulate information ("Information communication technology," 2008.09.19).

- Gesture

This term, in this thesis, refers to motions that originate from any bodily movement, but commonly originate from hand, face and head.

- Universal Design

This term describes the concept of “design for all”. It means to produce products, buildings and context that are accessible to different user group such as older people, people without disabilities and people with different disabilities (The center of Universal Design).

1.4 Structure

The following part of this thesis is divided into six sections.

In Chapter 2, previous studies and relevant researches are described. Through the literature review, the author found elderly people´s needs for GCUI and also some limitations of GCUI. Moreover, the author presented the image processing in gesture detection and recognition.

In Chapter 3, the methodologies being used in this research are described, for instance, the user-centered design, interview, user testing and so on.

In Chapter 4, the design and development process is explained. Furthermore, there is a description of EBAPP.

In Chapter 5, the final evaluation of usability and accessibility of EBAPP is presented. At the same time, the results were described.

In Chapter 6, the discussion of the result and limitations of this study are analyzed.

In Chapter 7, the conclusion and future work are presented.

2 Literature review

2.1 The need of GCUI for elderly people

2.1.1 The development of GCUI

In today's ubiquitous computing environment, use of gesture to interact with computer becomes more and more popular. Moniruzzaman Bhuiyan and Rich Picking had collated a lot of research information about the GCUI over 30 years. They did a survey of those researches and analysis the type of gesture, interface, technology, the user groups and some relative issues (Bhuiyan & Picking, 2009). There were 17 research projects and 4 commercial projects mentioned in their survey result from 1980 to 2009. They mentioned that the most difficult technology like sensor, gloves used at beginning changed to webcam and image processing. And the last five years researches mainly focused on elderly people and people with disabilities. Easing of use technology, affordability and familiarity make GCUI can provide a new way for elderly people to interact with new technology.

A lot of work has been conducted in the research and development of gestural interfaces. Many disciplines of multimedia and communication go towards ubiquitous computing and hand free interaction with computers (M. Nielsen, Störring, Moeslund, & Granum, 2004). Therefore, within these features of gesture interfaces mentioned above, gesture interfaces can be used in great diverse fields, e.g. in entertainment, education, and aiding people with disabilities.

- Entertainment

  Beyond any doubt, the major producers of computer games are engaged in a technological race that aims at providing their respective customers with the most exciting and entertaining human- computer interface. Recent trends show that games with true-to-life interfaces have higher chances of beating their competitors in the market share arena (Roccetti, Marfia, & Semeraro, 2012). Therefore, there are sets of gesture-based interfaces in the computer games market. For instance, the leap motion controller let users experiencing computer games by hand gestures. The flick of finger can start a scroll. Steer, slice, grab, push, pull, crush, and shoot with your hand and fingers. There are some popular games from Airspace like Fruit Ninja, and Cut the Rope ("Leap Motion," n.d.). The following figures (Fig 2.1) show the most exciting user experience of gesture-based games. However, most of these interfaces are based on home settings.

Figure 2.1 Gesture-based games of Leap Motion

Moreover, there are some other interfaces or devices based on gesture-control. For example, Microsoft Kinect and Nintendo Wii also can provide some video games of motivating physical activity.

Apart from gestural interfaces used in computer games market, there is a trend that introducing gestural interfaces into public scenarios. In Roccetti´s paper, they introduced a gestural interface in an exhibition, where visitors can experience the art by playing (Roccetti et al., 2012). In addition, with the new technical innovations, it opens a new path to artistic creations. For instance, new gestural interfaces let all the artists create new paintings, songs, even movies by intuitive gestures. However, it might cause problems with regard to context accessibility and player heterogeneity when employing gestural interfaces in public scenarios.

- Education and Training

The GCUI also can be developed for training and education. Alf Inge Wang addressed that gesture-based education interface can be beneficial in many area. Such as the gesture-based education interfaces are more natural to users. And it also can reduce the physical passivity when student use their body to control the interface(A. I. Wang & Ibánez).

Arash Fallahi and Lingguang Song used gesture-based interface to enhance the construction training. The construction training is to improve the technical and practical competence of students in the construction industry. Students can exercise through the visual construction scene by using hand gesture. And this training based on hand gesture-control can enhance the learning experience of students through hands-on exercise(Arash Fallahi).

- Aiding people with disabilities
  Without any doubt, traditional interfaces such as keyboards, mice, and trackballs create great obstacles for people with disabilities to communicate with computers. However, gestural interface may provide an accessible way for people with disability to interact with computer. Besides, it is crucial to ensure people with disabilities have access to computers in terms of human rights. Currently, there are sets of gestural interfaces that are used to aid people with disabilities. For instance, people with disability can use head gestures to control the intelligent wheelchair. And this decreases the difficulty of controlling by joysticks especially for people with restricted limb movements (Gray, Jia, Hu, Lu, & Yuan, 2007).

Gestural interface refers to combining necessary sensors that for detecting motion with body motion to communicate with computers or the other devices, which heavily depends on the physical movement of human body. In this case, the designers should consider the following aspects when design gestural interfaces, which are 1) what is the range of human body movement, it means what kinds of gestures are human capable of; 2) how do human body move. The ergonomic of human body movement should be considered in the GCUI design process. Thus, Saffer (Saffer, 2008, pp. 31-44) identified the following aspects for gestural interfaces designers to make better interactive gestures, those are 1): Avoid “outer positions”, those that cause hyperextension or extreme stretches; 2): Avoid repetition; 3): Relax muscles; 4): Utilize relaxed, neutral positions; 5): Avoid staying a static position; 6): Avoid internal and external force on joints.

GCUI is a fast growing technology. And it becomes a trend for people to easily access the computer or other devices. Moreover, the population is growing older all over the world. Therefore, GCUI can open a new opportunity for elderly people to interact with computer.

2.1.2 The existing GCUI for elderly people

Kathrin (Gerling, Livingston, Nacke, & Mandryk, 2012) mentioned that decreased activity may reduces the individual´s life expectancy. Hence, she and her colleagues designed a game for institutionalized elderly people using gesture for full body motion control. During the project, they conducted two studies. One was to evaluate a set of gestures using by elderly people. The result of the first one shows an overall positive experience. And through the comparison of static and dynamic hand gesture, they found that the completion rate of static hand gesture was higher than the dynamic gesture. Moreover, the second study was to design a gesture-based game for elders based on the result of first study. Through those two studies, they proposed seven guidelines for design of full-body gesture. (1) Age-inclusive Design. The designer should consider about the age-related physical and cognitive impairments. (2) ROM-adaptability. The games should be adapted to individual´s difference of rang of motion. (3) Exertion management. The fatigue management can prevent the overexertion. (4) Dynamic Game Difficulty. The difficulty degree of game should be adjustable. (5) Easy Gesture Recall. A brief introduction can support the gesture recall. (6) Continuous Player Support. Continuous tutorials and support can facilitate gesture learning and interaction. (7) Simple Setup Routines. It should be easy for elderly people to setup and shutdown. This study offered an opportunity of elderly people to become more active. Thus, the importance of gesture controlled user interface for elderly people is being highlight again. Moreover, the guidelines of design full-body gesture also can be referred to our project.

Wiimote as the gesture-based input device of Nintendo Wii gaming console attracts a lot of attention nowadays. Cornelius Neufeldt conduct a study of Wii play with elderly people (Neufeldt, 2009). Since there were many success reports in German newspaper and journals, they want to investigate playing Wii with elderly people from two aspects. One is from the usage of Wii, which can encourage elderly people to be more active. And the other one is to investigate the new ways of interacting with multimedia system combined pointing and gesture input together. During the observation, they found that the attitude of seniors changed from skepticism to curiosity. And some elderly participants showed a great interest of Wii bowling games. The Wii can help improving the coordination abilities. However, the easy use of Wii depends on the mental and physical situation of elderly people. And there were some problems during the games. For instance, several buttons were useless that interrupt the normal game sequence. Therefore, elderly people will have a great interest of gesture-based interface if the design is easy to understand and use.

With the ubiquitous computing, ambient technology and increasingly older population, Moniruzzaman Bhuiyan and Rich Picking tried to get away from the traditional methods of interaction. Hence, they did a survey of last thirty years and designed a gesture controlled user interface prototype called ´Open Gesture´. This prototype was used on television and enabled elderly users to undertake everyday tasks like answering the door, turn on or off the light and so on. They also did a usability testing of this prototype. The usability testing consisted of three testing sessions and questionnaire. According to their usability questionnaire result, there was a neutral value. However, as the neutral value of result, there was no clear statement of the reason. But they mentioned more information of understanding and learning need to be provided in the interface. And they planed to combine more popular gestures in the future work (Bhuiyan & Picking, 2011). Therefore, as a reference, waving a hand to right direction to execute ´Next´ can be used in this thesis. And the usability testing also should be applied in this study to find out the detail usability problems faced by elderly people.

Chiara et al. (Leonardi, Albertini, Pianesi, & Zancanaro, 2010)´s study showed the touch-based gesture interface attracted and motivated their participants. They designed a gestural touch-based interface used in a movable device. In their previous study, they mentioned that a lot of projects typically deal with the accessibility but failed with familiarity. Hence, familiarity should be considered into the design process, and participants can equip the device based on their shared background of meaning and practices. Through the testing, they also addressed some problems of dynamic gestures. For instance, the ´dragging´ gesture needs high demands of finger movements. The finger should tap first and then drag the objects. However, the unsure touch and lack of constant pressure conduces the failure of tap and drag gesture. Thus, the touch-based gestural interface can attract elderly participants take part in the social activities. But there are still some shortcomings like the requirements of tablet, the demands of finger movement and complex operations.

Jan Bobeth el at. (Bobeth, Schmehl, Kruijff, Deutsch, & Tscheligi, 2012)´s study focus on the performance and acceptance of older adults using gesture to control the TV menu considering their motor issues. As they mentioned, the current researches of elderly people using gesture deal mainly with touch interfaces. The touch interface is easy for elderly people without the using experience of computer. The performance was similar to the younger generation but a little bit slower. However, there is no clear identification that freehand gesture is same to the touch gestural interface. They found that the direct pointing the object with the hand movement tracking is the best performance for elderly participants according to the result of completion time and error rate. At the same time, they addressed that the elderly people seems to prefer the cursor-based interaction and there was lack of analysis of fatigue due to the short interaction.

All in all, there are many studies of GCUI for elderly people. However, the research of study the usability and accessibility of using hand gesture to control the computer is limited. Hence, this study will investigate the accessibility and usability problems of hand gesture controlled user interface faced by elderly people with the ubiquitous computer.

2.2 The challenges of the gesture control for elderly people

W.Chen (Chen, 2013) conducted a study of gesture-based application for elderly people. In the paper, she summarized some challenges of gesture-based application that should be overcome. The challenges mainly consist of two parts. The first one is technological challenges. There were many existing technologies of detecting and recognizing the gesture. It is important to improve the reliability and accuracy of gesture detection and recognition. And it also needs to provide a clear benefit such as low learning effort, easy understanding, in order for elderly people to easily accept it. And another part is about methnological challenges. During the design process, the user-center design approach should be applied. Due to the gap between perspective of younger designers and the requirements elderly users, the participance of elderly people can verify the assumptions to improve the efficiency of design process. Moreover, it is also important to use objective measures like performance data to evaluate the gesture-based application for elderly people, not only depends on the attitudes and subjective evaluation.

Therefore, in this study, the user-centered design approach will be used to identify the demands of elderly users. And the performance data will be recorded to evaluate the gesture controlled user interface.

2.3 The technology accessibility barriers faced by elderly people

According to the Cathy Bodine, there are around eighty percent of elderly people have some type of functional issues that may affect at least one daily activity (Bodine, 2007). Hence, the technology accessibility barriers of seniors were stated at the beginning of this section and some relative assistive technologies that support elderly people with successful aging were described afterwards.

2.3.1 The psychological issues among elderly people

Loneliness refers to a subjective feeling state be alone or apart from others. By contrast, social isolation is an objective feeling which focus on the lack of interaction in community and separated by others (Tomaka et al., 2006). All in all, people always feel loneliness and isolation because the intense feelings of emptiness and abandonment. The prevalence of loneliness in older adults is estimated to be 40% (Bekhet & Zauszniewski, 2012).

Moreover, communication is an important part of a healthy life. Emotional and social loneliness increases as social communication decreases for everyone (Hacihasanoğlu, Yildirim, & Karakurt, 2012). And a lot of challenges will be caused in elderly people´s daily activities due to the insufficient communication amongst elders (Wiley, Sung, & Abowd, 2006). From this result, it can be concluded that effective communication is important for elderly people after they know how to use ICT devices. As for a multifunction platform, communication with family and friends turns to be the biggest part of interesting improvement for elders after they used these kinds of platform (Tutoky, Babic, & Wagner, 2013).

The frequency of going online among residents from independent and assisted living communities (AICs) is related to experiences of loneliness and social isolation. This can be revealed in the Cotton´s study (S.R. Cotten, 2012). They found that frequency of going online associated with decrease in loneliness. Moreover, considering with those elderly people who always go online, most of them have no close companion. Thus, frequency of going online has a positive impact on decrease the loneliness and perception of isolation among old adults. And it also assists elderly people´s independence living ability. In addition, the participants in their study admitted that going online has contributed to their ability to stay in touch and has increased the quantity of communication with others. The author also mentioned that most of participants did not perceive that using Internet has made it easier for them to reach people, meet new people, helped them to feel more connected with family or increased the quality of their communication.

Even if, H.B. Gibson addressed that ”Older people are not in general loneliness than younger people”. He mentioned that people feel lonely because they are not satisfied with their relationships and circumstance than compared to that they would like to be. Thus, he thought that there is no directly relationship between lack of communication and loneliness among elders. However, this study prefers the previous opinion that the sense of loneliness will increase as the insufficiency of communication for seniors.
In addition, elders have willingness to use mobile for contact with others. Pricing system shapes the effective use of mobile communication in reaching everyday life goals of interpersonal communication. Some of participants can use mobile for stay in touch to enjoy themselves. It is easier for them to use mobile phone rather than Internet. Most of participants who have relatives abroad use Skype. Because of the cost of phone is the mainly consideration. And most of participants addressed that they don´t use Internet because of lacking the skill.
So if there is a easy way to use Internet to communication and do not need to pay for anything, will they change their mind to use new technology.(Ivan, 2013)

2.3.2 The physical issues of some elderly people

Considering about design process and implementation of a user interface and device for a social networking application among seniors, the risk of becoming demented is 60% higher when seniors living alone with a poor social network compared with those with an active social network (Kivim et al., 2013). And according to the result of survey, illiteracy was the most important barrier to interact with new technology in both South Africa and Tanzania (Elder & Clarke, 2007). Since the ageing population and the relevance of the web to current society, it has created a need for web accessibility for seniors, who have major and varied accessibility barriers when going online. Moreover, Sayago addresses two important questions (Sayago & Blat, 2009):(1) Which are the most and least relevant accessibility barriers for older people to interact with the web in their daily lives and why?(2) How does vary the relevance of web accessibility barriers according to older people’s previous experience with the web and educational levels? By collecting the data from observation and conversation with 388 older people, the result was exposed that the prioritization of accessibility barriers is largely independent of technology, experience with the web and educational levels. It is difficult for senior to remember all the task´s steps, understand technic word and use input devices. Namely, those obstacles appeared due to age-related changes in functional abilities (vision, hearing, cognition and mobility) and a general lack of experience with the web. There are some implications for web accessibility such as those that might be obtained by using different input devices or enlarging web elements do not seem to be appropriate. Following part will describe the age-related changes faced by elderly people.

- Vision

Vision as one of the important human sensory, the vision impairments impact people´s functional status and the independence of them as they grow older(West et al., 1997). Meanwhile, loss of contrast sensitivity vision is strongly associated with the independent ability to carry out the daily activities (Dargent-Molina, Hays, & Breart, 1996). For instance, contrast sensitivity can assesses the ability to see the object of different sizes and contrasts. Hence, the contrast sensitivity may reflect the difficulties of elderly people to complete the daily activities such as reading the sign or labels.

Moreover, in the Blue Mountains Eye Study (J. J. Wang, Mitchell, Smith, Cumming, & Attebo, 1999), the visual impairment has a corresponding increases in dependency relationship with the community support or the support from family by elderly people.

In general, the decline of visual ability faced by elderly people mainly present on the following aspects, the width of their visual field, light sensitivity, color perceptions, resistance to glare, dynamic and static acuity, contrast sensitivity, visual search and processing and pattern recognition. And those changes should be considered when they use computer (Van De Watering, 2005).

- Mobility

Aging is accompanied by a decrease of motor skill performance. And elderly people need to take longer time to adapt their ongoing action to the target location shift (Rossit & Harvey, 2008). Moreover, some elderly adult may suffer the temporary or permanent mobility difficulties. For in stance, in a recent survey, there are around 41% elderly people feel painful with their hip or knee within a 12-month period (Birrell, 2004). Moreover, Those motor impairments will affect the quality of life for elderly people.

However, some new technologies can improve the motor skill of some seniors. For instance, Shao mentioned that computer program can be used to treat hand contractures associated with Parkinson´s disease(Shao, Carriere, Lee, Youssef, & Mesioye, 2015).

- Memory loss

While it is well acknowledged that memory performance declines faced by elderly people (Balota, Dolan, & Duchek, 2000).

- Hearing

People will experience the hearing decreased form middle age and this situation will increase from then on. It is mainly represented in hearing high frequency. Moreover, after 50 or 60 years old, it may become difficult to hearing in general (Van De Watering).

Overall, the barriers for older to interact with new technology mainly focus on two parts, one is the lack of information communication technology skill and another one is due to their physical impairments. Therefore, the applications or websites should be designed easy to use and understand especially it do not need to spend a long time to train. And the icons on the screen should be bigger enough for some of older with visual impairments.

2.3.3 Some other technology accessibility problems faced by elderly users

Dengfeng et al. (Yao et al., 2011)addressed some other accessibility problems faced by Chinese elderly people in his article. Besides the health-related and circumstance barriers, knowledge barriers, economy barriers and psychological barriers also affect the accessibility of computer.

- Knowledge barrier

  Some elderly users have not learned about the computer in the past. Moreover, some of elderly users never learned Chinese alphabet characters and cannot master the input methods like typing.

- Economy barrier

In their study, some participants said that the retirement income was little and cannot afford the fee of computer or Internet access. Especially in the rural area in China, the low-income and unsuitable incomes are the main limitations.

- Psychological barrier

  Some participants are afraid to learn to use computer because of the lack of confidence and bashfulness. They said that they are too old to learn the computer. And they are afraid of being laughed at for learning slowly.

2.4 Some other existing applications for elderly people

- StoryVist

Figure 2.2 StoryVist UI

Considering children and adults have a lot of time and motivations to contact with each other in a long-distance, it can be advantageous to have an application, which can provide function to connect each other. StoryVist (Fig 2.2) is an application that can help children and adults to experience the sense of togetherness by reading storybook together online. Since there is an age gap between two generations, reading storybook can provide an opportunity for them to sharing one thing at the same time.

They mentioned that there are some technical difficulties. Their video conferencing infrastructure based on Adobe Flash Media, was the best browser-based solution they could find, yet it was flawed with audio echo and feedback problems that plagued users and severely compromised the experience for many families. The StoryVist does not make the interaction easier for family but make it much more richer especially for the children and grandparents. In other words, how to enrich the content of communication applications is also necessary for family when they contact with each other.(Raffle et al., 2011)

- The AMCOSOP system

Figure 2.3 AMCOSOP system UI

The AMCOSOP system (Fig 2.3) provides elderly users the ability to stay connected with their personal safety net by a home terminal device, which is a touch screen computer with a user interface designed specifically for the elderly people. It use large screen elements and intuitive controls and features. It describes how such a system would be set up and presents a number of foundations for its use. From the result of requirements analysis, the functionalities considered most important were delivering the availability information, possibility to show contacts as photos and the possibility to personalize the visualization of the UI. After they evaluated the system, they found that the Perceived Usefulness of the Home Terminal is slightly above average. Participants comment that it can improve their quality of life by using Home Terminal, though the improvement is minor. Since the elderly people found the system cost few effort to interact with and it easy to use, the Perceived Ease of Use has remarkable high value. However, the shortage of system is that it is better to add writing and sending messages. Similarly better possibilities to express his or her status, activity and mood will be implemented. (Kivim et al., 2013)

2.5 Gesture detection and recognition

Before describing the overview of gesture, the different categories of HCI will be shortly expounded. Each of the different independent single channels is called a modality. Depending on the amount of modality used in the system, HCI system can be separated into unimodal HCI and multimodal HCI. Unimodal HCI system is based on only one modality. And it can be divided into three main types (Karray, Alemzadeh, Saleh, & Arab, 2008).

- Visual-based HCI (Gesture)

The visual based human-computer interaction is probably the latest and hottest research area compared to the others. Considering about the diversity of applications and variety of challenges and problems, the visual based human-computer interaction can be defined as the human response are tricked by the visual signals. Some of the main research areas mentioned as follows: Facial expression analysis, body movement tracking (long-scale), hand or head movement tracking and eye tracking.

Those areas based on the images of movement, which detected and recognized by the computer. Considering about the human-computer interaction inputs method, visual based HCI maybe can provide an intuitive and natural way for individual to interact with computer especially for the elderly people. Seniors require less learning time to know how to use it (Chen, 2013). And the knowledge of this section will be detailed described in the next part.

- Audio-based HCI

The audio-based human-computer interaction is also another important research field. The difference between visual based and audio-based HCI is that audio-based HCI needs audio signals to analyze the responses. Research fields can be divided into those following parts: 1) Speech Recognition, 2) Auditory Emotion Analysis, 3) Human-Made Noise/Sign Detections, 4) Musical Interaction.

As the example of speech recognition, this part discuss about the disadvantages and advantages of audio-based HCI. Speech recognition system normally use the ” speaker-independent speech recognition” while others use ”training” system which individual read the text into the speech recognition system. And the system analyze the person´s voice and use it for recognition ("Speaker Independent Connected Speech Recognition-Fifth Generation Computer Corporation,"). The first benefit of speech recognition is no training required for users. And the significant advantage is that it does not need any device like mouse and keyboard, the way of interaction is natural and intuitive. Meanwhile, there are some disadvantages of speech recognition, even if audio-based HCI just need the audio signal that is not too many compared with the visual signals. But considering about the different accents, it is different for system to recognize those fine shadows. And if the context of interaction is noise or there are some other sounds, the errors, which made by the speech recognition system will be increased.

- Sensor-based HCI

The sensor-based HCI is used at least one physical device between users and computers to offer the interaction such as mouse, keyboard, pen-based interaction and pressure sensors. Considering mouse and keyboard is commonly used in the daily life, the following part describes these two sensors in detail.

I. Mouse

Mouse can locate the cursor on the current screen and operate the element that cursor position by using its buttons and scroll wheel. In general, the mouse is easy for users to focus on the elements on screen and also it is easy to bring. However, as for the elderly people, most of them cannot concentrate on the mouse and screen at the same time. So using mouse to operate the computer has some problems for some elderly people.

II. Keyboard

The keyboard is arranged through the system refers to a set of keys operate a machine or device, the main function is to input data, in accordance with the number keys on the keyboard. It can provide many different input methods to write text messages or articles. Also using the shortcuts on the keyboards can use it to operate the computer. But the problem is that it needs long-time training to remember the position of different characteristics. If users cannot memory the position, the efficient of input is lower compared to the other input devices.

As previous mentioned, with the rapid development of modern technologies, they have invaded every sector of our daily life. Nowadays, people are accustomed to the daily use of computers in workplaces, campuses, and even in home settings. It seems that people are using computers anywhere. Traditionally, people are used to use keyboards, mice, trackballs and other input devices to communicate with computers. However, these traditional interfaces seemed to be a lot more cumbersome and less attractive. As the modern technologies stepping into their own maturity, they have been continuing changing our preferences when it comes to the interaction between human and computers. Indeed, nowadays people prefer more flexible, nuance and innovative way of interaction between human and computers. Thus, gestural-based interfaces came as the bridge to bridge the gap.

2.5.1 The overview of gesture

Gesture-based interfaces offer an alternative to traditional keyboard, menu, and direct manipulation interfaces which meet all the requirements mentioned above. However, what are the main differences between gestural interfaces and traditional interfaces? First of all, gestural interfaces have a great diverse of actions with which can be used to manipulate computers or applications. In addition to being able to type, click, point to perform all the other standards of interaction available to computers, gestural interfaces take advantage of physical motions to trigger system behaviors. For instance, a simple scroll enables keyboard event next page. Besides, gestural interfaces providing users with the most entertaining and intuitive computer interfaces. The ability to specify objects, operations, and additional parameters with a single intuitive gesture appeals to both novice and experienced user (Rubine, 1991). According to Saffer (Saffer, 2008), this book identified the following advantages of gestural interfaces against traditional interfaces, which are (1) more natural interactions; (2) less cumbersome or visible hardware; (3) more flexibility; (4) more nuance; (5) more fun.

Gesture recognition enables humans to communicate with the machine and interact naturally without any mechanical devices, which is an innovative topic in computer science and language technology with the goal of interpreting human gestures via mathematical algorithms ("Gesture recognition," n.d.). Gesture recognition can be used in many fields, for example, emotion recognition, sign language recognition, or immersive game technology. Moreover, gesture recognition is the key stage when designing gestural interfaces.

The most popular mode of HCI is based on some traditional input devices such as keyboards and mice. However, using those traditional input devices sometimes is not intuitive especially for elderly people. Hence, using gesture to interact with computer may be more familiar. Gesture can originate from any body movement or state but usually focus on hand or face gesture. There are many typical commands for the control of application by using gesture, such as pinch-to-zoom, confirm the choice, look forward and back, etc. In order to perform those commands, it is possible to use hand gestures, head movements or expressions. However, different gestures for human-computer interaction have different pros and cons. Therefore, this study will discuss these gestures in the following parts.

- Hand gestures

Hand gesture is a very natural form of human interaction and can be used effectively in human computer interaction (Wan & Nguyen, 2008). In this thesis, the hand gestures are defined as the motions of fingers, hands and arms. The hand gestures can be achieved by various kinds of techniques. Free-hand gestures normally use bend sensors to detect fingers or wrist movement as well as magnetic tracking devices to track the pinch, select, scroll and some other gestural movements. Using those sensors can improve the accuracy and efficiency for detecting and recognizing gestures. But those contact-based devices are restrained by their prices and inaccessibility for users (Hasan & Abdul-Kareem, 2013). Moreover, we can use camera to detect the hand movement and recognize the hand gesture. On the other hand, hand gesture can utilize some assistive devices like mice and stylus. There are many patterns for hand interactive gestures, such as point to select, wave to active, tilt to move, shake to change and so on. However, the primary challenge for hand gestures is how can computer distinguish the hand gesture like pointing with the movement resulted from motor impairment such as epilepsy and Parkinsonism.

- Head movements

Another kind of body-movement interaction is based on head motion. Since the webcam is located above the computer display, it can acquire and detect the user´s face features in a sequence of images (Hannuksela, Heikkilä, & Pietikäinen, 2004). Detecting face features does not require physical contact with any devices. A large number of researches focus on head movements are directed for people with physical disabilities. They use their limited motion to interact with computer (Sachin, Rakshit, Darshan, Yadav, & Prashanth, 2013). And people have a better motor control of head rather than eyes to make a point selection. This is also a reason to increase the making use of voluntary head movements and gestures in development of natural interaction system (Dirican & Göktürk, 2012).

- Facial expressions

Facial expression recognition is an essential part of human-computer interface study, because facial expression plays an important role in social interaction. The camera on laptop or mobile phone can be easily used for face detection, face recognition and facial expression recognition. Many previous facial expression recognition researches extract the facial features using Principal Component Analysis (PCA).

" PCA is a second-order statistical method to derive the orthogonal bases containing the maximum variability in an unsupervised manner that provides global image features."(Uddin, Lee, & Kim, 2009)

As the author mentioned in the chapter 1, hand gesture is the most effective manner of interaction input to the computer. Thus, in this project, EBAPP was based on hand gesture to help Chinese elderly people interact with computer. Selecting the appropriate device to collect hand gesture data becomes the first problem.

2.5.2 Hand gesture detection and recognition system

According to the different hand gesture data collection methods, currently the hand gesture detection and recognition system is divided into two categories. One is vision-based and the other one is based on mechanical sensors.

2.5.2.1 Vision-based

Theoretically, vision-based gestures can be classified into two types, static and dynamic gestures (Hasan & Abdul-Kareem, 2013). Static vision-based gestures refer to the position of hand or other part of body without any movement in space during an amount of time. Dynamic vision-based gestures involve body parts movement, such as waving the head or hand. However, no matter what kinds of vision-based gesture it is, the vision-based gestures analysis is always based on video sequences captured by one or several cameras.

- Gesture detection method

Plenty of methods have been addressed in detecting gesture based on visual features, such as skin color, shape of hands or other parts of body, pixel values, 3D model and motion(S. Rautaray & Agrawal, 2012).

1. Skin color

Skin color segmentation has been used in several approaches for gesture detection. In skin color segmentation approach, each skin and non-skin pixel is considered individually, independently from neighboring areas, especially for detection of face from a picture or eyes. But the limitation of skin color segmentation is to detect the object from a similar color background.

2. Shape

The characteristic shape of object can be used in detecting them in an image in several ways. Extracting the outline of object depends on the edges detection results.

3. Pixel values

Some previous work have already mentioned that some researchers attempt to detect hands based on hand appearance, by training the classifiers on a large number of image samples. The fundamental of this method is comparing the difference between hand appearances and hand gestures, the differences among people performing the same hand gestures can be ignored. However, this method can always be used in combination of the skin color segmentation.

4. 3D model

View-independent detection is clearly an advantage of 3D model over other methods. Different models require different features of image in order to construct the consistency for the feature-model. And using those 3D models fit the image data to achieve the gesture detection.

5. Motion

The use of motion as a cue for object detection is limited. Therefore, in some recent methods, motion information is combined with additional visual cues, such as color and edges. Because the difference between two adjacent images is nearly zero for pixels of the background, therefore, the moving object can be detected in this way.

- Gesture recognition method

Considering the classification of vision-based gestures, the vision-based gesture recognition also can be further classified into two aspects. For static hand gestures, it is common to use general classifier or a template-matcher to recognize the gestures. The dynamic gesture is considered as a path between an initial point and a final point. The recognition technique for dynamic gesture needs to handle the dimension through the hand gesture representation like motion-based model. Some common techniques used for vision-based recognition are as follow: K-means, *K-nearest neighbor, and Support vector machine (*non-linear classifier*), etc.*

2.5.2.2 Mechanical sensors

Employing mechanical sensors is one of the approaches to analyze the gesture. In this part, it mainly focus on how mechanical sensors can be used to analyze hand gestures. The mechanical sensors are usually attached to a glove which then acts as a transducer of finger flexion into electrical signals, as showed in Figure2.4.

Figure 2.4 Mechanical sensor

- Gesture detection method

When the hand or fingers move, the sensor is active immediately. Therefore, the intensity of signals can be related to the angular displacements of finger joints, such as the gloves with optical signals and touch screen with pressure signal. Those gestures can be easily detected by various signals.

- Gesture recognition method

There are some software toolkits only works for the hand gesture recognition with glove. Most of software analyzes the gestures by using different algorithms. Kevin, Ranganath and Ghosh developed a gesture recognition system that uses the trajectory-matching algorithm. They mentioned that this algorithm uses a probabilistic framework to match the trajectory models to the multi dimensional input data varying in time. And the trajectory modeling is visualized as Hidden Markov Models (HMMs) (Kevin, Ranganath, & Ghosh, 2004).

The mechanical sensors-based hand gesture detection and recognition depends on the data gloves or sensors. It can catch the accurate gesture data compared to the vision-based system. However, this mechanical sensors-based system is limited with flexibility and expensiveness by using specific gloves or sensors.

2.5.3 Devices for vision-based gesture detection and recognition system

In this section, many devices for vision-based hand gesture detection and recognition system are described. It provides the description, price, usage and other features of those devices to explain the reason of chosen webcam as the research device in this project.

- Webcam

Figure 2.5 The exterior of webcam

Webcam is a video camera, which can provides or streams the images in real time by computer or computer network. The video stream is collected by the lens. Images processing will be done by the light-sensitive components and control circuit components inside of the camera and be translated to the digital signals, which can be recognized by computer. Then the signal will be input by the parallel port or USB connection and then restore the images.

Nowadays, most laptops come with the build-in camera. It makes videoconference much more convenient. People do not need to pay for the extra fee for the webcam. The usability of webcam is taken into account when it is used for the gesture detection and recognition. However, the biggest problem of using webcam to detect and recognize the gesture is that the low accuracy of detection and recognition.

- Leap Motion controller

Figure 2.6 Leap motion controller

Leap motion was released in American market by the gesture motion controlling company on 27th of February 2013. It is similar to the mouse.

The device supports the inputs by using the hands and fingers motion and also handheld tools. The most important feature of leap motion controller is touch less. General, Leap sensor based on a built-in two cameras to capture images from different angles, to reconstruct the palm motion information in the real world 3D space. Sensor detection range substantially between 25 mm to above 600 mm, the detection space is a substantially inverted quadrangular pyramid. During using process, Leap Motion sensor periodically transmits information about the movement of the hand, each of such information is called "frame". Each frame containing these information which been detected:

1. A list of all the palms and information;
2. A list of all fingers and information;
3. Hand tool (a thin, straight, longer than the finger thing, such as a pen) list and information;
4. All point to an object (Point able Object), that list and information on all the fingers and tools;

Nevertheless, the leap motion controller must be connected via wired. So the position of gesture control users is not flexible. They should sit before the devices and using hand to provide the input commands.

- Kinect

Figure 2.7 Kinect

Kinect was developed by the Microsoft and use voice commands or gestures to the operating system interface of Xbox 360 and Xbox One. It can capture the motion of player body to control the system and play the game. Hence, compared to the Leap motion, the range of detection and recognition of Kinect is bigger. This device mainly used for entertainment.

The sensor of Kinect looks like the webcam but it has three lenses. The central camera is a color camera based on RGB, the others are the 3D optical depth sensor composed with the infrared transmitter and infrared CMOS camera.

- Haptix

Figure 2.8 Haptix

The Haptix is another somatosensory control equipment. It looks like Kinect with hand gestures control feature, but the feeling of application is similar with Leap motion. Haptix is still a concept and did not put into the market. It can provide two different touch control method. One is 3D model like using finger to operate the screen in the air, the other one is 2D model, which can turn any plane to a touchpad for operation.

Compared with Haptix, the other sensor requires users to handle multiple stays in the air, which can easily lead to fatigue of hand. The multi-touch layer, which Haptix can provide can alleviate this fatigue for users. The reason of not using Haptix to be the research device is that it is difficult to find the real product.

Thus, some features for different devices can be conclude and showed as follow (Table 2-1).

Table 2.1 The features of different devices

Device	Content of detection	Price ($)	Connection method
Webcam	Images stream	Free (build-in)	Build-in/wired
Leap motion controller	Hand gesture	69.9	Wired
Kinect	Body motion	249	Wireless
Haptix	Hand gesture	Not available	Wired

A lot of Chinese families have at least one laptop or desktop computer in their home. Most of laptops have the webcam build-in and as for the desktop computer without build-in webcam, it cost around 6$ for Chinese elderly people to buy a webcam. Considering the popularity and the economic situation in China, webcam was chose in this project as the hand gesture data collection. In order to improving the accuracy of hand gesture detection and recognition, author was committed to find a appropriate algorithm for hand gesture detection and recognition in this project.

2.5.4 The image preprocessing

Any image in the process of collection and transmission will inevitably influenced by the external factors, and produce corresponding noise that will decrease the image effect and the accuracy of the hand gesture detection and recognition. Thus it is necessary to preprocess the image before detect and recognize the hand gesture image.

Image smoothing and image binarization are the two parts of image preprocessing (Liang & Ma, 2012). Smooth pretreatment can eliminate the noise from the original images in order to strengthen the useful information and reduce the influence of the useless information.

2.5.4.1 Image smoothing

As for the hand gesture detection and recognition, the original images are captured from the video stream. In the meanwhile there are many noises because of the impact from the environment such as light and complex background. Filtering operator is commonly used method for image smoothing (also called image blur) to remove the noise from the original images (Liang & Ma, 2012).

Gaussian smoothing (as known as Gaussian blur) is a traditional smoothing method and is the result of blurring an image by a Gaussian function. It is a low-pass filter, which is typical to reduce the image noise. Gaussian smoothing uses Gaussian function for calculating the transformation to apply for each point in image. To put it simply, Gaussian filter is a processing to set the weighted average by each pixel´s neighbors as their new value.

The equation of a Gaussian function in one dimension (Equation 1) is

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}} \quad (1)$$

In two dimensions, it is the product of two such Gaussians, one in each dimension (Equation 2):

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (2)$$

The x and y is the distance from the original in horizontal axis and vertical axis and the σ is the standard deviation of the Gaussian distribution (Nixon, 2008).The effect of Gaussian smoothing can be shown as follow (Fig 2.9):

(a) Before Gaussian smoothing (b) After Gaussian smoothing

Figure 2.9 Gaussian smoothing

2.5.4.2 Image binarization

Image binarization is a processing of converting a pixel image to a binary image that the pixel gray value is 0 or 255. The process can be addressed as: The image set to $f(x,y)$ after image similarity calculation and the range of this image gray value $[a,b]$, and the threshold set as T which fulfil this formula $T \in [a,b]$, then the formula (Equation 3) for binarization can be shown as

$$f(x,y) = \begin{cases} 1 & f(x,y) \geq T \\ 0 & f(x,y) \leq T \end{cases} \quad (3)$$

(a) Original image (b) After image binarization

Figure 2.10 Image binarization

Figure 2.10 (b) reveals the image after the binarization, however, the boundary of image after binary treatment becomes unsmooth. Hence, as for the image processing, the mathematical morphology processing should be included, that is, the image should be eroded and dilated.

Image binarization is also widely used in image segmentation and this will be informed afterwards.

2.5.5 Skin-color-based hand gesture image segmentation and detection

Skin-color-based image segmentation is the process of partitioning a digital image into multiple segments. And the main purpose of image segmentation is to divide the image into regions which is more meaningful and easy to analyze (Ibraheem, Khan, & Hasan, 2013). In this project, image segmentation is based on skin color to distinguish the hand image from the complex background thereby gaining the hand gesture detection. With the purpose of effectively partitioning hand gesture from the collected images, an appropriate hand gesture model was required which is suitable with different skin color and robust to the light changes. Many researchers have compared the effect of skin-color-based modeling in different color model. As Zarit said, there are two histogram-based method to study the effect of color space on skin detection performance. One is the lookup talble method and the other one is Bayesian Method. After comparing those two method, Zarit got that using different color space provided very little variation when using Bayesian(Zarit, Super, & Quek, 1999). Terrillon compared the efficiency of nine different color space for face segmentation and detection against complex background and suggested several color space that have higher efficiency when partitioning the meaningful region during image segmentation(Terrillon & Akamatsu, 1999). Therefore, this study separates the lightness and saturation in order to reduce the influence of light changes for skin-color-based segmentation. Before describing the segmentation approach used in this project, color model was informed at first to get a better understanding of image processing.

2.5.5.1 The concept in color

- RGB color model

  The name of RGB comes from the three primary colors, red, green and blue. In the RGB model, each color was reproduced by these three colors(Rafael C. Gonzalez, 2008). And it is described by representing how much of each primary color and the value can vary from zero to a defined maximum value. Normally in computer, the range of color value is from 0 to 255 (Basilio, Torres, Pérez, Medina, & Meana). RGB color model´s main purpose is for sensing and representation and display image in electronic system. And RGB is a device-dependent color model. The color subspace of interest is in the cube shown as follow (Fig 2.11). The RGB primary colors are at three corners. The secondary colors are at other three corners.

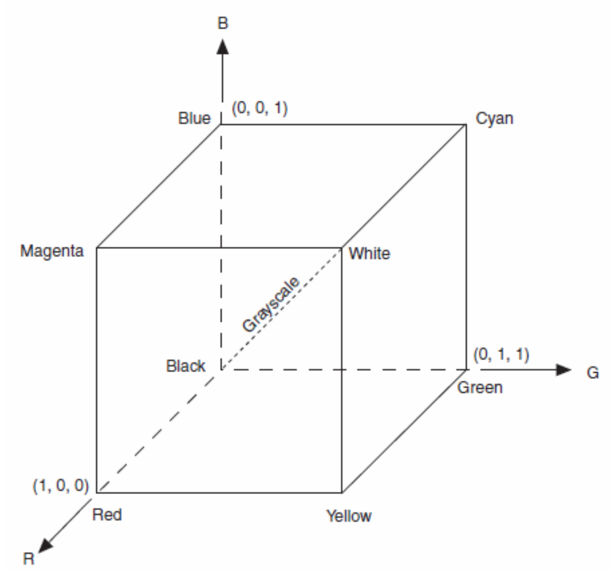


Figure 2.11 RGB Color Model

Color TV, video camera, image scanner and digital camera are the typical RGB input devices. Thus, in this project, the original images from webcam are based on RGB color model.

- Grayscale

  From Figure 2.11, the grayscale (points of equal RGB) extends from black to white along the line joining these two points (Rafael C. Gonzalez, 2008). In the RGB color model, the range of color value is from 0 to 255, which means each primary color has 256 degrees. Hence, the grayscale has 256 degrees include black and white. Another convention is to use percentage to inform the scale. The scale is then from 0% to 100% which is reversed compared to RGB. 0% is indicated to white and 100% is black.

- YCrCb color space

  YCrCb color space is widely used in digital image processing. Y represents the luminance information and color information is stored in Cb and Cr. Cb and Cr are the blue-difference and red-difference Chroma component compared with a reference value. The Chroma information combines with hue and saturation. YCrCb color model was developed as part of ITU-R BT.601 during the development of a world-wide digital component video standard (Basilio et al.).

  The luminance react the information of color brightness. It is a metric when people observe the brightness variation that can be calculated by a weighted sum of the specific lighting intensity components. The formula of Y was shown as follow (Equation 4):

$$Y = 0.299R + 0.587G + 0.114B \tag{4}$$

And the transformation used to convert between RGB and YCrCb color space is informed in this formula (Equation 5 and 6):

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.2990 & 0.5870 & 0.1140 \\ -0.1687 & -0.3313 & 0.5000 \\ 0.5000 & -0.4187 & -0.0813 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{5}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.0 & 0 & 1.371 \\ 1.0 & -0.3336 & -0.6980 \\ 1.0 & 1.7320 & 0 \end{bmatrix} \begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} + 128 \begin{bmatrix} -1.731 \\ 1.034 \\ -1.732 \end{bmatrix} \tag{6}$$

2.5.5.2 *Thresholding segmentation approach*

The Thresholding segmentation approach is one of the traditional image segmentation approaches. Depending on the image is part information or the overall information, Thresholding segmentation can be divided into two ways, non-contextual (or it can be called point-dependent) and contextual (region-dependent). Also Thresholding segmentation can be separate as global Thresholding and local Thresholding based on the category of Thresholding.

The basic principle of Thresholding segmentation: by setting the different Thresholding value, the image pixels are divided into different categories. The Thresholding value can be the gray-scale or color features form the original images. The Thresholding segmentation is to simplified represent an image into something that are more meaningful and easy to understand (Stockman & Shapiro, 2001).

We use $f(x, y)$ to represent the original image, according to certain criteria to find the feature value at T, the image is divided into two parts, the image after segmentation showed as follow (Equation 7):

$$f(x,y) = \begin{cases} b_0 & f(x,y) \leq t \\ b_1 & f(x,y) \geq t \end{cases} \tag{7}$$

As shown in Figure 2.12, when $b_0 = 0$ (black) and $b_1 = 1$(white), we usually refers this to the image binarization processing.

(a) Original image (b) image after segmentation

Figure 2.12 Thresholding segmentation

Image segmentation process has received extensive attention of several researchers in past decades, and also there are hundreds of segmentation algorithms. But so far, there is no algorithm can be used and fit for all different image segmentation.

In general, when the current surrounding is as following: uniform illumination, single background and without noise, the global Thresholding can be used during the image segmentation process. However, local Thresholding should be applied when the environment is non-uniform illumination, complex background with noise. The global Thresholding is simple, the processing data is small and the speed of segmentation is fast compared to the local Thresholding.

Moreover, the Chroma of different skin color is almost similar in Cr channel and the difference is only on the brightness and saturation. Hence, this study used Thresholding segmentation only for the image of Cr channel.

2.5.5.3 Morphological image processing

Morphological image processing (Pratt, 1991) is to improve the visual effect of the image, at the same time to facilitate the next step of image processing. In order to highlight the target item of image, morphological image processing will add some information or transform some data in the image. For instance, it will highlight some characters of image that researcher interests and hide those useless information.

The method of morphological image processing method belongs to Mathematical Morphology. Mathematical morphology is composed of a set of morphological arithmetic operators, mainly including: erosion, dilation, opening and closing. Mathematical morphological method is mainly used to analyze and process the image shape and mechanism, which is widely used in many fields, such as gesture segmentation, gesture boundary detection, feature extraction, image enhancement and restoration.

The purpose of image erosion is to eliminate the boundary of the object in the image. By narrowing the pixel point of the border to one of the pixels within the target object. As for gesture image processing, erosion can separate those close pixels of object. For instance, image erosion can separate fingers when the finger of the hand gesture image is slightly adhered.

Image dilation is mainly to expand objective pixel into a close pixel point set, so that the value of the surrounding pixels and the objective pixels are consistent. Compared with image erosion, image dilation will combine the boundary of close fingers together. In the acquisition of hand gestures, researchers often have a hollow phenomenon in the area of the sign, and the expansion of the gesture image can be used to fill the void. When the image is expanded, it can choose from two directions, four directions or the eight directions.

In general, as for morphological image processing, image erosion and dilation are combined together used in the image process.

2.5.5.4 Skeletonizing

Skeletonizing is a process for reducing foreground in a binary image to skeletal remnant. In the digital image, the edge is the most significant part of the image transformation. Feature extraction as an important method of image edge detection, it has developed a number of algorithms in the past decades. These algorithms have been studied by a lot of practice. Commonly used edge detection operators are: Sobel operator, Roberts operator, Prewitt operator, Canny operator and so on, they are using a predefined edge template for image matching. According to Raman´s study, they found that Canny operator is better than others operators under almost all scenarios (Maini & Aggarwal, 2009). Hence, there is a brief introduction of Canny operator.

Canny operator can be said to be the most perfect edge detection algorithm in theory at present. Edge detection based on Canny operator is mainly divided into five steps (Moeslund, 2009).

1. Smoothing by using Gaussian filter. Without doubt, there are some amounts of noise. In order to prevent the effect of noise, noise should be reduced. Hence, the first step of edge detection is to smoothing image by using Gaussian filter.
2. Finding the intensity gradients of image. Canny operator is based on finding the most changes of gray intensity to decide the edge. Moreover, these areas can be found by determining gradients. Canny operator detects horizontal, vertical and diagonal edges in the blurred image. The equation can be showed as followed (Equation 8).

$$G = \sqrt{{G_x}^2 \quad + \quad {G_y}^2} \tag{8}$$

$G_x$and G_y are the gradients in the x and y directions respectively.

The direction can be determined by

$$\boldsymbol{\theta = arcten\left(\frac{|G_y|}{|G_x|}\right)} \tag{9}$$

3. Non-maximum suppression. This step is to change the ´blurred´ edges to ´sharp´ edges. It maintains all local maximum in gradients image and delete everything else.
4. Double threshold. After non-maximum suppression, some edge-pixels are the true edge of image, but some may be influenced by noise and color variations. Hence, Canny operator uses double thresholding. Edge pixels stronger than high threshold are marked as strong, and edge pixels weaker than low threshold are marked as weak.
5. Edge tracking by hysteresis. The strong edge can be directly included in to the final edge. However, as for weak edges that are weak and not connected to the strong edge, those are suppressed.

3 Methods

This chapter mainly lists the four methods used in this research: the user-centered design, interview, user testing and accessibility testing. The concept of each method is explained first, and then the reason of using it is discussed.

3.1 User-centered Design

A variety of design approaches can be used during the design process. User-centered design is one of them. ´User-centered design (UCD) is a user interface design process that focuses on usability goals, user characteristics, environment, tasks, and workflow in the design of an interface. UCD follows a series of well-defined methods and techniques for analysis, design, and evaluation of mainstream hardware, software, and web interfaces. The UCD process is an iterative process, where design and evaluation steps are built in from the first stage of projects, through implementation.´ (Henry, 2007) Furthermore, UCD is an associated design discipline for HCI (Dix, 2009). It concerns the design artifact that is effective, efficient and easy to use. Moreover, the UCD principles can be described as follows (Rubin & Chisnell, 2008):

- *Early focus on users and tasks*

  The information gathering should be structured and systematic from beginning. And experts should train designer before conducting data collection session.
- *Empirical Measurement and testing of product usage*

  The testing should focus on the ease of learning and use. And it should be done with actual users.
- *Iterative Design*

  The product should be designed, modified and tested repeatedly. Moreover, it allows the complete overhaul and rethinking of design by early testing of conceptual models and design ideas.

Thus, in order to obtain more detailed user requirements and construct a useful design artifact, this thesis should elaborately stick to the UCD model as Figure 3.1 illustrates.

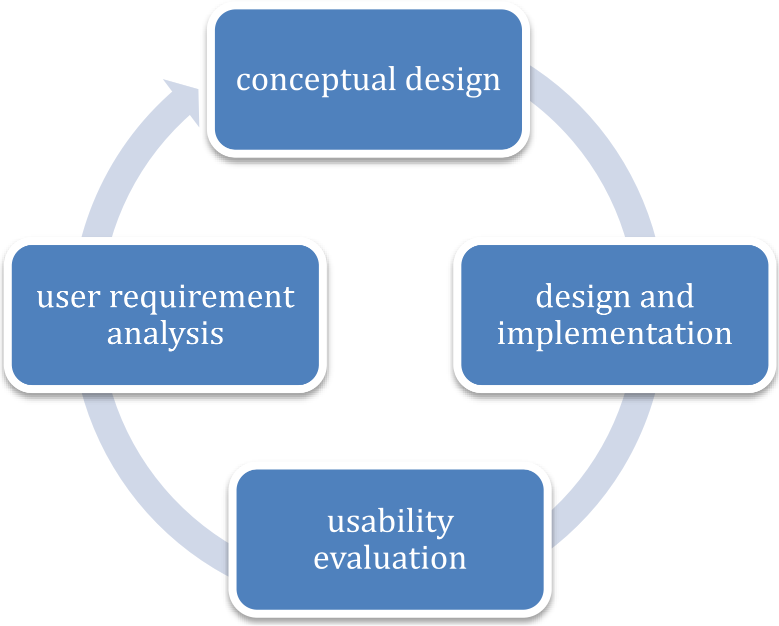


Figure 3.1 User-centered Design process

In addition, usability is an important aspect in UCD process. It addresses that a product can be used by a specific user group to achieve a specific goal in a particular context with effectiveness, efficiency and satisfaction (Bevan, 2001). Considering the usability in design process, Jeffrey Rubin (Rubin & Chisnell, 2008) described usability objectives as four parts: usefulness, effectiveness, learnability and attitude.

1. ***Usefulness - product enables user to achieve their goals - the tasks that it was designed to carry out and/or wants and needs of user.***

The EBAPP should enable elderly users to achieve their goal and fulfill their needs of interaction with computer to get the daily information from Internet.

2. ***Effectiveness (ease of use) - quantitatively measured by speed of performance or error rate and is tied to a percentage of users.***

This objective mainly depends on the speed of hand gesture detection and recognition. An appropriate algorithm for detection and recognition can reduce the error rate to operate the EBAPP.

3. ***Learnability - user's ability to operate the system to some defined level of competence after some predetermined period of training. Also, refers to ability for infrequent users to relearn the system.***

The hand gestures for EBAPP cannot be too complex for elderly people to remember and to achieve. This concerns those with physical issues or illnesses. At the same time, the interface should be easily understandable.

4. ***Attitude (likeability) - user's perceptions, feelings and opinions of the product, usually captured through both written and oral communication.***

The interface of EBAPP should be designed in accordance with by users´ requirements. For instance, the size of the characters should be suitable. The functions of EBAPP can satisfy elderly people´s needs.

However, due to the fact that elderly people are the primary user group in this thesis, and the purpose of this thesis is to provide a usable and accessible GCUI to help them intuitively interact with computer by using hand gestures, it is not enough to consider only the usability in this thesis. Moreover, as a primary principle of universal design, accessibility should also be considered in design process, which ensures that the product or software can be used by a wide rang of user groups. The design artifact should be accessible to all. Hence, a theory (Henry, 2007) which integrate accessibility into UCD process was applied.

3.2 Interview

Direct feedback from users is the fundamental to HCI research (J. Lazar, Feng, & Hochheiser, 2010). The functions of the application depend on users requirements. It should fulfill the needs of users. However, there are a number of ways to get responses from users, such as case study, survey and interview. Case study is widely used when researchers study a small number of participants in depth. It is a study of a specific instance within a specific real-life context. Considering the nature of this project, case study will have limited effect in gathering the result for gesture-control. Because individuals have different habits by which they interact with computer using hand gestures. As for survey, on the contrary, its result is too general for an understanding on hand gestures. Survey can get a numbers of responses from a population of users but it is not as in-depth as other research methods. And some open-ended question in survey with long, written answer are likely to go largely unanswered (J. Lazar et al., 2010). Hence, this thesis picked interview as research method to get requirements and feedbacks from elderly users.

Interview is a conversation where questions are asked and answers are given. Normally interview is performed face-to-face, but there are also some electronically mediated interview, for instance, one-to-one call, conference call and online chat. All these interview-based studies can help author to explore a wide range of concerns about a problem and gathering some data, which are difficult to obtain in other research methods. There are two forms of interview: interview with individuals and interview with focus groups of multiple participants. Interview with individuals can help capture more detail and useful data when interviewee and interviewer communicate with each other. Compared with individual interview, focus group interview has several participants. The discussion is not only focus on interviewee and interviewer but also between interviewees. This in-group participation and discussion provides a broad range of opinions. Therefore, choosing an appropriate approach is the first vital question before conducting an interview. In this research, focus group interview was used for the initial exploration, to gathering a general understanding of the requirements from elderly users. And individual interview was used in the process of design and development to help the author find the obstacles faced by users.

3.3 User testing

User testing refers to the situation when the user interface is tested by real users carry out real tasks. User testing is widely used in the process of design and development. A user testing can identify some issues of the design that make users confused and application inaccessible. Hence, user testing is an effective methodology to identify the problems and obstacles confronted by users during the design and development ("User Testing ").

In this thesis, in order to design and develop a usable and accessible GCUI for elderly people, the senior users play an important role. User testing was conducted after the interface was designed. The author tried to discover the obstacles faced by elderly users through the user testing. There were two parts of user testing in this research. One is in the process of design and development. The other is for the final prototype after the development. The user testing in final evaluation can be considered as usability testing in order to identify the usability problems for the interface.

3.4 Accessibility testing

Accessibility historically focuses on the design of products that can be used by the people who experience disabilities or have special needs, or enabling access through assistive technology like screen reader. In other words, accessibility refers to the property which enables a product, web, design or device to be used by a wide rang of people (Henry, Abou-

Zahra, & Brewer, 2014). Hence, it is necessary to identify the accessibility of objects when it is designed and developed.

In this research, a heuristic evaluation was performed on the accessibility of GCUI. Heuristic evaluation is done by looking at the interface and trying to find out some usability problems according to certain rules or guidelines (J. Nielsen, 1994). Meanwhile, heuristic evaluation also can be used to identify the accessibility problems. Therefore, this thesis used this method to find out the accessibility problems according to the accessibility guidelines. There are many accessibility guidelines published by the World Wide Web Consortium (W3C). For instance, the Web Content Accessibility Guidelines aims at the improvement of accessibility of the websites. There are also some guidelines for mobile application like accessibility programming guideline for IOS and so on. However, the accessibility guidelines for GCUI are rare. Taking into account the fact that the majority of EBAPP´s content comes from website, WCAG 2.0 was referred to as guideline in this research. Meanwhile, GNOME (GNU Network Object Model Environment) developer published some user interface guidelines for supporting accessibility, which is similar to the WCAG 2.0. Hence, WCAG 2.0 guideline was referred in this thesis. Moreover, WCAG principles and relevant accessibility guidelines from WCAG 2.0 (Consortium, 2008) were listed in the following Table 3.1 and 3.2. However, considering the GCUI´s characters, some guidelines are not relevant in this study. And the reason also presented in the Table 3.2.

Table 3.1 WCAG principle

Principle	Description
Perceivable	Information and user interface components must be presentable to users in ways they can perceive.
Operable	User interface components and navigation must be operable.
Understandable	Information and the operation of user interface must be understandable.
Robust	Content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies.

Table 3.2 Relevant accessibility guidelines

The accessibility guideline	Description
Text Alternatives	As for non-text content, it should be provided text alternatives so that it can be changed into other forms people needs, such as large print, speech, symbols and so no.
Time-based Media	Provide alternatives for time-based media.
Adaptable	Create content that can be presented in different ways (for example simpler layout) without losing information or structure.
Distinguishable	Make it easier for users to see and hear content including separating foreground from background. For instance, the color is not used as the only visual means. The text should be resized without assistive technology.
Keyboard Accessible	Make all functionality available from a keyboard. This is not relevant to this thesis. Because EBAPP is used gesture to control the interface.
Enough Time	Provide users enough time to read and use content. This is not relevant to this thesis. There is no flashing, moving or scrolling content in EBAPP.
Seizures	Do not design content in a way that is known to cause seizures. Because there is no flashing content so that this is not relevant to this thesis.
Navigable	Provide ways to help users navigate, find content, and determine where they are.

Readable	Make text content readable and understandable.
Predictable	Make Web pages appear and operate in predictable ways.
Input Assistance	Help users avoid and correct mistakes.
Compatible	Maximize compatibility with current and future user agents, including assistive technologies.

The heuristic evaluation is performed in accordance with these guidelines. Then color contrast analyzer was used to evaluate the color contrast as a supplementary reference. Color contrast analyzer was developed by Jun in collaboration with the Paciello Group. And it can determine the legibility of text and contrast of interface.

4 Design and development

This chapter focuses on the design and development of EBAPP. Firstly, the process of design and development is described. Secondly, the design of EBAPP including the interface, function and the algorithm for hand gestures recognition is explained.

4.1 Process of design and development

Initially, the author used hand movement as mouse movement to control the cursor. Then, it was found out this type of hand gesture is not suitable for elderly people. Such action leads to fatigue of long time extension of shoulder muscle. Hence, this conceptual model had a complete overhaul at beginning. In the second phase, the design idea of gestures-control shifted to using several single dynamic gestures to control the interface. Requirement gathering was performed in order to get some more detailed requirements from elder users. Subsequently, three iterations were performed, assisted by user testing and interview. The author tried to find out the usability and accessibility obstacles faced by elderly participants during these iterations.

4.1.1 Initial exploration

Based on many literatures and previous studies, gesture-control can provide an intuitive way for people to interact with computer. However, considering some age-related deterioration, elderly people´s requirements of GCUI should be identified at first. Those demands provided an understanding and overview of design of GCUI. Hence, the focus group interview was adopted in this phase.

Since discussion between participants can reveal the similarities and differences between opinions, focus group was introduced in this phase. A broad question can promote participants to discuss and address some different and unexpected ideas. 25 elderly people (15 participants were female and 10 were male) were invited to participate in focus group interview. All these participants were retired. Since 60-year-old is used as the definition of elderly people in this thesis, the age of all these 25 participants is above 60 years old. Moreover, these elderly people are the members of Xi´an (a city of China) senior community. Among those participants, 13 of them have some experiences of using computer. They know how to start the system and use mouse and keyboard. However, the rest of them have no using experience before they were interviewed. The focus group interview continued for over 1.5 hours in a meeting room. And the author prepared some tea and snacks so that the participants would not feel so tired and nervous during the interview.

The questions of focus group interview were focus on three aspects. The first is access problems by using computer faced by elderly participants. Secondly, the author asked about the functional demands, like what kinds of information they want to obtain by using computer. In the end, the user experience and opinions about GCUI were asked.

As the result of focus group interview, all participants said that the operation of mouse and keyboard is too difficult to learn and remember. Moreover, due to the long time training and repeatable learning, some participants mentioned that they are afraid of being laughed by their children. Besides, half of them have the user experience by using touch screen devices such as mobile phone or Apple iPad. They said the gesture-control is easier for them to operate and understand. However, there are also some problems, for instance, the screen size of device limited the font and image size. Furthermore, there was no participant who has the user experience by using gesture to control the computer. They showed a lot of interests when the author mentioned about using computer by gesture-control in focus group. Hence, the author designed the first prototype of EBAPP based on those feedbacks and previous studies.

The first prototype of EBAPP was based on the OpenCV (Open Source Computer Vision). OpenCV is a library of programming functions mainly aimed at real-time computer vision and machine learning. It was originally developed by Intel's research center in Nizhny Novgorod (Russia), later supported by Willow Garage and now maintained by Itseez ("About OpenCV,"). The participants use hand as mouse to control the cursor on the computer screen. They used the following gesture (Fig 4.1) to simulate click.

Figure 4.1 ´Click´ gesture used in initial exploration

The user testing in this phase was done at the beginning of 2014. The participants of this user testing were nine seniors selected from the focus group. The characters of participants were listed in the following table 4.1.

Table 4.1 The participants´ character in initial exploration

Participant	Age(year) Gender(M/F)	If with any disability	Knowledge background	Frequency of using computer
1	65F	None	Middle school education level	Once a week
2	72F	Low vision	High education level	Three times a week
3	70M	None	High education lever	Once a week
4	75M	Periarthritis of shoulder	Middle school education level	Twice a week
5	60F	None	High education level	Almost everyday
6	66F	Low vision	Primary school education level	Once a week
7	65M	None	Middle school education level	Twice a week
8	60M	None	Illiteracy	Once a week
9	67M	Low vision	High education level	Twice a week

As elderly participants mentioned in the focus group, they want to look through some news from Internet and video chat with their child or grand child. Hence, the user testing was to ask elderly participants to use browser and video chat application by gesture-control. However, the result of this user testing was not very ideal. The participants kept their arm and hand in the air to control the cursor. This increased the fatigue of shoulder and arm. Hence, most of participants could not achieve the testing because of pain in the muscle and joints. Most of participants gave a negative feedback on the first prototype.

Consequently, the author concluded the limitation of this user testing from two parts. On one hand, the author ignored the influence of the previous user experience by using mouse and keyboard on GCUI. After the user testing, when author asked about the feedback of GCUI, participant 2 and 5 said they are not satisfied with gesture-control since they can easily use mouse and keyboard. This subconscious comparison with previous experience may effect the evaluation of usability of GCUI. On the other hand, the lack of elderly people´s participation during the design process induced the inaccessible of first prototype. Because there were no question asked about the elderly people´s preference on type of the hand gestures in focus group. And the author designed the GCUI based on personal experience. Hence, there was a complete overhaul of conceptual models and design idea after initial exploration. Afterwards, the UCD approach was applied in the next phase.

4.1.2 Requirements gathering

In the second phase, the author decided to introduce some simple gestures, as well as simplified the interface according to the elderly participants´ preference. Thus, the requirement gathering was done at first.

As for the requirement, it is a statement about an intended product that specifies what it should do or how it should perform. The goal for requirement gathering is to make the requirements as specific and unambiguous as possible. So the initial exploring interview is not enough for requirement gathering. Some more detailed information needs to be addressed such as which hand gesture should be designed for EBAPP, which functions should be applied and how much items should be created in each function. Compared with initial exploration, the author decided to use individual interview in the requirement gathering process. The requirements included the type of gestures they want to use and information they want to get from Internet.

Before the interview, the observation was used in order to generate empirical material in naturally occurring settings. The purposes of this observation are divided into two main parts. (1) Uncover the latent needs and looking for the surprise, since there are some differences between what people say and what they do. (2) Gain the empathy for participants and discover their behaviors and emotions (J. Lazar, Feng, H. J., & Hochheiser, H. , 2010). Note taking is very important for observation the same as recording audio feedback. Note and audio recording reflect the real reaction when people using computer and help author recall the problems and activities they encountered in the course of interacting with computer. The author spent almost 30 minutes to observe each participant. During these 30 minutes, participants were free to dominate their time to do the things they want to do as usual. The author took the notes about what they did, what kind of information they tried to get and some especial behaviors when they interact with computer. For instance, one participant was unconsciously close to the screen when she looked through the webpage. Some participants focused on the hand movement instead of the cursor on the screen when they used mouse.

In addition, the participants for this individual interview were the same users as the user testing in initial exploration. Because they had experience of using hand gesture to interact with computer, they may have a certain understanding or feedback of design of interface and hand gestures. The interview followed by the semi-structure questions and continued for over 1 hour at participant's´ own place. In this process, the author narrow the interview questions down to some specific applications or situation based on the note of observation, for example, the demands of specific functions. All participants said that they want to use this interface to look through the news and video chat with their child. And five participants mentioned that they want to obtain some daily information like weather forecast. According to these results, there were three functions in EBAPP. And the interface was designed like following image (Fig 4.2).

Figure 4.2 The prototype of EBAPP after requirement gathering

Moreover, as for the gesture, the author showed a hand gesture list to elderly participants. And the list was as shown below (Fig 4.3).

Figure 4.3 The gesture lists used in requirement gathering

Author asked elderly participants about their understanding of each gesture´s function. At the same time, elderly participants needed to pick the preferred gestures. Thus, the author got some favorite gestures with regard to the effort of hand gesture performance.

Some participants mentioned that gesture 1 and 6 was quite frustrating for them. The most intuitive gesture was gesture 9. At the same time, taking into account of the understanding of the meaning of the gesture, gesture 6 and 7 can be understood as achieve the task or operation. Hence, the hand gestures for EBAPP were listed in the following Table 4.2. There were three gestures adopted in the EBAPP. They can achieve the operation of select, go next and previous and return.

Table 4.2 The gestures for EBAPP (first version)

Gesture			

Description	Move hand up	Move hand up	Go previous: move hand to left Go next: move hand to right

4.1.3 Evaluation and subjective reactions

The evaluation part started from the October to December of 2015. The main purpose of doing the evaluation was to figure out the usability obstacles faced by elderly users.

The whole evaluation of design and development process can be divided into three iterations. Each iteration was done through user testing and interview. Thus, in the following part, the evaluation process in each iteration is described at first and then the results of user testing and interview were stated.

Moreover, as for the participants, some people say that five users in testing part will find approximately 80% of usability problems and some studies say that five users are not sufficient (J. Lazar, Feng, H. J., & Hochheiser, H. , 2010), the author chose nine elderly people as the participants in the evaluation part. Because the author wanted to identify the universality of EBAPP, to make sure the design of interface and gestures is not only depends on the feedback of nine participants who involved in requirement gathering phase. Hence, among these nine participants in this phase, there are six new elderly participants. Furthermore, all these participants are the friends of the author´s grandparents. They showed a positive attitude and big interests with GCUI. They tried their best to help author find the usability issues. Four of them are female and five are male. The average age of these nine participants is 65 years old. And six participants have the educational background, which means they are not illiterate.

4.1.3.1 Iteration 1

- User testing

1) Process

The prototype was designed according to the result of requirement gathering. Three main functions (weather, news and video chat) are combined in the EBAPP. At the same time, considering the painful and low efficiency of dynamic gestures that were designed in the first phase, two simple hand gestures were used in the new version EBAPP. The interface of EBAPP and hand gestures was described in the previous part. Before these nine participants started the tasks, there was an introduction to show them how to use those two hand gestures to control the computer and get the information from different functions. After introduction, they started practice. The testing began after participant makes sure that he or she was ready. In order to test the usability issues faced by elderly people, sets of tasks have been identified as listed in below Table 4.3. During the testing, considering the effect of complex background, the task will be treated as failure when participant has attempted over five times without the help of author.

Table 4.3 The user testing in iteration 1

Tasks	
T1	Go to weather forecast function, and get the temperature information then return to the main page.
T2	Go to news function, and pick the third news then return to the main page
T3	Go to video chat function, and select the testing account from contact list, start video chat then stop it and return to the main page

2) Result

The result of user testing in iteration 1 was listed in the following Table 4.4. In the table, the ´X´ means that this participant achieved the task. The average of completion rate was 37% in this iteration. Among those participants, two participants (participant P3 and P9) failed with three tasks mainly because the low accuracy of hand gesture detection and recognition. Participant P3 said, " It is a little bit frustrating. Although the gestures are easy to understand and remember, the computer cannot recognize my gesture." In this version of EBAPP, the detection was based on one time image skeletonizing. Hence, it resulted the low accuracy of hand gesture recognition.

Table 4.4 The result of user testing in iteration 1

Participant	T1	T2	T3	The completion rate
P1	X			33%
P2		X	X	67%
P3				0%
P4		X		33%
P5	X			33%

P6	X	X		67%
P7	X	X		67%
P8			X	33%
P9				0%

- Interview

The interview was done after the user testing. The main purpose was to understand the user experience by using EBAPP and find out the problems faced by elderly participants. The interview questions involved the difficulty degree of using EBAPP, the understanding of the interface especially for the different sections and the pros and cons for the EBAPP. Among these 9 participants, three of them did the user testing in the initial exploration. Hence, one more question was asked about the comparison of these two different versions of EBAPP in order to get a better understanding of GCUI´s usability and accessibility.

Four participants who achieve task 2 mentioned that the information in the news section was too board. Participant P5 said, " I am not interested in technology and economy news, it is a little bit difficult for me to find some interesting news. " So it will be better to have news categories to help elderly users find the news that they interested.

In addition, three of elderly participants addressed, as the description of different section´s function, word description by itself may not work for some elderly people who are illiterate. And all the participants complained about the accuracy of the hand gesture detection and recognition. In order to achieve one operation, some participants said they needed to repeatedly operate this gesture for two or three times. However, as for those participants who took part in the initial exploration, they mentioned that this version of EBAPP made the operation concise and easy. They can easily get information from functional modules rather than different websites and application. And with the reduction in time of arm in air, the fatigue degree of muscle was reduced. Hence, compared with the initial exploration, the EBAPP had some improvements but still had some disadvantages for elderly people to use.

4.1.3.2 Iteration 2

In the iteration 2, taking into account the feedbacks of user testing and interview in iteration 1, the EBAPP added image to each module to interpret its function, not only described by characters. And it also added different categories into news module such as technology news, entertainment news, economy news and sports news (Fig 4.4). So that elderly participants can easily obtain their interested news by selecting relevant news category. Compared to the last version of EBAPP, the main page was also changed. Considering the development of EBAPP, it may append more functional modules into the interface in the future, the original main page will be full of the functional icons like Figure 4.5 showed. Referring to the guidelines of WCAG 2.0, the content should be adaptable and distinguishable for elderly people. Hence, the main page of EBAPP in iteration 2 is changed as shown in Figure 4.6.

Figure 4.4 The main page of news in iteration 2

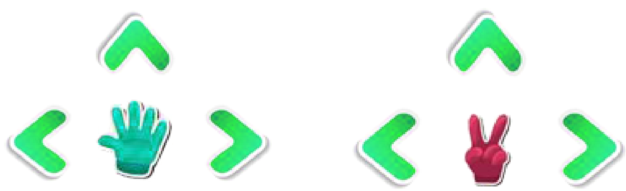
Function 1	Function 2	Function 3
Function 4	Function 5	Function 6
Function 7	Function 8	Function 9
Function 10	Function 11	...

Figure 4.5 The interface of many modules

Figure 4.6 The main page of EBAPP in iteration 2

Meanwhile, the algorithm for hand gesture detection and recognition was improved. The algorithm with one time skeletonizing was changed to two times, so that the edge of the hand becomes clearer.

In addition, in order to help elderly participants identify the result of hand gesture detection and recognition, there was a small icon added in the corner. The gesture will be shown in the center of icon after it was detected. Green color (Fig 4.7 (a)) means the gesture was recognized and operation was achieved. On the contrary, the red color (Fig 4.7 (b)) means the gesture could not recognized. And the other three parts of icons means the direction of hand movement. This icon also can give a remind to elderly participants of these two gestures used in EBAPP.



(a) (b)

Figure 4.7 The icon of hand gesture detection and recognition

- User testing

Taking into account the changes, the user testing in iteration 2 added picking news categories in the task of news module. At the same time, avoiding the influence the tasks sequence, the user testing changed the sequence of those module tasks showed in Table 4.8. Moreover, the user testing in iteration 2 started after three weeks of iteration 1 was done. During these three weeks, elderly participants were asked to practice using EBAPP once a week on their computer.

There was only a short introduction about improvements of EBAPP before user testing. Meanwhile, the author demonstrated the new EBAPP to elderly participants.

Table 4.5 The user testing in iteration 2

Tasks	
T1	Go to weather forecast function, and get the temperature information then return to the main page.
T2	Go to video chat function, and select the testing account from contact list, start video chat then stop it and return to the main page
T3	Go to news function, and select one of your favorite new category and pick the third news then return to the main page

According to the result of user testing in iteration 2, the completion rate was higher than the last time (Table 4.6). Many gestures were successfully detected and recognized. The double skeletonizing improved the accuracy of hand gesture detection and recognition.

Table 4.6 The result of user testing in iteration 2

Participant	T1	T2	T3	The completion rate
P1	X	X		67%
P2	X	X		67%
P3	X		X	67%
P4		X		33%
P5	X		X	67%
P6	X		X	67%
P7		X		33%
P8			X	33%
P9	X	X		67%

- Interview

During the interview in iteration 2, the author asked about the opinions of the improvements of EBAPP. Because the author wanted to identify whether these changes really work for the elderly users. Moreover, some questions about the user experience were addressed because the author tried to find out more obstacles faced by elderly users.

Five participants mentioned that the characters in news were too small to get information and they needed to move their eyes quite closed to the screen to read the news. Furthermore, some participants addressed that the module without outside borders confused them sometimes. It was a little bit difficult for them to distinguish different modules before they used gesture to control the computer. As for the new design of interface, the most participants gave a positive feedback. They said the new design of interface was interesting and they can get a better understanding of how hand gestures control the computer.

4.1.3.3 Iteration 3

Since some participants addressed that the characters in news are too small for them to get clearly information. The author added one operation for zoom in. This gesture was same like ´select´ gesture and it was presented in Figure 4.8. However, this gesture only can worked in the news modules. After elderly participants use ´select´ gesture to pick one of news, they can use this hand poster to zoom in this news. Hence, after elderly users selected one of news, the operation of ´select ´ gesture changes to zoom in. And the interface of before zoom in and after was showed in Figure 4.9.

Figure 4.8 The hand gesture for zoom in

(a) News section before zoom in

(b) News section after zoom in

Figure 4.9 The before and after contrast of zoom in

Meanwhile, according to the feedbacks of elderly users, those modules in main page of EBAPP should be more obvious. For instance, outside borders is needed for those modules and the selected module should be bigger and highlight. Hence, these were changed in the new version of EBAPP and it can be showed in Figure 4.10.

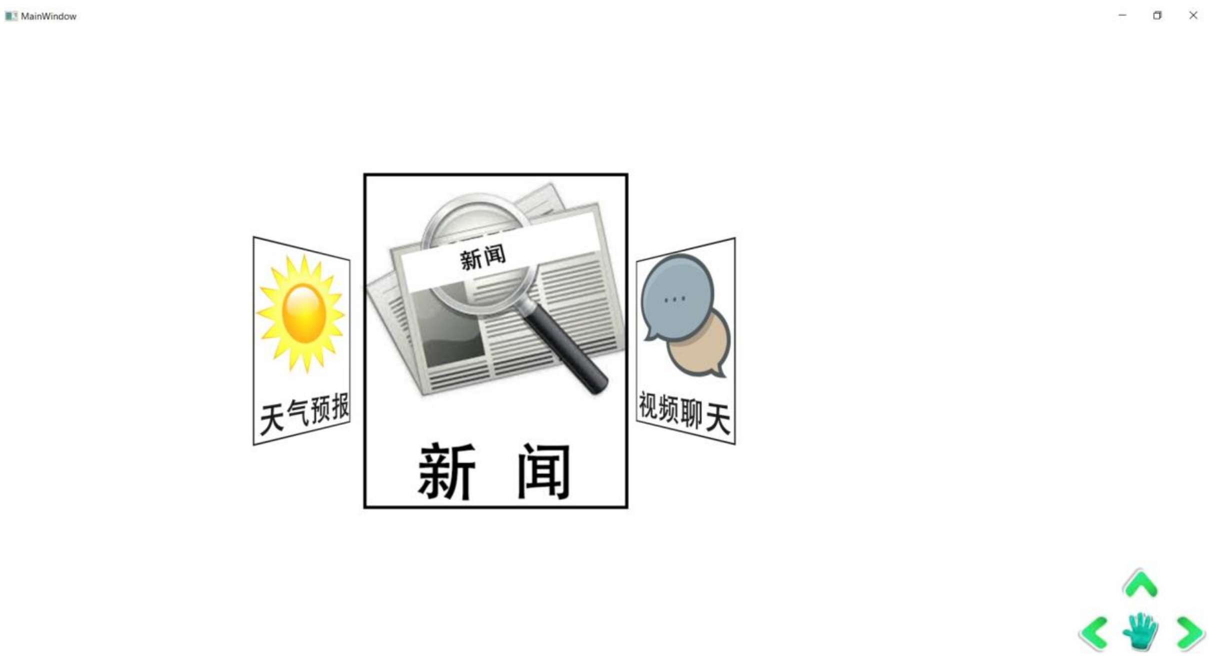


Figure 4.10 Main page in iteration 3

- User testing

The user testing in iteration 3 added the task of testing ´zoom in´ gesture. Hence, before the third time user testing begun, an introduction and training was given to the elderly participants. The training of using hand gesture to zoom in only lasted for 5 to 10 minutes. Because the hand gestures for ´select´ and ´zoom in´ are the same. The elderly participants only need to realize that they can use the same gesture to zoom in the characters when they looking through the news. Moreover, there was not extra introduction to the others gesture. Furthermore, the same as the user testing in iteration 2, the sequence of tasks was changed (Table 4.7).

Table 4.7 The user testing in iteration 3

Tasks	
T1	Go to weather forecast function, and get the temperature information then return to the main page.
T2	Go to video chat function, and select the testing account from contact list, start video chat then stop it and return to the main page
T3	Go to news function, and select one of your favorite new category and pick the third news, and zoom in to see the news then return to the main page

The result of user testing in iteration 3 was similar to the result in iteration 2. The average completion rate was almost same. Although there was one month between these two testing, most participants still remember the gestures for EBAPP and they were more practiced when they used EBAPP.

- Interview

In iteration 3, the interview consisted three aspects. The first one was same as last time. It was focus on the effect of those changes for senior users. And the second aspect was mainly talked about the advantages and disadvantages of the EBAPP. The third was the comparison between hand gesture and mouse and keyboard.

After these three testing, the participants stated that they got used to control the computer by hand gesture. All participants said that they would like to install the final version of EBAPP to obtain information and introduce this GCUI to their friends.

Through these three iterations, the author found out some obstacles faced by those elderly participants. Followed by their requirements, the EBAPP were improved from different aspects. However, those participants have different background of using computer, some of them use computer for a long time and some are only used it a few times. Hence, in order to identify the usability and accessibility of EBAPP, the author decided to conduct a final evaluation based on the last version of EBAPP. And a comparative study of using different input methods to control the computer was done afterwards. This will be stated in the following chapter. Meanwhile, there were some limitations for user testing and interview. For instance, during the design and development, each task consists of several steps. And the success of task meant all the steps should be achieved. Nevertheless, it was difficult to find out every detailed and small usability problems. Hence, the author separated the steps into different task.

4.2 Design

This section mainly introduced the functions of EBAPP and the algorithm of hand gesture detection and recognition. EBAPP as one GCUI helps elderly people to easily interact with computer. The development environment is Visual Studio Microsoft 2013. The author used C# as the programming language and also used the WPF application template to develop EBAPP. Furthermore, there are some demands of operating system. For example, the operating system should be Windows 7 or the new version. And it also requires for the Microsoft .Net Framework 4.5 or the new version. As for the hardware equipment, it should have webcam to capture the hand gesture.

4.2.1 The functions of EBAPP

In consideration of the functional needs addressed by the elderly participants in requirement gathering phase, there are three functional modules for EBAPP, news, weather forecast and video chat with their family and friends.

- News

  With the popularity of Internet, the e-news is gradually accepted by a lot of readers. Moreover, with the decline of reading newspaper, the elderly participants said that they got the current news information from TV and radio. However, they could not pick their interested news information through those two ways. Therefore, the news is one of the modules of the EBAPP. In the news module, there are four categories of news (Fig 4.11 (a)). Through the separation of the news categories, the elderly users can get the news information directly from their interested news categories. Hence, after the elderly users pick the interested news categories, the relative news information will be showed on the page (Fig 4.11 (b)). The users can use ´select ´hand gesture to pick one topic, and then use ´zoom in´ hand gesture to make the characters bigger. After they looking through this news, they can use ´return´ gesture to return to the previous page.

(a) News categories (b) News information page

Figure 4.11 The interface of news section

- Weather forecast

  As a result of the requirement gathering, many participants mentioned that they want to use this GCUI to check the weather forecast. Since if they miss the weather forecast, they cannot know the weather for the next day. Hence, weather forecast is added as one function to help elderly people easily get the weather information. The weather of the next three days will be displayed on the interface (Fig 4.12).

Figure 4.12 The interface of weather forecast

- Video chat

There are many studies talk about the social isolation and loneliness of elders due to the decrease of communication (Hacihasanoğlu et al., 2012; Tomaka et al., 2006). Moreover, considering with ´ empty nest syndrome ´, the author decided to use video chat as one functional modules of EBAPP to increase the elders´ social communication. In this part, the elderly users can move the hand to select one user to start video chat. Elderly participants can select user by looking through user´s pictures and name.

Figure 4.13 The interface of video chat

4.2.2 The algorithm of hand gesture detection and recognition in EBAPP

In general, the main steps of hand gesture detection and recognition should include three parts: image preprocessing, gesture skeletonizing and gesture image template matching.

In image preprocessing stage, this study chose the YCrCb color model as the fundament of the subsequent image processing, so the direct acquisition of image data need to transfer from RGB model to YCrCb color model, and use the transformed Cr channel image as the input image I.

In the hand gesture detection stage, according to the previous research results of the image skeletonizing analysis, the author found that the effect of once gesture skeletonizing is not ideal. Therefore, this paper puts forward the idea of the two times of image skeletonizing. At first, the input image I go through the Gaussian smoothing processing, then using Canny operator for skeletonizing to obtain the image M. At the same time, based on the image I after Gaussian smoothing processing, the author selected those pixel with values between 140-160 as the target. 140-160 is skin color pixel values in Cr channel according to the result of many times experiments. Through the image binarization to those target pixels, the author got image N. The image P was obtained through fusing image M and N. After the closing operation of dilation and erosion to image P, the image Q was obtained. In the end, through the second time of using Canny operator for skeletonizing to the image Q, the author got the image F with the hand gesture outline. The following flow chart described the process of hand gesture skeletonizing in this thesis.

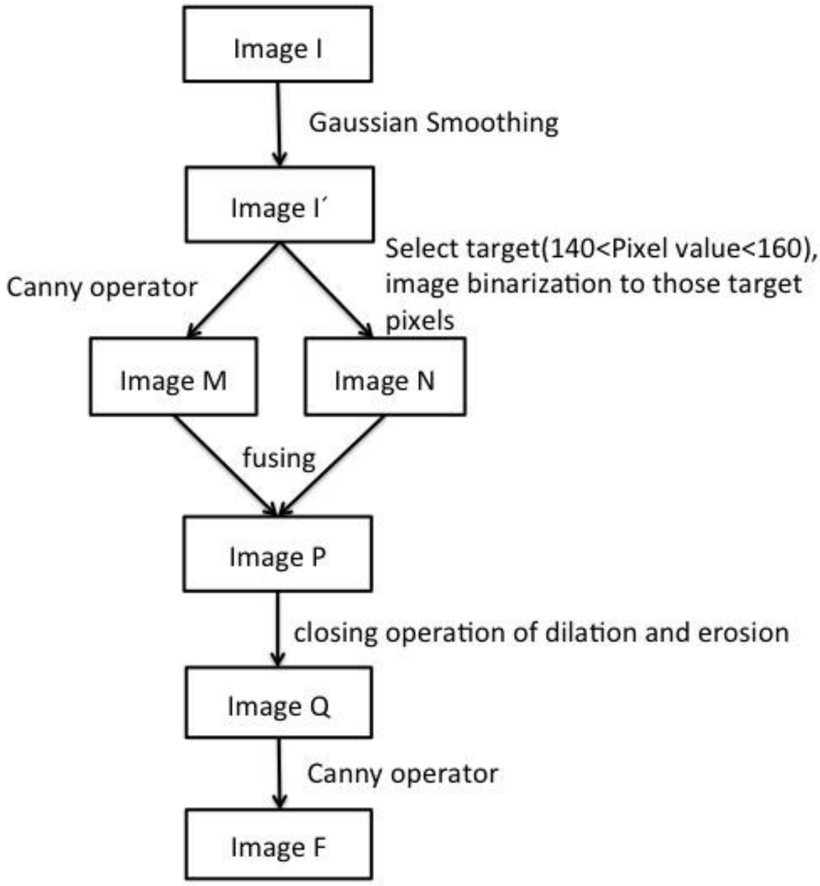
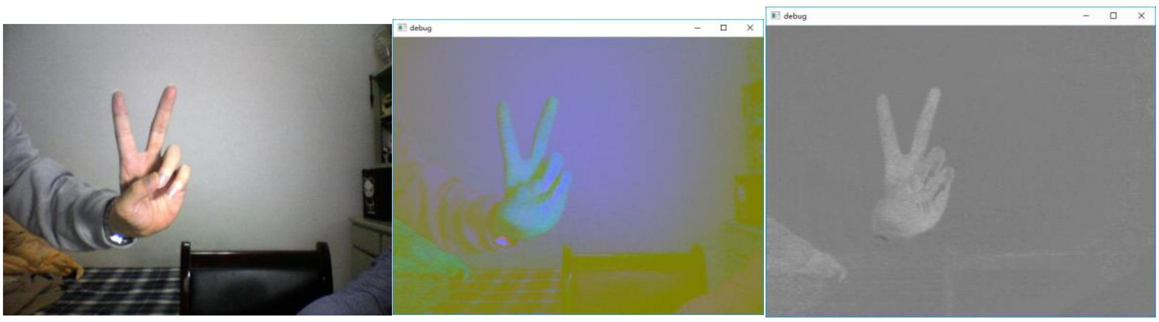


Figure 4.14 The image process of hand gesture detection

In order to better describe the hand gesture detection process, the result of image process can be showed as followed:

(1) Change the color model from RGB to YcrCb



(a) RGB image model (b) YCrCb color model (c) Cr channel image

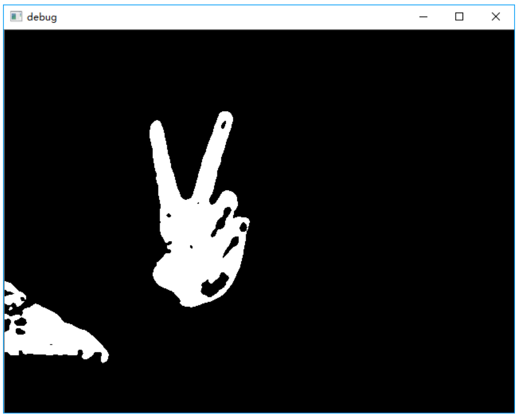
Figure 4.15 The result of changing color model

From Figure 4.17, image of Cr channel (Image I) has been able to highlight the skin color region.

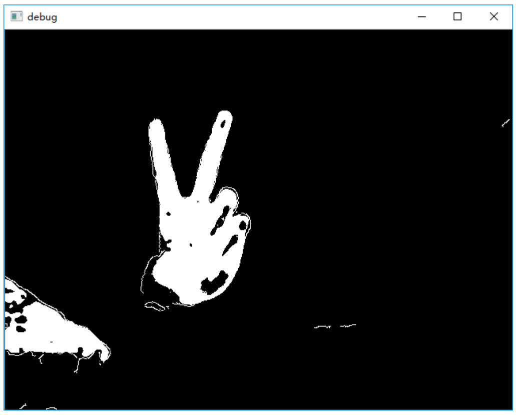
(2) The result of image smoothing and fusion process

(a) Image I´

(b) Image M



(c) Image N

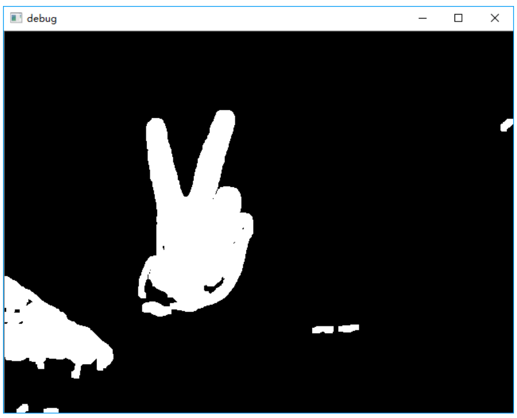


(d) Image P

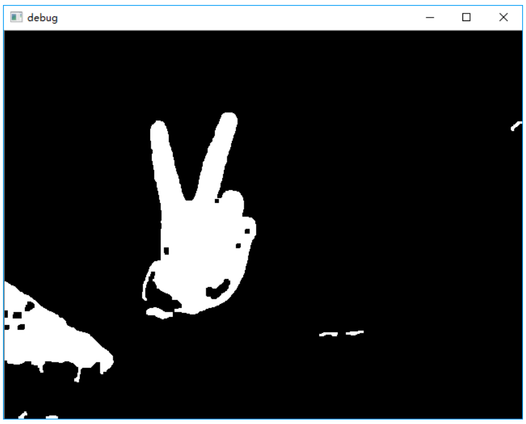
Figure 4.16 The result of image smoothing and fusion process

Figure 4.16 (a) Image I´: Image I after Gaussian smoothing, (b) Image M: Image I´ after Canny operator, (c) Image N: Image I´ after Image segmentation, (d) Image P: fusing Image M and Image N

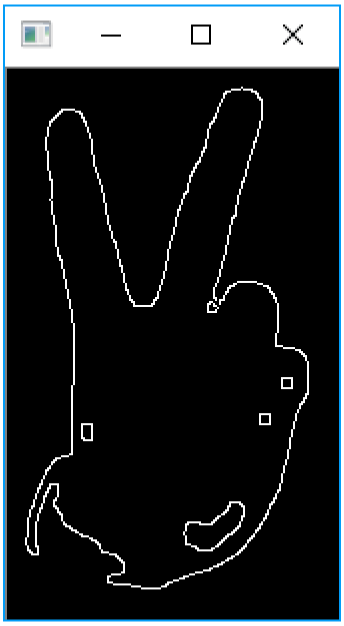
(3) The result of morphological image processing



(a) Image dilation



(b) Image erosion



(c) Image Q: Close operation

Figure 4.17 The result of morphological image process

In the stage of gesture image template matching, a lot of artificial intelligence methods can be used to identify a large number of gestures, but the method needs to be massive machine learning. Considering the object of this study and using environment, this research do not need to distinguish a lots of gestures, so the traditional template matching method is abandoned. In stead, one type of gesture based physiological information of a simple and effective algorithm for gesture recognition is used.

First of all, the author named nCount as the amount of pixels on the hand gesture edge for one row. As for the image F, which obtained in the previous step, were progressively scanned from top. And then the amount of rows was calculated depends on the setting value of nCount. If nCount is 6 or 8 of the number of rows in the proportion of the image number of rows ratio reached more than 25%, it is assumed that the gesture for "select/zoom in"; if nCount to 4 the number of rows in the proportion of the image number of rows than reached more than 30%, that the gesture as "return"; otherwise, the wrong gesture as special treatment.

Figure 4.18 The hand gesture recognition

Moreover, the following flow chart (Fig 4.16) shows the process of hand gesture detection and recognition in this thesis.

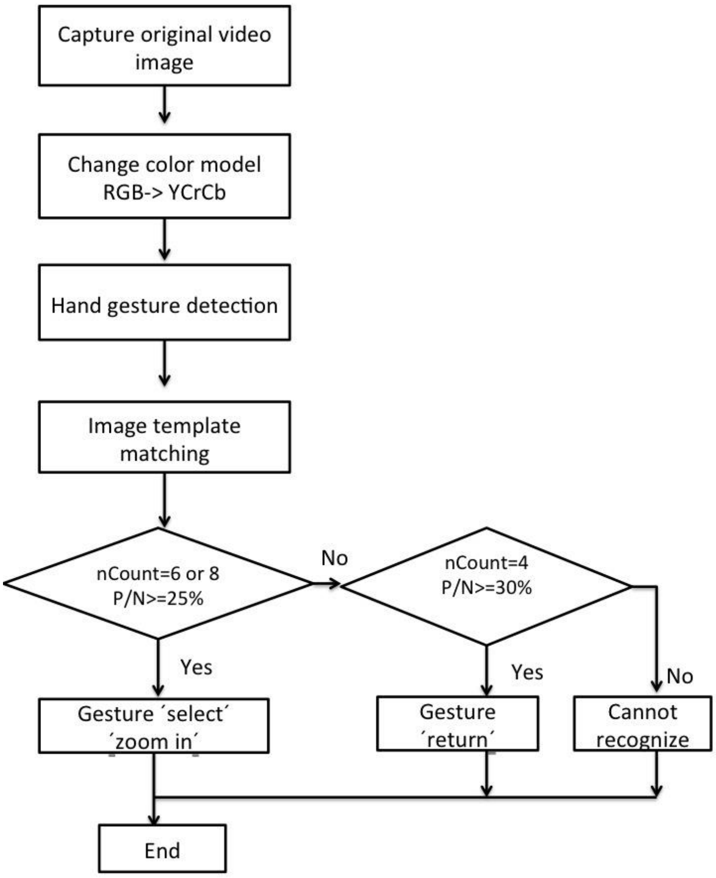


Figure 4.19 The process of hand gesture detection and recognition in EBAPP

5 Evaluation

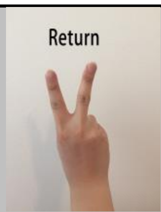
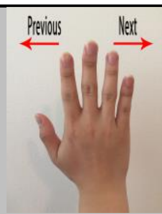
To validate the intuitiveness and efficiency of the EBAPP, the author conducted a comparative study with two other input methods: mouse and keyboard, and touchscreen gesture. These two input methods were chosen because they are commonly used at present. Hence, two devices are applied in this section. One is desktop with camera, mouse and keyboard. Another one is Apple iPad mini. A bigger touchscreen was not considered due to the increasing weight and problem of screen targets that are harder to reach.

Moreover, these three input methods will be analyzed from three aspects, learning effort, comfort degree and fatigue degree. This is to identify the difference between these three input methods and the usability and accessibility of EBAPP.

- *Comparison of the learning effort*

The operations of each input method were listed in the following Table 5.1. The feedback of participants´ learning effort will decide the learnability of design product.

Table 5.1 The operations of three input methods

	Select	**Zoom in**	**Return**	**Previous page**	**Next page**
Hand gesture		 * only worked in news modules			
Mouse and keyboard	Double click / click on the item	Hitting the ´ctrl´ and turning the mouse wheel	Click on the back button	Rollin the mouse wheel down	Rolling the mouse wheel up
Finger-touch	Hit the item	Spread by two fingers	Pinch by four fingers	Swipe left	Swipe right

- *Comparison of comfort degree*

The comparison of comfort degree will focus on the user experience. A lot of facts may affect the comfort degree for users. For instance, the high efficiency and accuracy of operations can help participants easily obtain the information. The participants also can also evaluate the comfort degree from hardware and software aspects.

- Comparison of fatigue degree

Different input methods may result in different feedback of fatigue degree. For instance, as for fatigue degree of wrist, touchscreen devices may need more effort compared with computer because touchscreen device needs to be handheld.

5.1 Hypotheses

The author decided to study the following hypothesis: Compared with two commonly used methods of interaction, there is a difference in user experience of GCUI. And the EBAPP is usable and accessible for elderly people to use as interface to computer.

5.2 Participants

The author recruited 5 elderly participants from the same senior community mentioned in chapter 4.1.1. Three of them are female and two of them are male. Their age ranges from 60 to 75. Moreover, in order to avoid the influence of previous user experience, those five participants have never use computer or touchscreen devices before. In addition, the participants were asked to wear dark clothes to improve the accuracy of hand gesture detection. All the participants showed a lot of interests to this thesis and indicated that they would actively cooperate with author to complete the testing.

5.3 Setting

There were two devices used in this evaluation, one is computer with windows system and the other one is Apple iPad mini. The computer is used for the testing EBAAP and for mouse and keyboard.

Moreover, the author marked Sina websites as bookmark in the Chrome for testing mouse and keyboard. Sina is a widely used webpage to get all kinds of information include weather forecast and different categories of news in China. Elderly participants can directly get information by clicking the bookmark. The QQ as the video application also set up on the computer. QQ is a chat application that is already be known to a lot of people in China. Moreover, these relevant applications are also installed in the touchscreen device such as weather forecast application, the application to acquire the Sina news and QQ chat application. The author collected the number of errors and some usability problems through the tasks.

In addition, in order to avoid the impact of environment on the hand gesture detection and recognition, the testing environment should have enough light and single background.

5.4 Tasks

The participants were asked to carry out some tasks by using different input methods as fast and accurate as possible. They were asked to acquire the information of the weather forecast, news and achieve the video chat.

Table 5.2 The user testing in evaluation

Setting1 hand gesture (EBAPP)	
T1.	Open News page
T2.	Pick the technology news and read the second news
T3.	Make the characters look bigger (zoom in) and read the news
T4.	Return to the previous page (news category) and pick economy news
T5.	Back to the main page
T6.	Open weather forecast page and get the weather information of the day after tomorrow and make it looks bigger
T7.	Back to the main page
T8.	Open chat function
T9.	Select the ´test user´ and start video chat
T10.	Return to the main page

(a) Tasks for EBAPP

Setting2 Mouse and keyboard	
T1.	Open Chrome main page
T2.	Open the main page of sina.com.cn
T3.	Select the technology news and choose the second news to read
T4.	Make the characters look bigger (zoom in)
T5.	Return to the previous and select economy news
T6.	Select weather forecast link and get the weather information of the day after tomorrow and make it looks bigger
T7.	Open QQ (chat application)
T8.	Select the ´ test user´ and start video chat
T9.	Close the application

(b) Tasks for mouse and keyboard

Setting3 Touch screen device

T1.	Open ´SINA NEWS´ the application to get the news from sina.com.cn
T2.	Pick the technology news and choose the second one
T3.	Make the characters look bigger (zoom in)
T4.	Back to the previous and select the economy news
T5.	Return to the homepage
T6.	Select weather forecast application and get the weather information of the day after tomorrow and make it looks bigger
T7.	Return to the homepage
T8.	Open QQ (chat application)
T9.	Select the ´ test user´ and start video chat
T10.	Close the application

(c) Tasks for touchscreen gesture

5.5 Procedure

These five participants can be seen as one group to test three different methods. And each participant has to complete a series of tasks in different setting.

In order to reduce the difficulty of remembering all the operations, the procedure were divided into four steps except short break. The first three steps aimed at interacting with computer by using three different input methods. Each step consisted of introduction and training, testing and brief interview. And the last step was final interview. The procedure was showed in the following flow chart.

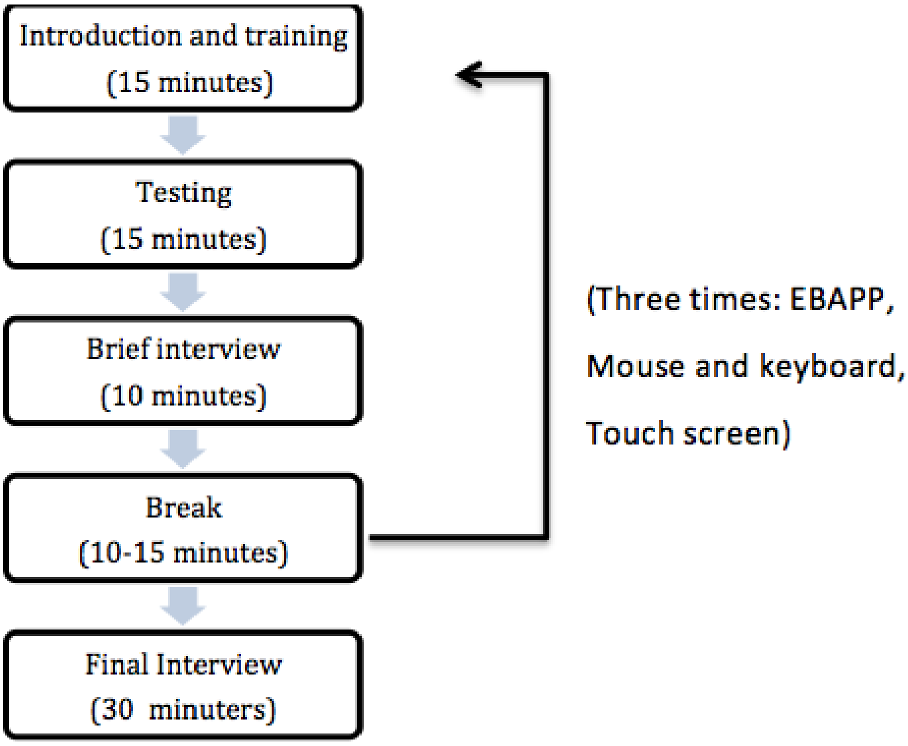


Figure 5.1 The procedure of evaluation

Before the tasks, there is an introduction for how to use one of these three input methods. This introduction and training continues for around 15 minutes. During the training, they can ask questions and get help from the author. At the same time, the author observes the body movement of participants. Mainly from three aspects, the movement of head, the movements of arm and hand, and the posture of wrist. From observation of these casual movements, the author will identify some unconscious usability obstacles face by elderly people.

After they state that they are ready for the task, the testing part began. The tasks will be achieved one by one. Every Participant can try four more times if they encounter the problems. If the participant cannot achieve the task after five times of operation, this task will be considered as failed. And then the author will help elderly participants to fix this problem, so that the participant can continue with next task.

Moreover, a brief interview will be interposed into the testing process. The main purpose of doing this brief interview is to get the feedback of using each input method. The question focused on the user experience such as the degree of ease of use and the fatigue degree of muscles. The participants were asked to give a mark on learning effort and comfort degree. The mark provided an objective understanding of user experience. The participants can evaluate the learning effort from two aspects. One aspect is hand gesture. For instance, is hand gesture easy or difficult for elderly people to memory? Another aspect is interface design. Is interface complex or brief for them to understand? The same as learning effort, the participant should describe the comfortable degree of the hardware (for example, the size of device) and software (design of interface) aspects. Moreover, the participants also gave a mark to the fatigue degree of different parts of body such as eyes, neck, shoulder and so on. Furthermore, they can have 5-10 minutes break if they feel the muscle soreness. After finishing all the testing part, the interview will be conducted. It does not only focus on the using experience but also some detailed comparative information. The participants were asked to compare these three different input methods through its advantages and disadvantages. And then the author asked about additional comments on hand gesture operation. For each participant, the sequence of the testing setting was different. Some participants started with EBAPP and other began with mouse and keyboard. This is to avoid the influence the similar sequence.

5.6 Result

This section was divided into three parts. The first part stated the results of each setting through user testing and interview. Average percentage of completion rate was used to evaluate how many tasks participants can achieve. It would be considered as a factor for evaluating the learnability associated with usability while using the different input methods. Meanwhile, the author summarized some comments and data from the brief interview after doing the tasks for each input methods. Those data and comments provided a reference for author to evaluate the different input method´s learning effort and comfort degree.

The second part addressed the result of comparative study and some additional and detail comments from the participants. Through the comparative study, the author can obtain the pros and cons for these three input methods. And this result can not only addressed the most appropriate and intuitive way for elderly people to interact with computer, but also the suggestions to improve the accessibility and usability of existing application and websites. In the end, the accessibility testing result will be stated.

5.6.1 User testing result

- **EBAPP**

After the introduction of EBAPP, the participants mentioned that they only spend 5 to 6 minutes to memorize the gestures. Hence, the introduction and training continued for ten minutes. The average completion rate of the whole tasks of EBAPP was 74%. There were two participants failed with task 1 ´open News page´. One of the reason for failure was EBAPP could not detect and recognition the correct hand gesture. All the participants passed the task 2. And during the task 2, participant P5 mentioned that it would be better to have audio feedback. However, among those tasks, the most frequencies of errors occurred between task 3 and 9. Only participant P1 and P4 achieved the task 3. Some of users said that they got confused between ´zoom in ´ gesture and ´select´ gesture. Hence, when they were asked to zoom in the characters in new modules, they became hesitated. Poor network connection was the main reason of failure of task 9. Participant P3 and P5 failed task 4 because of remembering the wrong gesture. They used ´select´ gesture to return.

Due to the speed of hand gesture detection and recognition, the soreness of muscles increased especially on the muscle of shoulder. Participant P2 who has the periarthritis of shoulder required breaks for many times. Periarthritis of shoulder is a kind of disease with shoulder ache and hypo-activity. He pointed out it will be better to reduce the time of holding arms in the air to activate the functions. After task 6, four participants mentioned that they need some time to have a rest. Hence, they had half minute break after finishing the task 6.

The following tables were summarized by the results of the brief interview after finishing the tasks. Table 5.3 and 5.4 represent the mark of the learning effort (1-10, difficult to easy) and comfort degree (1-10, comfortless to satisfying) of each participant and the fatigue degree (1-10, painful to satisfying) of several parts of the participants´ body.

Table 5.3 The mark of learning effort and comfort degree (EBAPP)

	P1	P2	P3	P4	P5
Learning effort	7	8	8	8	7
Comfort degree	6	4	7	7	6

Table 5.4 The mark of the fatigue degree (EBAPP)

	P1	P2	P3	P4	P5
Eye	9	9	8	8	8
Neck	8	8	9	8	9
Shoulder	6	3	7	7	6
Arm	7	4	7	7	7
Wrist	8	8	8	9	8
Waist	8	8	8	8	8

It can be seen from Table 5.3, most of participants considered the hand gestures of EBAPP easy to understand and operate. From learning effort aspect, the participant P1 indicated that two hand gestures are quite easy to memorize. The operation of EBAPP was merely based on these two simple gestures. This is to activate the functions in an intuitive way. Moreover, the majority participants claimed the interface of EBAPP was brief and clear. Each function was made into a separate square. There was no extra information causing interference.

However, from comfortable aspects, hand gesture for the participant with periarthritis of shoulder was a little bit uncomfortable to use. Four participants mentioned that the accuracy of hand gesture detection and recognition was low. As for one task, they needed to repeatedly operate gestures for two or three times so that the system could detect and recognize the correct gestures. Thus, the low accuracy of EBAPP influenced the grade of comfortable degree for these elderly participants.

Moreover, Table 5.4 reveals the fatigue degree of several parts of body. This can be used as one of objective data to judge the comfort degree. Since keeping the arms in the air without extra support for a long time, participants felt more tired with shoulder and arms than other parts of body. Hence, during this testing process, the most stressed parts were shoulder and arms. Supposing EBAPP increase the speed of hand gesture detection and recognition, the efficiency of hand gesture detection and recognition will improve. As the time for keeping arms in the air decreases, the stress of shoulder and arms will also reduce.

- **Mouse and keyboard**

From the observation during their training of using mouse and keyboard, the author found out the low eye-hand coordination faced by a lot of elderly participants. When they tried to move the mouse and select one item, their attentions were focus on the hand movement not on the screen. Meanwhile, some participants´ wrists were too stiff to move the mouse when they were asked to stare at the screen and position the mouse. In the Figure 5.2, it was the wrist posture of participant P3 when she tried to position the mouse on the screen. She said that it was difficult for her to adjust the wrist posture in a comfortable way when she was asked to stare at the screen and position the mouse simultaneously.

Figure 5.2 The hand posture of Participants P3 using mouse

Regarding mouse and keyboard as the input method, the average of the success was only 66.8%. As for the task 1, two of users failed by click and drag the icon instead of double click to open the chrome application. Meanwhile, another participant failed because of the interval between the double click was too long. Furthermore, the operation of using mouse and keyboard to zoom in made 4 of the participants failed with the task 4. During the training part, they were instructed to zoom in and out by hitting the ´ctrl´ key while turning the mouse wheel. However, most of them forgot to hit the ´ctrl´ key or they hit the wrong one while they turned the mouse wheel. This also can be showed in Table 5.5, the average grade of learning effort was 4.2 which means using mouse and keyboard for senior beginner is quite difficult. Participant P2 and P3 mentioned that there are too many operations such as double click, click and hitting ´ctrl´ and turning mouse wheel at the same time that confused them. It was difficult for them to remember. They can not exactly remember the right keys without long time training. And this is also one reason that the comfort degree was low. The participants cannot interact with computer in an intuitive way. Moving arms and rotating the wrist to position the mouse on screen was unaccustomed for those senior users without training and experience.

Table 5.5 The mark of learning effort and comfort degree (M&K)

	P1	P2	P3	P4	P5
Learning effort	6	3	3	4	5
Comfort degree	5	4	3	5	4

Table 5.6 The mark of fatigue degree (M&K)

	P1	P2	P3	P4	P5
Eye	3	5	4	5	5
Neck	4	7	4	8	6
Shoulder	6	7	7	8	6
Arm	8	7	5	7	7
Wrist	4	5	2	7	6
Waist	8	8	8	8	8

From the Table 5.6, it reveals that eyes and wrist were most stressed in the process of testing mouse and keyboard. On account of the design of the website, the complex content and unsuitable size of character, participants paid more attention and effort of eyes to find the correct content or link. And the fatigue of wrist was not avoided due to the way of using mouse and keyboard. Furthermore, two of the participants said that they feel slight painful on their neck. Because they pay too much attention and keep staring the screen for a while, the muscle of neck was continuously tensioned. It made them feel painful and fatigue.

- **Touch screen device**

In the testing of using touch screen device, the participants achieved 80% of the tasks. Three of them made a mistake of the task 2 because of the complex content in the app. In task 2, the participants were required to pick the technology news and choose the second one to read. However, the interface (showed in Fig 5.3) was full of the content and the navigation bar was not clear and obvious for some elderly users. And some categories are hidden. This can be revealed in Fig 5.4. The users should swipe up to find the button of technology news. During the brief interview, participant P3 mentioned that even though there is an introduction and training before the testing, she still couldn't clarify where the navigation bar is and how to find the hidden categories. Hence, she failed to find the technology news during the test. And the other two participants failed since the characters are small. They tapped other button or link instead of ´technology´. With regard to the participants who achieved the task, they spend around half minute to one minute to find the button of technology news.

Figure 5.3 The navigation bar of Sina application

Figure 5.4 The hidden button of technology news

As for the task 3, the participants need to zoom in to make the character bigger. They were told by using two fingers to spread. Nevertheless, participant P1 and P5 activate ´select´ instead of ´zoom in´. Their finger slowly touched the screen one by one. The system detected the gesture as ´press´ instead of ´spread´. At the same time, when there were some unexpected function induced by touching happened, most participants expressed nervous and anxiety. Therefore, some participants said they were afraid to finish the next task.

Another problem was task 9 to start video chat with tester account. From the Figure 5.5, the author had circled the icon of video chat. Two participants mentioned that they could not understand the meaning of icon with a smile on it, and when they clicked on it, it was video message not video chat. And they could not find the icon of video chat.

Figure 5.5 The interface of QQ video chat

Table 5.7 The mark of learning effort and comfort degree (touchscreen gesture)

	P1	P2	P3	P4	P5
Learning effort	7	7	8	8	7
Comfort degree	6	7	6	6	7

Table 5.8 The mark of fatigue degree (touchscreen gesture)

	P1	P2	P3	P4	P5
Eye	4	6	5	5	5
Neck	3	4	3	4	3
Shoulder	5	5	4	5	5
Arm	6	6	5	6	7
Wrist	4	4	4	5	6

Waist	6	6	7	7	7

As for the result of the brief interview, most participants claimed gestures for touch screen devices were easy for them to learn. However, the interface design for them was a littlie bit difficult to understand and learn. There are too much content and functions for them to remember. Furthermore, the grade of the comfort degree was at an intermediate value. From the Table 5.8, we can see clearly that most parts of body were stressed especially eyes, neck and shoulder. Taking into account of the posture of participants when they use iPad or other touch screen, users are always handholding the device and lowering their head. This may lead to stiffness on the neck and shoulder.

5.6.2 Comparative study and interview result

After analyzing each input method, this section mainly focuses on the comparative study and the result of the final interview.

First of all, the following Table 5.9 concluded the data from user testing. The author analyzes the result of comparative study according to this table.

Table 5.9 The result of learning effort, comfort degree and completion rate

	EBAPP	Mouse and keyboard	Touchscreen gesture
The average completion rate	74%	66.8%	80%
The average mark of the learning effort	7.6	4.2	7.4
The average mark of the comfort degree	6	4.2	6.4

From the aspect of learning effort, the gestures of EBAPP are the easiest since there are only two gestures to memorize and the operation depends on moving hands to four directions (up, down, left and right) with this two gesture. Followed by the gestures for touch screen devices and then is the mouse and keyboard. Most of the participants mentioned that the operation of the mouse and keyboard is complex and difficult for them such as the ´click´ and ´double click´. Considering the comfort degree in this testing, the touchscreen gesture´s grade is highest.

As for the average of completion rate, using touchscreen gestures is highest. Elderly people achieved 80 percent of tasks by using touchscreen gestures. And followed by hand gesture of EBAPP is 74%. The lowest is by using mouse and keyboard.

Moreover, the average of fatigue degree was concluded as following Table 5.10. In general, EBAPP caused the lowest fatigue degree in this study. The most stressful parts of body are shoulder and arm. By using mouse and keyboard, participants feel more tired with eyes, neck and wrist. The fatigue degree of using touchscreen gesture is the lowest especially for neck, shoulder and wrist.

Table 5.10 The average fatigue degree

	EBAPP	Mouse and keyboard	Touchscreen gesture
Eye	8.4	4.4	5
Neck	8.4	5.8	3.4
Shoulder	5.8	6.8	4.8
Arm	6.4	6.8	6
Wrist	8.2	4.8	4.6
Waist	8	8	6.6

Results about the final interview are summarized in the following table. Table 5.11 lists the advantages and disadvantages of these three different input methods according to the answers from the participants.

Table 5.11 Pros and cons of three input methods

	Advantage	Disadvantage
EBAPP	• Easy to learn • Low fatigue of muscle • Brief and clear interface • Clear functional classifications	• Low accuracy of detection and recognition • High requirement of light and background • Functions are limited
Mouse and keyboard	• Can locate the mouse on the screen	• Difficult to learn • Complex operation • Muscles get stiff easily

Touch screen devices	• Easy to use and learn • It can be used everywhere	• Limited screen size • The response of the touch screen is too sensitive and the operation is too fast for some seniors • It is easy to feel tired. Especially with neck and shoulder.

By asking about the preferred input method, three participants chose EBAPP and the other two participants chose touchscreen gesture. Moreover, all the participants mentioned about the accuracy of hand gesture detection and recognition. For instance, participant P5 said that compared with other input methods, she preferred using EBAPP to obtain the information. ”The icon is big. And there is not too much information. I can easily learn how to use it. But it always makes mistakes. For example, I want to move left but it recognized as select sometimes.”

5.6.3 Accessibility testing result

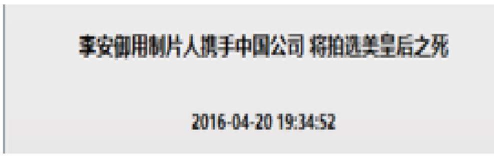
The following Table 5.12 is the final result of heuristic evaluation using the relative guidelines according to the WCAG 2.0.

Table 5.12 The result of heuristic evaluation for accessibility testing

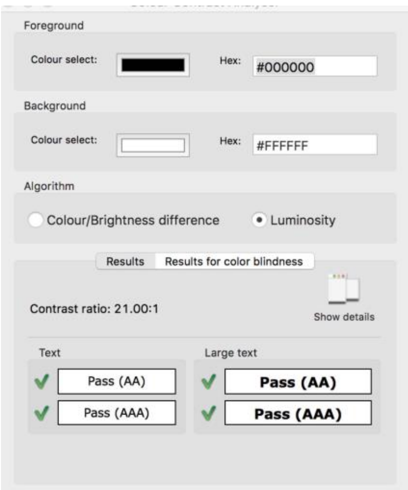
The accessibility guideline	**Description**
Text Alternatives	Meeting the requirement. As for the icons used in the EBAPP, there are text descriptions of images.
Time-based Media	Not meeting the requirement. Although there is no prerecorded time-based media, the video chat in EBAPP did not provide captions or alternative description.
Adaptable	Meeting the requirement but partially. EBAPP provide simple structure but the

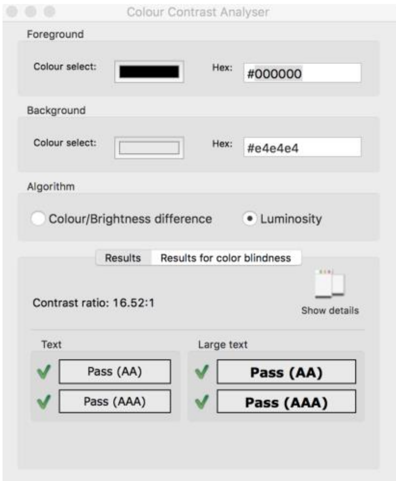
	content cannot be presented in other ways like tactilely and audibly.
Distinguishable	Meeting requirements but partially. The text in news section can be resized but cannot be 200 percent. The contrast of EBAPP also meets the requirement and it will be detailed described afterwards.
Navigable	Meeting requirements but partially. EBAPP provides clear and brief structure. But there is no title in each page.
Readable	Meeting requirements but partially. The text does not need high reading level. But the language cannot be programmatically determined.
Predictable	Meeting requirements. Compared with web page, EBAPP only has three main functions. There is no useless component. Moreover, EBAPP can present content in a predictable order.
Input Assistance	Not meeting the requirement. EBAPP cannot provide error suggestion for users when they use a wrong gesture.
Compatible	Not meeting the requirement. EBAPP cannot support using assistive technology like screen reader.

Due to the fact that the information of EBAPP comes from the web, this research adopts some relative guidelines to evaluate the accessibility. According to the WCAG 2.0, the guideline 1.4 addressed the distinguishability of the web content in such that it should be easier for users to see and hear content including separating the foreground from background. The visual presentation of text and images of text has a contrast ratio of at least 4.5:1, except for the following: (Level AA). Large Text: Large-scale text and images of large-scale text have a contrast ratio of at least 3:1 (group, 2008). In this study, the main parts of text are present on the white background and the colors of characters are black (Fig 5.6 (a)). And some character´s background color is gray (#e4e4e4,Fig 5.6 (b)). The author used Color Contrast Analyzer to analysis those two different color contrast. There is a result of the color contrast between white and black (Fig 5.6 (c)). And Figure 5.6 (d) shows the result of the color contrast between black (#000000) and gray (#e4e4e4).



(a) (b)





(c) (d)

Figure 5.6 The result of color contrast

These two results show that the contrast ratio of black and white is 21:1, and the color contrast of black and gray is 16.52:1. And both of them fulfill the requirements of normal text size and large text. Hence, as for the contrast, EBAPP is accessible for elderly people to get information.

6 Discussion

The objects of this study is to identify the access obstacles of interacting with computer faced by elderly people and provide an usable and accessible GCUI for them to easily obtain information. In this chapter, the result of final evaluation will be analyzed first. Then, some usability and accessibility issues were addressed. In the end, the limitation of this study was concluded.

6.1 Analysis of final evaluation

In this section, the author analyzes the result of final evaluation. Initially, the objective result of completion rate is described. It can be seen from the result of comparative study (Table 5.9), elderly participants achieved more tasks by using touchscreen gesture and hand gesture of EBAPP, rather than using mouse and keyboard. As many previous researches highlighted, compared to the mouse and keyboard, gesture interface is more simplified and natural. This conclusion can also be verified by the result in the thesis. However, compared with touchscreen gesture, the accuracy of hand gesture detection and recognition of EBAPP affect primarily the task completion rate. The algorithm of hand gesture detection and recognition of EBAPP has not matured yet. Light condition and external environment still affect the accuracy of hand gesture detection and recognition.

Moreover, the average mark of comfort degree and learning effort are also concluded in the Table 5.9. Due to the limited accuracy of EBAPP, participants had to repeatedly operate one gestures for two or three times. This resulted in the low comfort degree compared to the touchscreen gesture. However, there were some limitations of touchscreen gestures as well. For instance, the small screen size and character limited the comfort degree of touchscreen gesture. As for the learning effort, because of brief interface and two simple gestures, EBAPP is the easiest input method for elderly participants to learn and remember. The gestures for touchscreen are also easy to understand and operate. But the interface designs of existing applications are too complex for seniors to memorize and learn.

According to the average fatigue degree of three input methods, in general, EBAPP is more suitable for elderly participants to use since it leads to low fatigue degree. On the contrary, elderly participants easily feel tired by using touchscreen devices. For instance, due to the small screen of device and complex content, elderly participants focused their eyes more on the screen when they used mouse and keyboard, or touchscreen devices. On the other hand, EBAPP is more suitable for them to obtain the information. Brief interface and bigger characters reduced the fatigue degree of eyes. Moreover, as for neck and wrist, elderly participants normally hold the touchscreen devices and bend their head downwards to read the screen. This increased the fatigue degree of neck and wrist. Considering the hand gesture of EBAPP is keeping the arm in the air, elderly participants easily get tired with shoulder and arms.

6.2 The usability and accessibility of GCUI

Since the ultimate goal of this study is to provide a usable and accessible GCUI for elderly people to interact with computer. Therefore, it is necessary to identify the usability and accessibility of GCUI. Thus, this part will focus on the evaluation result to identify the usability and accessibility of EBAPP, a prototype of GCUI.

The usability of EBAPP was described from its four principles (Rubin & Chisnell, 2008).

- ***Usefulness - product enables user to achieve their goals - the tasks that it was designed to carry out and/or wants needs of user.***

  As the result of requirements gathering interview, elderly people want to obtain some information that relates to their daily life. Therefore, EBAPP contains three main functions: news, weather forecast and video chat. The EBAPP used user-centered design approach during the design and development process. So that EBAPP fulfilled the requirements of elderly users. In the final evaluation, four of elderly participants mentioned that the EBAPP provide a new manner to use computer and get the information they wanted.

- ***Effectiveness (ease of use) - quantitatively measured by speed of performance or error rate and is tied to a percentage of users.***

  The effectiveness of EBAPP is limited. Compared to the mouse and keyboard and touch screen devices, the main reason of failure of testing is due to the accuracy of hand gesture detection and recognition. Since this study only has two gestures to detected and recognized, the author selected global thresholding in image segmentation to improve the speed of hand gesture detection and recognition. With the uniform and simple surrounding, the speed of hand gesture detection and recognition is fast and accuracy is high. However, if the circumstance is complex, the background and other parts of body skin will influence the result. For instance, participant 5 failed task 3 and 9 due to the low accuracy of hand gesture detection and recognition. The participant used correct hand gesture, but the application detected and recognized as other gestures. In order to improve the effectiveness of EBAPP, a better performing algorithm would be needed to achieve high speed of detection and recognition, and accuracy in a complex environment.

- ***Learnability - user's ability to operate the system to some defined level of competence after some predetermined period of training. Also, refers to ability for infrequent users to relearn the system.***

According to the feedback of participants in final evaluation, all the participants stated that the EBAPP has the least learning effort of operation compared with other two input methods. It only requires two hand postures to achieve five operations. And the operations are based on the human instinct reaction. One of the design ideas of EBAPP was to use the least and simple hand gestures to intuitively achieve the most operations. Moreover, the design of interface is clear and brief with different functional sections. Each section has image and text description to help elderly users to understand.

- ***Attitude (likeability) - user's perceptions, feelings and opinions of the product, usually captured through both written and oral communication.***

The likeability of EBAPP can be studied from the result of interview. Compared with the other input methods, using hand gesture is easier for them to interact with computer. And the two gestures used in EBAPP are simple to perform. Although there are some influences on the detection and recognition result due to the background, the elderly participants in this study still showed a lot of interests. However, they also worried a little about the fatigue degree of using hand gesture while keeping the arm and hand in the air for a period of time.

Hence, the usability of GCUI can be concluded as following. The usefulness, learnability and likeability are satisfied. Hand gesture-control can provide a new opportunity and intuitive way for elderly people to interact with computer.

As for the accessibility of GCUI, EBAPP fulfilled most guidelines of WCAG 2.0. It can provide text resizing, which can help elderly people with reduced sight or vision impairment to get information. Moreover, as for the functional icons, there are image and text to describe its function, which can let people with illiteracy to access the new technology. At the same time, the color contrast of EBAPP also fulfilled the guidelines of WCAG 2.0. The participants can easily distinguish the foreground and background. Nevertheless, there are also some accessibility problems of GCUI. There is no audio feedback for older users that leads to the inaccessibility for blind people. Because hand gestures keep arm in the air, some people with motion impairments, for example people with paralysis, cannot access the application. And EBAPP cannot support assistive technology.

6.3 The suggestions for GCUI accessibility guidelines

According to the accessibility testing, it can be seen that most guideline of WCAG 2.0 can be used for GCUI. However, considering gesture, WCAG 2.0 offers little. Hence, the author concluded some suggestion for GCUI accessibility guidelines based on this thesis.

(1) Simplification of gestures. The gesture should be simple. More gestures used in the GCUI may increase the difficulty of learning and understanding.

(2) Low fatigue degree. The design of GCUI should take into consideration physical impairments. It should lessen the usage of muscle to reduce the fatigue degree faced by users.

(3) Easy to recall. The gesture of GCUI should be easy to memorize. Moreover, the interface can provide some suggestions or description to help user remember gestures.

6.4 The limitation of study

It can be concluded that hand gesture as the input method can provide an intuitive way for some Chinese senior online users. Advantages and disadvantages of hand gesture based interaction were described in previous section. Through comparing those three existing and widely used input methods, it is obvious the hand-gesture-based interaction has a broad prospect of development. At the same time, the hypothesis that EBAPP is usable and accessible for elderly people to interact with computer was proved. When the testing environment meet the requirement with bright and single background, most of elderly users gave a positive feedback. The simple gestures and operation free elderly people from heavy memorizing and learning. Although, some tasks were failed due to the light problems and complex background, the participant still showed great interest and expectation for EBAPP. Different from usual applications, EBAPP only adopt two simple and intuitive gestures to achieve five operations. However, there are some limitations of this study.

One limitation is the small number of participants. In the initial exploration and design and development process, only nine participants were involved in. With the different knowledge background and user experience, the author got an overview of user requirements from these nine elderly participants. And the changes of EBAPP depended on the feedback of each user testing and interview. There were five participants without any using experience of computer attended the following final evaluation. And among these five participants, the conditions are similar. All of them are with low vision. Only one participant is with the periarthritis of shoulder. Hence, the accessibility of EBAPP mainly focuses on the vision aspect. As for the motion or cognitive impairments, it was limited in this study. It should involve more participants in different conditions to identify more usability and accessibility problems faced by elderly people with disabilities. Nevertheless, as Virzi (Virzi, 1992) mentioned that five users will find approximately 80% of usability problems in an interface. Hence, the result of this study still can be referred.

In addition, the computer operating system is limited. Because the EBAPP developed as an .exe application and can only run on the Windows system. The EBAPP cannot run on the laptop with IOS system. At the same time, the participants need to use mouse to open the EBAPP. During the user testing, the application was opened by the author before they started the user testing.

Besides, the single webcam operation is also one limitation in this research. Due to the consideration of using ubiquitous desktop or laptop, there was only one webcam used in this research. However, as the function of video chat, the single webcam cannot simultaneously support the hand gestures detection and video chat. The webcam is used to capture the image of hand gesture. Thus, in the video chat function of EBAPP, the elderly participants can only see the video image of the other users in the video chat. User on the other side can only operate the EBAPP application by using mouse. Taking into account of the demands of video chat for Chinese elderly people, they want to video chat with their family especially with their children and grandchildren. The younger generation can easily use the mouse and keyboard to control computer. Hence, the EBAPP with single camera still can still satisfy lots of requirements of elderly people.

Another limitation was the high requirements of light condition and background of EBAPP. As many previous studies addressed that complex environment will influence the result of hand gesture detection and recognition. It also happened in this study, during the user testing. The environment was selected to be a room with simple background and uniform light. At the same time, the participants were asked to wear dark clothes. The skin color may affect the result of image segmentation. The application will detect the skin color as hand gesture parts.

Furthermore, due to the time limited, some parts of functions need to be improved. For instance, as for weather forecast, the location is already set by author. So that elderly users cannot change the location by using hand gestures. And elderly participants also cannot add other news categories or video chat friends. Hence, EBAPP still has development of spaces.

Lastly, the variety of participants is limited. All the participants come from China. There are many other external factors that may influence the interface design or the result of user testing. For instance, the economy circumstance differs from country to country. This may affect the demands of elderly people. And the culture difference also may influence the understanding of the same gesture.

All in all, there are some limitations in this thesis. However, it is obvious that GCUI can provide a new way for elderly participants to interact with computer. And it is easier for them to use gestures to control the computer compared with external devices like mouse and keyboard.

7 Conclusion and Future work

Due to the contradiction between the aging society and lack of attention to deal with the usability and accessibility problems faced by elderly user group, this study designs a GCUI for elderly people to interact with computer, based on a Chinese population background. And it also identified the usability and accessibility of this prototype. A user-centered design approach was applied during the design and development process. A focus group interview was used for initial exploration. Nine participants involved in the design process and they provided a lot of useful feedback to improve the prototype. Furthermore, user testing and interview were used to identify the usability and accessibility of EBAPP. It was conducted with five participants without any user experience of computer.

Through the study of previous researches, it is found that gesture can provide an opportunity for elderly people to interact with technology. However, there are some usability and accessibility obstacles faced by elderly people according to the previous study and interview in initial exploration. For instance, complex content and operations increase the difficulty of learning and understanding. Flashing content like advertisement will confuse elderly people. Hence, this thesis designed a prototype of GCUI and identified its usability and accessibility problems faced by Chinese elderly people. Reflecting from the result of final evaluation of EBAPP, EBAPP as a prototype of GCUI provides an intuitive and easy way for elderly people to interact with computer. They can use EBAPP to easily get the daily information such as news and weather forecast. At the same time, they can use the video chat function to communicate with their family. As agreed by all the participants, the gestures of EBAPP are easy to learn. The interface is brief for elderly participants to understand and use functions. Although external environment may affect the accuracy of hand gesture detection and recognition, all the participants still show big interests of using hand gestures to control the computer.

At the same time, some usability and accessibility problems of GCUI were addressed during the design and development process. For instance, the number of gestures should be appropriately adopted. The gestures cannot be too many such that it increases the learning effort. Moreover, the gestures should be easy to perform in order to reduce the fatigue degree of muscles. It is necessary to avoid the gestures that require long time extension of using muscles. Furthermore, as for non-text content, it should have alternative text to describe it. As for the icon or content, it cannot only described by text or image. It should provide more ways like text, image and speech to present its meaning. This can increase the accessibility of GCUI for some elderly people with illiteracy.

As for the design of EBAPP, some essential features can be added in the future development. First of all, adding more functions into EBAPP. As previous studies mentioned, there are many studies about GCUI with different categories such as entertainment, training and e-health management. Hence, the EBAPP can add some functions like games, watching movies and e-health management. Secondly, it can also integrate other input and output method. For instance, participant 4 said it was better to have an audio feedback in order to help them better use the application.

Moreover, some works can also focus on formulating the accessibility guidelines for GCUI on desktop or laptop. While there are accessibility guidelines for the web content and applications on mobile phone with Android or IOS system, the accessibility guidelines for GCUI are limited. This guideline can refers to the existing guidelines such as WCAG 2.0, User Agent Accessibility guidelines and some previous accessibility study of gesture controlled user interface.

In addition, considering the Chinese background in this study, there are a lot of accessibility obstacles faced by elderly people in existing website and applications, for instance, health-related obstacles, knowledge obstacles. Moreover, designer and developer lack of the awareness of usability and accessibility is also a main reason. The design of website or application did not refer to relevant accessibility guidelines such as WCAG, UAAG. For instance, the design of website does not have the alternative text. Each image must have an alt attribute. Without alternative text, the content of an image will not be available to screen reader users or when the image is unavailable (Consortium, 2008). Moreover, the web page also contain some advertisements that flashes more than three times that may affect the understanding of content for Chinese older online users. The guideline 1.4.3 of WCAG 2.0 addressed that the text can be resized without the assistive technology up to 200 percent without loss any content or functionality. However, as for some Chinese websites, some content of main page will be lost when the original page is zoomed in to 200 percent.

The accessibility issue still remains in the public interest. In order to solve the problem, relative policies and laws should be customized to obtain more attention to help elderly people or people with disability to access new technology. For example, the accessibility is as a law to urge designer to improve the product´s accessibility in Norway, so that the websites or applications can be used by elderly people or people with disabilities. At the same time, the correlative courses should be appended in the university. The designers and developers can get an overview of the accessibility guidelines from beginning and apply it during the design and development process. It is necessary to increase the awareness of universal design, so that the usability and accessibility can be improved.

All in all, due to elderly participants as a potential user group for new technology, the usability and accessibility issues faced by them should be identified and solved. Moreover, GCUI provides a new opportunity for elderly people to interact with computer. Beyond doubt, there are rooms for improvement for EBAPP. Some more features and functions can be added in the new version of EBAPP. At the same time, the accuracy of hand gesture detection and recognition of EBAPP should be improved in the future work, which can increase the satisfaction of user experience.

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Appendices

- Requirement gathering interview question

Interview question	
1.	Do you have any problems when you use mouse and keyboard?
2.	I saw it took some times for you to find the location of the mouse, what do you think about this?
3.	If you can choose body language as input method to interact with computer, what do you think about this?
4.	If you use hand gesture as input method, which do you prefer to use static or dynamic?
5.	I saw you spend a lot of time on this application or webpage (this question depends on individuals), If this computer is controlled by hand gesture, could you show me how you want to use hand gesture to interact with this computer? Like selected, return or go to previous and go to next?
6.	Do you prefer to get information from different homepage or combine all these information together?
7.	If you could design an application based on hand gesture input method to help you using computer, what kinds of functions you want to add into your application?
8.	What do these functions look like? Are they link or module?
9.	How many items would you want to have for each function? Could you show me what does each function in your application looks like?

- The interview questions in iteration 1.
    1. Do you find this application easy to use?
    2. Do you understand all these icons?
    3. What do you think about hand gesture after you did this test?
    4. Do you achieve your goal? If not, what are the problems and how it should be improved?
    5. How does this using experience compare to before when you use mouse and keyboard?
    6. What (if anything) would you like to change about this application?
- The interview questions in iteration 2
    1. Compared to last time, do you find anything improved?
    2. What do you think about the speed of detection and recognition of hand gesture this time compared to last time?
    3. What do you think about this new layout of this application?
    4. For each function, what do you think about it? Does any items should be added?

The interview question in iteration 3

1. Do you still remember all the gesture? If not, what are the problems?
2. For zoom in, is that easy or difficult to memorize?
3. Compared to the version 2, what do you think about this new layout?
4. What are the problems when you use this application?
5. What do you think about hand gesture and mouse and keyboard?
6. Can you say some advantages and disadvantages about the hand gesture control?