**Virtual Puppet: Interactive Chinese Shadow Puppetry Using Microsoft Kinect V2**

A Thesis

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## Dedications

I dedicate this thesis project and give special thanks to my parents, Chunfeng Wu and Zhihua Wang, who have supported me throughout the process. Thank you both for giving me unconditional love and courage when I felt depressed during the development of this thesis work.

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I would also like to express my thanks to Professor Lydia Hunn, another committee member in my team. As we all know, controlling a virtual puppet using bodies really relies on acting. So thank you for the critiques on performing as a puppet and building the gestures.

Finally, I would like to acknowledge and thank Buddhist Tzu Chi Foundation Philadelphia for allowing me to conduct my research. Special thanks goes to teachers in the center, Margaret (Ying) Yu, Sue-ling Wang and Ke Xu from University City Art League for your feedback and being so generous with your time. In addition, I would also want to thank the children in the center for their great patience with my research system. Their excitement and willingness to participate made this experience really enjoyable, which has become a great and valuable memory in my life.

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## Abstract

Virtual Puppet: Interactive Chinese Shadow Puppetry Using Microsoft Kinect V2
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This thesis project produced a Virtual Chinese Shadow Puppet System used in concert with Microsoft's Kinect V2. The Virtual Puppet System enables players to use their whole body motions to control virtual puppets instead of using rods or sticks in a traditional way. There are two modes of play in the system. Players can elect to play in a group with multiple puppets performing at the same time, or an individual player may choose to play alone. Twelve puppets were produced for the Virtual Puppet System based on classical characters from the famous Chinese fiction, "Journey to the West." The thesis includes a literature review of relevant works that influenced the project; it describes the workings of the interface and gesture control systems as well as the 2D virtual puppets produced. It also describes lessons learned from observations of a group of 7 – 15 year olds studying Chinese culture who played with the system, and with conversations held with a panel of experts who also observed the children using the system.

# Chapter 1: INTRODUCTION

Chinese shadow puppetry, or shadow play, originated in China during the Han Dynasty over two thousand years ago. It is one of those rare performing art forms that combine exquisite carving with painting, music, singing, performance, and literature, which reflects the earlier popular culture of rural China [Chen, 2007]. The traditional stage for shadow puppetry is a white cloth screen illuminated from behind on which the shadows of flat puppets are projected. Traditionally, the puppets are made of leather or animal skin, such as donkey or oxen. That's the reason why shadow puppetry is also named as 'pi ying xi' in Chinese, which means 'shadows of hides'.

In a real performance, a skilled puppeteer can easily control the movements of three or four puppets with rods or sticks, to perform some well-known myths and legends, such as 'Journey to the West', 'Romance of the Three Kingdoms' and 'The Creation of the Gods', just to mention a few. At the same time, the puppeteer is supposed to ensure the balance between the movements and the music, singing voices and narration all by himself. Under this circumstances, a professional puppeteer needs years of practice to wholly master this skill. According to Zhenglong Qin, a professional puppeteer in China, who has performed the shadow play in the city of Xunyang for years, it takes at least eight years for an apprentice to become a master in this field. Unfortunately, most of the apprentices he recruited failed to stay on the course, and left during the halfway. Moreover, making a puppet, which can be performed successfully and vividly on the screen, also takes a long time for an artist to accomplish. Generally, the making of shadow puppets includes making animal skins thinner and semitransparent, engraving the skin into the desired image, and adding various colors to embody good and evil of characters. In the old times, folk artists had to make all their puppets manually. For example, it took more than three years to make one set of shadow puppets, including 300 characters. Due to the fact that those puppets are made of animal skins, they are strong enough to be used thousands of times without getting broken.

Even though the training and making process of shadow puppetry is truly difficult, it still was a people's art form during its heyday, and its portability and nighttime performances were perfectly suited for the working classes. Farmers and laborers took up puppeteering, singing, musical instruments and storytelling after the sun went down to create a tradition that gradually became the heart of their communities [Rollins, 2011]. So basically, this is the essence of Chinese shadow puppetry and the reason why people liked shadow play during the old times without televisions, when families and neighbors could gather together after a day's work and watch the adaptation of famous folklore or fictions. More importantly, what they were enjoying most in the show was the happiness of being together as a family.

While in the 21st century, with the emergence of new entertainment, such as movies, radios, TV shows and video games, just to mention a few, traditional shadow puppetry has gradually faded away in people's daily lives, encountering the risk of extinction [Shi 2014; Ying 2014; Chen 2014; Yu 2014]. In 2010, Michael Wines, a New York Times reporter, interviewed Yongping Cui, who owns the Shadow Play Art Museum in Beijing. For here, one can see 15th-century Ming dynasty puppets, 18th-century puppets from the Qing dynasty and many other elaborately outfitted puppets [Wines, 2010]. According to Yongping Cui, there are only 2000 visitors every year, but 70 percent of those are foreigners. It is sad that the young generations in China no longer appreciate this traditional art form. In November 2011, UNESCO added Chinese shadow puppetry to the list of Intangible Cultural Heritage of Humanity. The Chinese government finally realizes the importance of protecting this old folk art and started to fund some 'preservation' projects. Yet, Chinese shadow puppetry remains in great danger of loosing its relevance. From thousands of troupes at the end of the 1800s to hundreds after the opening of China in the late 1970s to just a few dozen troupes in 21st century China, the decline of performances has been swift and significant [Rollins, 2011].

Although new media technologies are one of the reasons why traditional performing art is losing its audiences, I think they also could bring fresh hope to these art forms. So in this paper, we created 'Virtual Puppet', an interactive experience allowing participants to use their whole body to control the virtual puppets. Our goal is to help the young generation raise their interest in and appreciation for traditional Chinese folk arts. The system is evaluated through an expert panel, consisting of teachers who need to work with children every day. Chapter 2 reviews the relevant literature and similar works related to digital intangible culture heritage and digital puppetry. Chapter 3 describes the research problem in more detail. Chapter 4 outlines the approach to design and development. Chapter 5 shows the evaluations and feedback of 'Virtual Puppet' in detail. Chapter 6 provides a discussion of the implications, limitations and future developments of the project.

# Chapter 2: LITERATURE REVIEW

## 2.1 Intangible Cultural Heritage

According to UNESCO, Intangible Cultural Heritages are 'traditions or living expressions that inherited from our ancestors and passed on to our descendants, such as oral traditions, performing arts, social practices, rituals, festive events, knowledge and practices concerning nature and the universe or the knowledge and skills to produce traditional crafts'. More generally, intangible cultural heritage is the culture that people within a community practise as part of their daily lives. It is considered as 'beliefs and perspectives, ephemeral performances and events' that are not tangible objects of culture like monuments, or paintings, books or artefacts [Kurin, 2013]. However, when we have entered the 21st century, those intangible cultural heritages are facing the important issue of whether they can survive in the face of modernization and globalization. Many old traditions had disappeared due to the fact that local artists could not find any descendants to pass the culture. Chinese shadow puppetry, which has been practiced and performed in rural China for thousands of years, was also on the endangered lists.

## 2.2 Chinese Shadow Puppetry

Chinese shadow puppetry is a unique and ancient performing art in China, which can be traced back to thousands of years ago. As stated in the previous section, puppeteers use rods or sticks to control puppets made of animal skins behind a white and illuminated backdrop to create the illusion of moving images. At the same time, puppeteers need to sing the stories in local accents, accompanied with lingering music played with traditional Chinese instruments, such as suo-na horn, banhu fiddle and many percussion instruments. During the old times without cinemas and televisions, shadow puppetry was extremely popular in rural China due to its exquisite sculpture, fresh color and lively performance.

### 2.2.1 Development of Shadow Puppetry

According to historical accounts, shadow puppetry first appeared in the ancient Western Han Dynasty. The legend tells the love story of Emperor Han Wu and his beloved concubine, which can be read in Appendix B. During the period of the Sui and Tang dynasties, according to Rollins [2013], more and more shadow puppets were designed and used to represent spirits and the presence of gods, in order for the preaching of Buddhism. By the Song Dynasty, shadow play gradually became a popular form of entertainment, accompanied with folk singing and dramatic narration. By the Yuan Dynasty, shadow puppetry had become one of the most popular street entertainment forms, taking on elements from folk art traditions of different regions in the country and from abroad, as reflected in the diverse and evolving design and performance styles. The Ming and Qing dynasties, especially the Qing Dynasty, were the golden age of shadow puppetry, when it was widely accepted and loved by people of different ages and hierarchy. During this time, there was an abundance of professional shadow play troupes and numerous small groups founded by families or individuals. Rich and influential families often displayed their wealth by employing elaborate shadow play troupes for celebration of birthdays, weddings and funerals. Generally those events were open to all the villagers living in the town. Those performances would be held continuously for several days in order to present the host's power, wealth and social connections. People loved these events since they would enjoy a puppet show along with a grand meal and other celebration activities.

In the late Qing Dynasty, some local governments were afraid that mobs would gather together and made trouble at the places where shadow puppetry was played at night, so all performances were banned. What's even worse, many puppeteers were arrested for no reason, which was a big blow for the industry. In the late 1800s, according to Rollins [2013], Chinese shadow puppetry underwent a long struggle to keep its audience as China headed into a string of internal and external battles for control of the country. After the Communist party declared victory in 1949, the remaining troupes started to pick up this old art again and things got a little better until the Cultural Revolution (1966-1976) started, which caused a catastrophic disaster to the shadow puppetry troupes and artists. According to some documents, in some provinces, an entire region's shadow puppet treasures were decimated by fire because the messages sent by the show might be out of the government's control. During the dark ages, many traditional art forms were entitled as 'superstitious activities', and as a result, most of them were banned or even destroyed. In order to survive, the troupes had to take their performance directives from the government, while the contents and aesthetics had been changed completely.

In the late 1970s, the ban was finally cancelled, and traditional troupes started to pick up what they left in the dark times, only to find out that their audience had completely changed. What's even worse, their place in the audience's heart had been replaced by many new entertainments.

## 2.3 Intangible Cultural Heritage in Digital Era

Even though new medias are the reason why people have abandoned the old traditions, new media technologies may also bring fresh hope to the endangered cultural traditions. New media and emerging technologies have the greatest potential to move heritage preservation beyond static displays, capturing in cinematic or narrative forms and revitalize the intangible aspects [Yehuda, 2007]. Cultural heritage, tangible or intangible, is getting more and more attention, due to the emergence of new media technologies, such as virtual reality and 3D scanning technologies. At a TED conference, Professor Sarah Kenderdine [2013], an expert in the creation of immersive and interactive experiences for museums, discussed how museums of the future might present their exhibits. She also demonstrated how laser-scanning technology is already enabling museum curators to produce exhibits that invite visitors to behold precious objects rendered with 3D digital models making visible attributes that could not easily be seen in a traditional exhibit [Kenderdine, 2013]. With many new interactive experiences being set up in museums, more people are getting attracted to and are interested in exploring cultural heritage in these immersive environments. Thus, they may have a better and far more interesting way to look into the past. Researches have found that the use of new technologies in the context of intangible cultural heritages, provides tremendous showcasing opportunities, and guarantees the spontaneous, undirected learning experiences for people of all ages as well [Tanenbaum, 2009; Bizzocchi, 2009].

Today people all over the world are able to appreciate cultural artifacts from the Louvre Museum just in front of their computers. It's incredible that cultural practices, which are on the verge of extinction, can be recorded and preserved completely through digital technologies [Zhou, 2011]. As Neil Silberman [2005] stated, "never before have so many people, in so many walks of life, had been offered so many avenues to the past, from the interactive touch screens of national museums, to the countless on-line archaeological databases." Kunqu opera, for example, is facing an embarrassing situation in that only a few senior people in China are practicing and appreciating it, due to the emergence of pop cultures. In 2007, Zhou and Mudur [2007] developed 3D-scanning animation techniques for Chinese opera facial expression documentation, in order to preserve Kunqu in the digital museum and make it more appealing to the younger audiences at the same time. Based on their experiment, Zhou and Mudur [2007] found that ordinary people have high anticipation on 3D technique that they are likely to be more interested in the product of 3D Kunqu Opera. So obviously, there is a huge advantage regarding to the digitalization of culture heritages. New technologies are changing the practice of preservation and communication, and digital media is a new platform for conserving cultural heritage [Kalay, 2007].

Khan and Byl [2013] explored the role of augmented reality and motion-detecting technologies in the context of Intangible Cultural Heritage for museum related environments. They created a prototype application, titled 'Virtual Arabic Calligraphy', in order to increase the awareness of indigenous calligraphic methodologies and movements. Technically, by using Microsoft Kinect device, users could use their hands in the air to write Arabic calligraphy, and a calligraphic mark on the screen would move accordingly. Their objectives here is to determine the overall effectiveness of the prototype with children in the context of intangible cultural heritage and to identify important perceptual and technical additions/add-ons that will help in providing recommendations for future development [khan, 2013; Byl, 2013]. After evaluating the qualitative and quantitative learning outcomes, collected from children between the ages of 6 and 18, they noted that most of the children found the content enjoyable and beneficial. The prototype offers physical participation and entertaining feedback, as well as authentic learning environment that immerses museum visitors within the ICH content in a truly unique way.

However, there also exist some limitations with the digitalization of intangible cultural heritage. In the process of transforming vibrant art form to a digital format, some artistic value is inevitable lost [Shi, 2014]. For instance, in the digital preservation of Kunqu Opera, an audience cannot smell fragrant rouge, which only belongs to ancient Chinese makeup. Besides, many old artists considered this facial animation documentation as a form of cartoon rather than treasured intangible cultural heritage [Zhou, 2011]. In addition, to capture and preserve the core content of the intangible heritage items is not that easy, and one must properly understand the concept and value judgements about ICH [Hong, 2015].

For digital media designers, our primary responsibility is to construct a 'global shared memory' that facilitates reflections. In the end, as Neil Silberman states [2005], our imaginations of the past, both scientific and creative, can serve as a vital role in shaping the future.

## 2.4 Digital Puppetry

Since shadow puppetry is a world-wide beloved art style, much research has been carried out in this field, and gradually it became a subject called 'digital puppetry', where people use digital arms or camera input devices as controllers. From many successful projects, we see great potentials in using digital technologies to revitalize the charms of shadow puppetry.

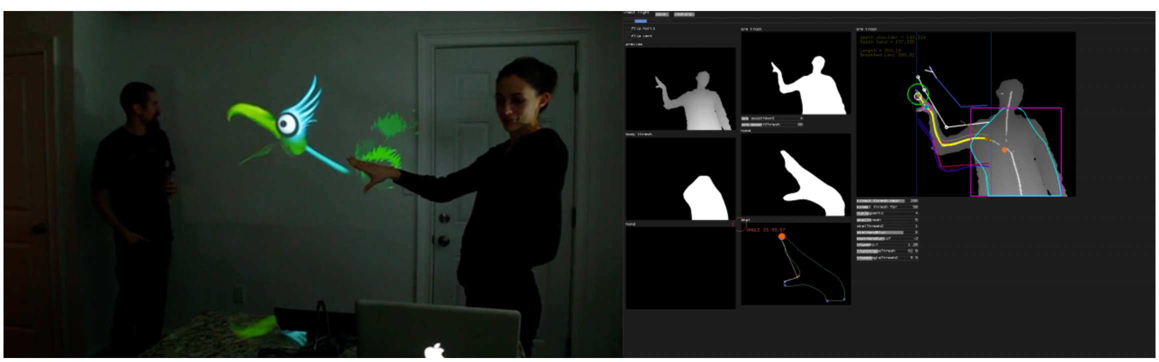


**Figure 2.1:** A screenshot of Gobeille and Watson's quick installation prototype of a giant bird using Kinect

Gobeille and Watson [2011] developed a quick installation prototype using the libfreenect Kinect and ofxKinect (see Fig. 2.1). In their system, the players can control the movement of a giant bird, by tracking the movement of their arms, and determining where the shoulder, elbow, wrist and hand are. For example, the bird's mouth is controlled by the player's hand. So when a player opens and closes his hand, the movements will be tracked and mapped to the digital bird's mouth. Visually the bird seems to be alive with its mouth opening and closing.

To make this experience better, in the project 'Puppet Parade' installed by Design I/O at CineKid 2011 (see Fig. 2.2), Kinect's simple gestural interface is utilized, so the kids can control countless colorful and larger-than-life creatures in front of the projector, by just waving their arms around [Holmes, 2012]. This dual interactive setup allows children to perform alongside the puppets, blurring the line between the 'audience' and the puppeteers, and creating an endlessly playful dialogue between the children in the space and the children puppeteering the creatures [Watson, 2012; Gobeille, 2012].

**Figure 2.2:** A screenshot of 'Puppet Parade' designed by team Design I/O

Moreover, instead of only one puppeteer controlling one puppet, Caitlin Boyle and Asa Foster [2011] developed an interactive collaborative Kinect puppet, 'We be Monsters', inspired by the Muppets and Chinese lion costumes. A pair of users can control the Behemoth, a quadruped puppet, with one user in front and the other one in the rear. Participants have to work collaboratively to mimic the movements and postures of a quadruped (see Fig. 2.3).

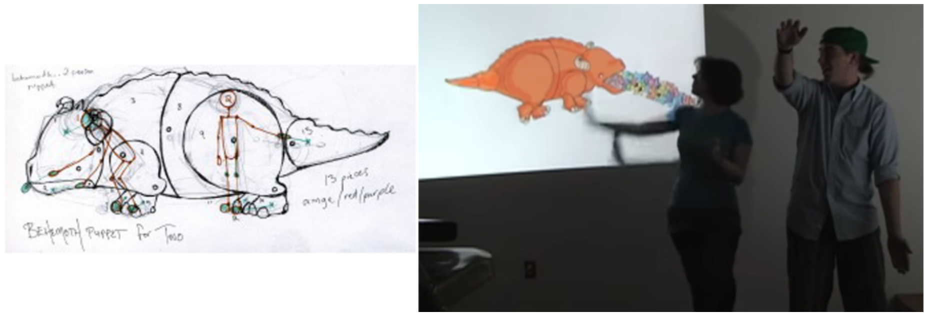


**Figure 2.3:** A screenshot of 'We Be Monster' designed by Caitlin Boyle and Asa Foster

Similarly, Leite [2012] designed a framework, using body as a puppetry controller to puppeteer virtual silhouettes through acting. In order to evaluate the feasibility of this tool, he recruited 11 volunteers, with an average age of 22, mainly for testing the interaction techniques, the manipulation level and the result expressiveness of each puppet. As a result, he found that most of the testers rated the animated puppets as highly expressive, and had no problems in handling the virtual puppets. More importantly, interacting with puppets with the body motion relies on the acting. Unless the system offers methods for simplifying the animation, the performer must try to interpret the character [Leite, 2012]. This is extremely true when it comes to controlling Chinese shadow puppets in a virtual environment. Since puppets are made to tell a story, all the movements they do need to be meaningful and help drive the story. In addition, those movements should also represent their personalities.

Speaking of Chinese shadow puppetry, there also exist many relevant projects in terms of the combination of shadow play and new technologies. Leo Chen and Ryan Chen developed an interactive game with the introduction of Leap Motion (see Fig. 2.4). Players can use their hands to control the puppets, which is pretty similar to a traditional puppet show, where people use sticks to control the puppets. Visually, the design of the puppets and props follows the traditional art style. While technically, the movements of the puppets are limited due to the limitation of hand gesture recognition. With the emergence of Kinect device, many new possibilities spring up due to the fact that now people can use their whole body as controllers.

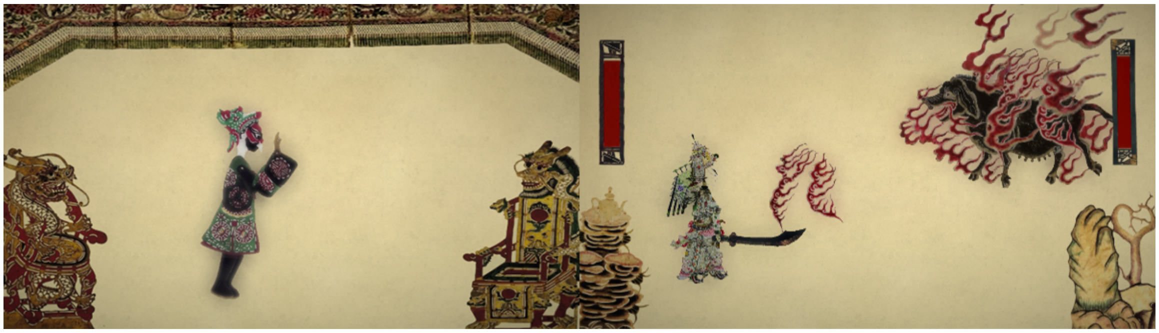


**Figure 2.4:** A screenshot of an interactive puppet game using leap motion, designed by Leo Chen and Ryan Chen

In 2012, Hui Zhang analyzed the motion of the actors in the famous Chinese drama, Wusong Fights the Tiger, and defined some special postures to represent difficult martial movements such as splits and back flips (see Fig. 2.5), which are pretty common in traditional Chinese shadow puppet shows. Considering the difficulty of transforming 3D behaviors of the skeleton into the movement and rotation of 2D puppets, they used 'data-driven method' or 'event listener' to trigger the character movement. For example, when the user's hands stretch to up-backward, the animation of back flips will be triggered [Zhang, Song, Chen, Cai, Lu, 2012]. Even though they came up with the solution to facilitate the performing of complex martial movements, the project itself seemed to be very technical and did nothing for disseminating the essence of Chinese shadow puppetry, that of storytelling and colorful, exquisite aesthetics.

**Figure 2.5:** A screenshot of martial movements designed by Hui Zhang, in their Wusong project

In 2013, by using Kinect, Shi and her team designed two systems to stimulate creativity within the digital revision of Chinese shadow puppetry (see Fig. 2.6). Through this experiment, they found that the essence of shadow puppetry is to preserve the precious spark of Chinese traditional culture through an innovative way, including the free control of movement, impromptu interaction between artists and audiences, and spontaneous expression of emotion. Therefore, the building of digital shadow puppetry art on the basis of tangible interaction has a significant practical value [Shi, 2013]. Moreover, people participating in this project were able to get completely immersed in the culture, and most of them did not feel isolated from the environment. While visually, the puppets in this experience look pretty cartoony, which may not help raise the appreciation for traditional aesthetics.


**Figure 2.6:** A screenshot of 'Piying: Kung Fu Panda', designed by Yan shi

Overall, the previous projects turned out to be really successful and popular, which stimulated us to utilize this technology in the discourse of cultural representation. Based on the previous analysis, a successful digital and interactive Chinese shadow puppetry experience should include two important elements. Visually, the looks of the puppets should follow the traditional style, with distinct silhouettes and bright colors. Thus the audience may have a basic understanding and memory of what Chinese shadow puppetry actually looks like. Technically, puppets should be mapped and controlled in a meaningful way. Although controlling puppets using body movements is different from the traditional way of puppeteering, it still has great potential since it blurs the lines between the 'audience' and the puppeteers. The audience may find this more enjoyable and be immersed in the experience.

## 2.5 Kinesthetic Interaction Design

Within the Human-Computer Interaction community, there is a growing interest in designing for the whole body in interaction design. In 2008, Fogtmann, Fritsch and Kortbek [2008] introduced a conceptual framework to reveal bodily potential in relation to three design themes and seven design parameters.

Generally, the three kinesthetic design themes are Kinesthetic Development, Kinesthetic Means and Kinesthetic Disorder. Kinesthetic development deals with "acquiring, developing or improving bodily skills. For example, knowing where and when to apply a certain action, knowing how to adapt the action to the changing environmental conditions, or by practicing the consistency of the action from time to time [Fogtmann, 2008; Fritsch, 2008; Kortbek, 2008]." Kinesthetic means deals with "KI as a means for reaching a goal other than kinesthetic development. While the interaction can be defined as kinesthetic, the goal of the interaction is something other than improving bodily skills such as learning activities, playful experiences and etc [Fogtmann, 2008; Fritsch, 2008; Kortbek, 2008]." Kinesthetic disorder deals with "transforming the kinesthetic experience in a given situation by changing the kinesthetic sense. This can be achieved by changing the possibility of kinesthetic experience, either by affecting how a person senses, or how the environment is perceived [Fogtmann, 2008; Fritsch, 2008; Kortbek, 2008]."

The seven parameters are derived from the theoretical development in relation to the three design themes, in order to reveal how the bodily potential is addressed in the design process.

1. Engagement describes interactions that engage users in a kinesthetically memorable manner, and facilitate interested exploration through the body in motion.

2. Sociality means that the interaction often moves into a collaborative and social place, where others are invited to take part in the interaction, actively or as spectators.

3. Explicit motivation means that the system tells the users explicitly how to interact with the

system.

4. Implicit motivation is when the interaction with the system is open, and there are no restrictions on the movements.

5. Movability is central for an understanding of whether the body can move freely, or is physically restricted while interacting with the system.

6. Expressive meaning occurs when the bodily engagement fits the system output, and the bodily interaction is meaningful for achieving the system goal.

7. Kinesthetic empathy is where specific and controlled movement patterns are affected by the relation to other people.

Based on theories, *Virtual Puppet* falls within both the kinesthetic development and kinesthetic means theme, by providing a kinesthetically engaging experience of interacting with the virtual puppets. Right now, the interactive experience does not invite for others to join in, thereby there is no kinesthetic sociality and empathy within the play. On the other hand, participants in this interactive experience can move freely without constraints, so the movability can be applied in this system. While for the transformation part, participants need to do specific gestures or movements, in order to trigger the transformations. So in other words, the bodily interaction is meaningful for achieving the system goal, which means that the 'expressive meaning' can also be applied to this system.

# Chapter 3: PROBLEM STATEMENT

This chapter demonstrates the research question of the study, as well as the research goals.

## 3.1 Research Question

What can be learned in observational research from direct observation of children interacting with the Virtual Puppet System and from interviewing cultural experts who have observed the children's performance?

We used this research question as the main guidance through the process of developing the system, as well as setting the evaluation criteria. The results were gained and analyzed through a panel of experts, who are mostly teachers from Buddhist Tzu Chi Foundation Philadelphia. The results are covered in detail in the Chapter 5.

## 3.2 Research Goals

In this paper, I tried to revitalize Chinese shadow puppetry with the help of Microsoft Kinect v2, enabling new generations to get access to the old art in a much more fun way. I know that controlling a real puppet in a real show is extremely difficult. To be honest, my prototype cannot facilitate this training process for puppeteers.

My main goal here is to raise interest in and appreciation for Chinese shadow puppetry among new generations. Hopefully, the use of new digital interactive technologies can be leveraged to generate interest in traditional shadow puppetry and can help attract large audiences to the theater again in the 21st century.

# Chapter 4: APPROACH

*Virtual Puppet* focuses on the interaction between the human body and 2D virtual puppets, in order to create a unique experience for kids to play as being the puppets instead of just sitting and watching. Hence, the audience can have a better communication and interaction with the puppets on the big screen.

## 4.1 System Flow Overview

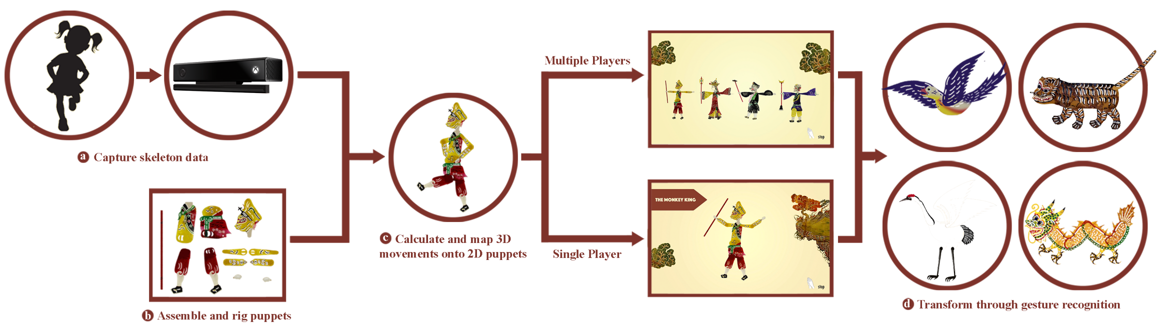



**Figure 4.1:** A screenshot of the system flow diagram

The Fig. 4.1 above is the system flow diagram, which presents how 'Virtual Puppet' works, and what players can actually do in this experience. To be more specific, the audience needs to stand in front of the Kinect field of view and perform various gestures. The gestures will be captured, calculated by the Kinect, and then mapped onto the 2D puppets which have been assembled and rigged using Unity 2D. The mapping method will be described in detail in the section of 'Skeleton Mapping'. So instead of controlling the puppets using rods or sticks, now the audience has the absolute control over the virtual puppets with their body movements. In addition, there exist two modes in this experience. The audience may play with the puppets individually, or multiple participants can play with the puppets at the same time. They can use those puppets to create their own puppet shows.

Basically it's a single-play experience, but in the 'Multiple Player' mode, more participants can join in. Their corresponding puppets will be shown on the screen once they walk into the Kinect field of view. Right now, there are only four characters in the mode, and the puppets are assigned based on their x position. From left to right, the leftmost participant will play as the Monkey king, the second as the Monk, the third as the Pigsy, and the rightmost player is the Sandy.

To make this experience more interesting and interactive, we introduced a transforming feature that the audience can transform into some animal puppets based on some specific gestures. This mechanic was inspired by our main character, 'Monkey King', who has 72 transformations, which allows him to transform into various animals and objects. While in our system, the participants can only transform into four animals, a bird, a tiger, a crane or a dragon. The transformations are triggered by some special postures, which are designed and analyzed in Visual Gesture Builder. The method will be presented in detail in the section of 'Gesture Recognition'.

## 4.2 Microsoft Kinect v2

The device in Fig. 4.2 is the Kinect v2 by Microsoft for Xbox 360 and Xbox One video game consoles and Windows PCs.

**Figure 4.2:** A screenshot of Microsoft Kinect v2

It is a line of motion sensing input device that enables users to control and interact with their computers without the need for a game controller. Generally speaking, Kinect is composed of a RGB and an infrared (IR) camera. With the new release in 2014, now Kinect v2 or Kinect for Xbox One has a four-microphone array that enables voice commands. Based on Lachat's [2015] first experience with Kinect v2 sensor, the RGB camera captures color information with a resolution of 1920x1080 pixels, whereas the IR camera is used for the real-time acquisition of depth maps and also IR data with a 512x424 pixels resolution.

The technical specifications provided by Microsoft announce an operative measurement range from 0.5 meters to 4.5 meters. In addition, Kinect for Xbox One has the ability to recognize up to

6 full skeletons with 25 joints per skeleton. The following Fig. 4.3 shows the skeleton that is made up of each of these joint types.

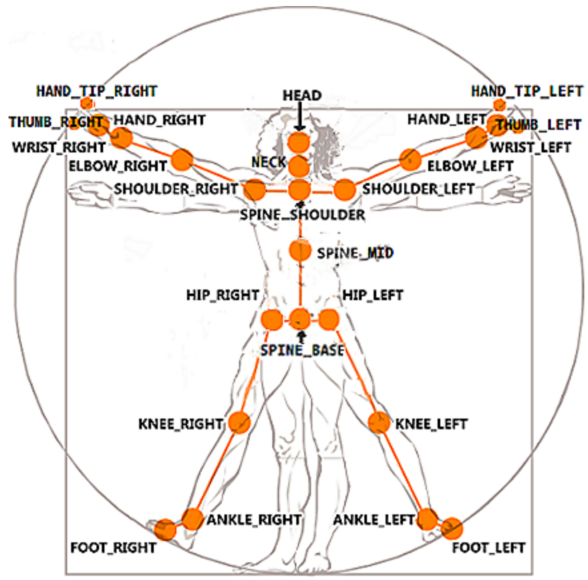



**Figure 4.3:** A screenshot of skeleton positions relative to the human body

In order to fully understand and make use of this sensor, Microsoft also provides an official SDK 2.0 (Software Development Kit) for developers and researchers, which is free downloadable on their website. The SDK provides not only the drivers, but also a set of functions or code samples that can be used for own implementations.

## 4.3 Visual Design

The visual design of *Virtual Puppet* follows the style of traditional Chinese shadow puppets. The puppeteers and researchers in China consider that Chinese Shadow Puppetry is the ancestor of Beijing Opera, which is a form of traditional Chinese theater with a combination of music, vocal performance, mime, dance and acrobatics. In addition, the shadow puppets are very colorful. Actually, the audience can see the colors projected on the cloth instead of just the black shadows, which is very different from shadow puppetry in other countries. The Fig. 4.4 presents some real puppets bought from China, and those four puppets are the main characters in our system.

**Figure 4.4:** A screenshot of some real shadow puppets bought from China

In order to use those puppets in our *Virtual Puppet* system, several steps are needed as follows:

1. Scan the real puppets into Adobe Photoshop, and redraw every parts of a puppet in different layers. The following Fig. 4.5 shows the final results of Monkey King. The image on the left is the sprite file, where all the parts of Monkey King are separate so Unity 2D engine can easily recognize later.

**Figure 4.5:** A screenshot of sliced puppet (left) and assembled puppet (right)

2. Now we have the body parts separated, Unity 2D engine will try to detect the different parts of the character we have in the image and then slice the various parts of the sprite into different rectangles in the Sprite Editor. Those parts will be used to build the character.

3. In order to make the rigging process much easier, first several changes are needed after slicing the puppets. Just like rigging a 3D character in 3D software such as Autodesk Maya, we should

rename the generated sprite and adjust its pivot point, which is of great importance for the animation. For example, a head's pivot should be placed near to the neck area, so that the rotations will orient around that point. This will make sure that the character can move more naturally and realistically.

4. Assemble the character is the next work. So basically all the sliced sprites should be dragged into the scene. In order to place the different parts on the right position, the original image of the real puppet can be used as a reference.


**Figure 4.6:** A screenshot of all the puppets in the system

5. Add specific orders to the different parts of a puppet, otherwise the overall character will look really weird. Some parts that should be under the body are over it, or vice-versa.

6. Organize the sprites of the character following a specific hierarchy. For example, the hand should be placed under elbow, and the elbow should be put under the shoulder sprite. That

makes sure that when you move the shoulder, all the parts of the arm will follow. While when you just rotate the hand, the upper arm will not follow. So our characters can move in a more natural and realistic way.

7. The character on the right of the Fig. 4.5 is what Monkey King looks like by the end.

8. Using the same method, now we have 12 puppets in the *Virtual Puppet* system, which are presented in the Fig. 4.6. The first four puppets are the main characters which the audience can play with. The middle four puppets are from the legend of Chinese shadow puppetry. The audience can read their story in the History section of *Virtual Puppet*, which can also be read in Appendix B. The last four puppets are animals which the audience can transform into based on specific gestures.

## 4.4 Skeleton Mapping

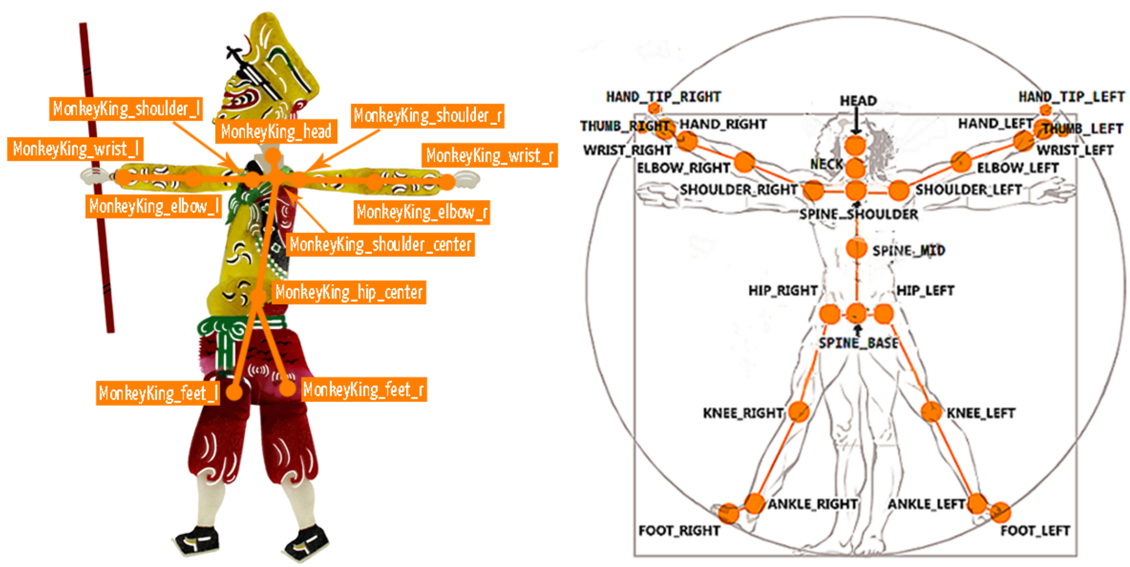


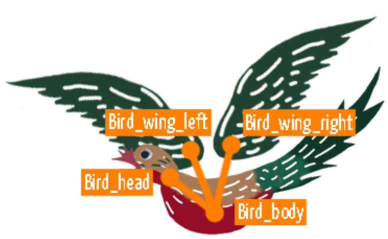

**Figure 4.7:** A screenshot of the skeleton information of Monkey King

Now all the puppets have been assembled in Unity 2D engine. It's time to map users' skeletons captured by Kinect v2 onto those 2D puppets. Since all the human-like puppets use the same mapping method, we will only use the Monkey King as an example. The Fig. 4.7 shows Monkey King's rigging system and its corresponding joint names. We set up 11 joints on the Monkey King puppet, which can be seen on the left side of Fig. 4.8. Since the structure of the Monkey King puppet looks pretty similar to the human beings, it is easy to directly map the Kinect skeletons onto the virtual puppets, parts by parts. The right side of Fig. 4.8 demonstrates the corresponding Kinect skeletons.

| PUPPET | CONTROLLER |
|---|---|
| MonkeyKing_head | NECK |
| MonkeyKing_shoulder_center | SPINE_SHOULDER |
| MonkeyKing_shoulder_r | SHOULDER_RIGHT |
| MonkeyKing_elbow_r | ELBOW_RIGHT |
| MonkeyKing_wrist_r | WRIST_RIGHT |
| MonkeyKing_shoulder_l | SHOULDER_LEFT |
| MonkeyKing_elbow_l | ELBOW_ LEFT |
| MonkeyKing_wrist_l | WRIST_ LEFT |
| MonkeyKing_hip_center | SPINE_BASE |
| MonkeyKing_feet_r | HIP_RIGHT |
| MonkeyKing_feet_l | HIP_LEFT |

**Figure 4.8:** A screenshot of how human skeleton is mapped to its corresponding joints on the Monkey King Character

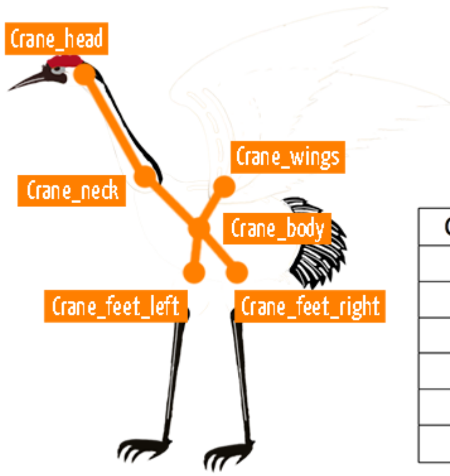
On the other side, we also provide four animal puppets for the audience to play with. Since controlling an animal puppet is totally different from controlling a human-like character, we can not directly map the skeletons to the corresponding animals. Instead, we have to re-target the captured joint information. The bird was rigged with 4 joints, where the wings were connected to the performers' arms and his neck was assigned to control the head of the bird (see Fig. 4.9). This was set up based on the common sense that when a person tries to act like a bird, he/she will definitely flap his two arms.




| BIRD PUPPET | CONTROLLER |
|---|---|
| Bird_head | NECK |
| Bird_wing_right | SHOULDER_RIGHT |
| Bird_wing_left | SHOULDER_LEFT |
| Bird_body | SPINE_SHOULDER |

**Figure 4.9:** A screenshot of how human skeleton is mapped to its corresponding joints on the bird puppet

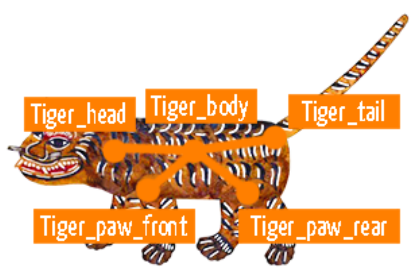
The crane was rigged with 6 joints, with hips controlling the crane's two long legs. The head and neck were mapped to one arm and the two wings to the other arm, which is a little different from the bird. (see Fig. 4.10)




| CRANE PUPPET | CONTROLLER |
|---|---|
| Crane_head | WRIST_LEFT |
| Crane_neck | SHOULDER_LEFT |
| Crane_wings | SHOULDER_RIGHT |
| Crane_body | HIP_CENTER |
| Crane_feet_right | HIP_RIGHT |
| Crane_feet_left | HIP_LEFT |

**Figure 4.10:** A screenshot of how human skeleton is mapped to its corresponding joints on the Crane Puppet

Similarly, there are 5 joints built on a tiger, where the head was controlled by one arm, and the tail was connected to the other one. In addition, the tiger's four paws were controlled by the performer's two hips. (see Fig. 4.11)




| TIGER PUPPET | CONTROLLER |
|---|---|
| Tiger_head | SHOULDER_LEFT |
| Tiger_body | HIP_CENTER |
| Tiger_tail | SHOULDER_RIGHT |
| Tiger_paw_front | HIP_LEFT |
| Tiger_paw_rear | HIP_RIGHT |

**Figure 4.11:** A screenshot of how human skeleton is mapped to its corresponding joints on the Tiger Puppet

Controlling a dragon is much easier in our system, because there are only 4 joints on a dragon, and those joints are only connected to the performer's two arms. (see Fig. 4.12)


| DRAGON PUPPET | CONTROLLER |
|---|---|
| Dragon_head | WRIST_LEFT |
| Dragon_body_front | SHOULDER_LEFT |
| Dragon_body_middle | SPINE_SHOULDER |
| Dragon_body_rear | SHOULDER_RIGHT |

**Figure 4.12:** A screenshot of how human skeleton is mapped to its corresponding joints on the Dragon Puppet

When the mapping is complete, the audience can bring the puppets into life using their whole body motions. From our play-testing in the school, we found that children really like the way interacting and communicating with their favorite puppet, which in this case is the Monkey King. While during the development, we also found that the puppets move and rotate in a three dimensional space due to the fact that the skeleton information collected by Kinect has x, y and z values. As we all know, and Zhang [2012] also points out that the shadow puppet is of two dimensions whose movement is on the screen plane, while the skeleton and its motion are three dimensional. Under this circumstance, we must add constraints to the joints of those 2D puppets, which are the X and Y axis rotations and Z axis positions. In addition, in order to keep the puppets on the screen all the time, in case that the performers walk outside the view of Kinect, we also add two barriers on the both side of the screen. So once the player is outside the view, the puppets will return to the center of the screen, and the player has to come back and stand in 'T-pose' in order to activate the puppets again.

As Leite [2012] states, interacting with puppets with body motion relies on acting. So in order to control 2D puppets on a big screen, performers must try to interpret the characters. There are no cues or tutorials on our system, because we hope that the audience can figure out by themselves. The reason for designing the interface like this is that we don't want to turn this experience into something completely automatic, where the audience just needs to perform what the system has told them to do. *Virtual Puppet* is somehow similar to the hand shadow performance, but with more body parts. So we hope that *Virtual Puppet* may work as an intuitive interactive platform that the audience may feel more connected to the shadow puppets since they themselves are the puppets.

## 4.5 Gesture Recognition

The biggest feature in *Virtual Puppet* is that there are a huge amount of gestures. Gesture recognition is a fundamental element when developing Kinect-based applications, mostly for navigation and interaction. For example, in our system, participants can swipe to left or right to choose the puppet they want to play with, and they can swipe down to return back to the previous menu. Moreover, standing in 'T-pose' is used to activate the puppets, and a Namaste gesture is for stopping the control of the puppets. In addition, there also exist many gestures for transforming into the animal puppets, not to mention the gestures that can help them to transform back. Initially we used codes to build the gestures, but it turned out to be a huge amount of work, and we can not get the perfect results. So we started to use Visual Gesture Builder to tag those gestures, which will be described in detail in the section of 'Visual Gesture Builder'.

### 4.5.1 Define Gestures through Codes

Initially we were using Rumen's Kinect v2 with MS-SDK to set up the bridge between virtual puppets and the performers. There are some pre-defined gestures such as swipe left, swipe right, and jump, just to mention a few, in the development kit. These gestures were defined completely through codes.

Before implementing, we needed to define what is a gesture. Based on Pterneas's [2014] research, Kinect provides us with the position (X, Y and Z) of the users' joints 30 frames per second. If some specific points move to specific relative positions for a given amount of time, then we have a gesture. So, in terms of Kinect, a gesture is the relative position of some joints for a given number of frames. Let's take T-pose gesture as an example. When the Kinect is connected, we can obtain the positions and orientations of all the joints. In order to define a 'T-pose', we need to compare the positions of the right and the left shoulders, elbows and wrists from time to time. If the Y positions are exactly the same within a certain number of time, we will consider that as a 'T-pose' gesture. There is a gesture listener in the system, so whenever it detects a certain gesture, the event will be triggered. For example, when a player stands in T-pose, the puppets will be activated, and then he/she can start to puppeteer the character using his/her whole body motions.

However when we started to create the transforming gestures, things just seemed to get much more complex. After all, in order that the detections can work reliably for a wide variety of different people in a wide variety of different environments, the code becomes much more complex very quickly and more codes need to be added so that the system can respond to the right gestures. To sum up, using codes is a right and quick method to do simple gestures, such as wave, jump, swipe and so on. While for complicated gestures, writing codes seems to become a problem. So that's why we started to use Visual Gestures.

### 4.5.2 Visual Gesture Builder

We used Kinect Studio to record depth and color streams from a Kinect, and Visual Gesture Builder to generate the gesture databases that can be used by applications to perform run-time gesture detection. According to Microsoft's official document, by using a data-driven model, VGB shifts the emphasis from writing code to building gesture detection that is testable, repeatable, configurable, and database-driven. The following Fig. 4.13 illustrates how the VGB is used in *Virtual Puppet*.

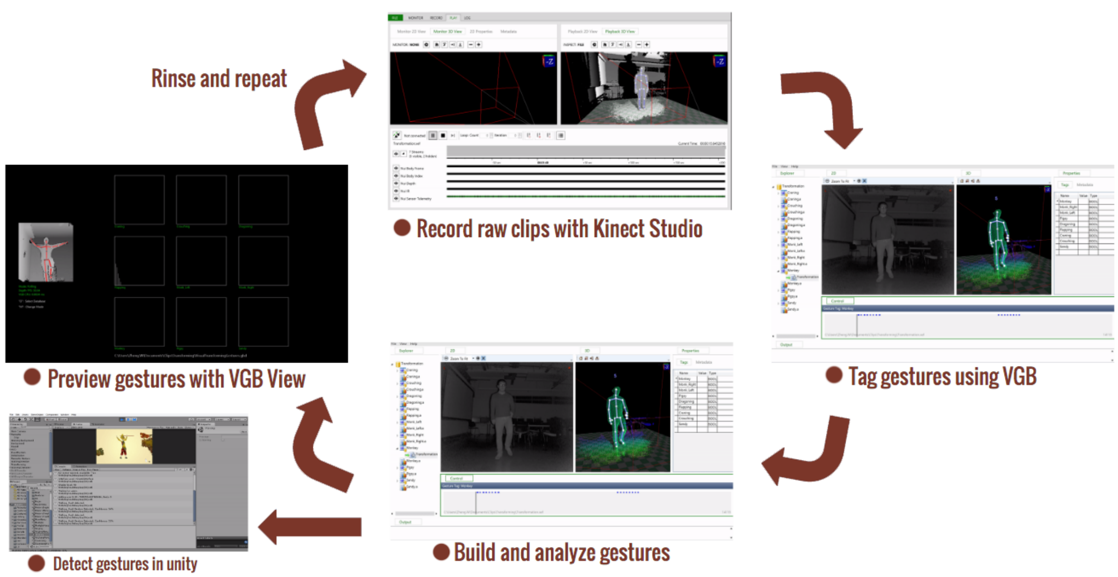



**Figure 4.13:** A screenshot of the process of creating a gesture detector using visual gesture builder

First of all, we analyzed all the gestures we needed in the system, and classified them into three categories. The first kind of gesture is for navigation, such as the namaste and swipe-down gestures. The second one is for transforming into animal puppets, and obviously the last one is used to help transform back to normal characters. For the normal gestures such as swiping down, it is easy to set up due to the fact that it's so universal that almost everyone will perform the same gesture when they are told to do a swipe-down gesture. While for the transforming gestures, figuring out a set of universal gestures became much more complicated. Due to its complexity, we started to figure out the gestures from the characteristics of the puppets. Additionally, it's worthy of asking people who have no idea about the project, what they will come up with if they are told to mimic a bird or a monkey. From those data, we finally designed all the gestures (see Fig. 4.14, Fig. 4.15, Fig. 4.16, Fig. 4.17, Fig. 4.18, Fig. 4.19, Fig. 4.20, Fig. 4.21). Even though the gestures are still subjective, since people have different ideas about a specific gesture, it‘s actually the fun part of the experience, where the audience may get much more involved.

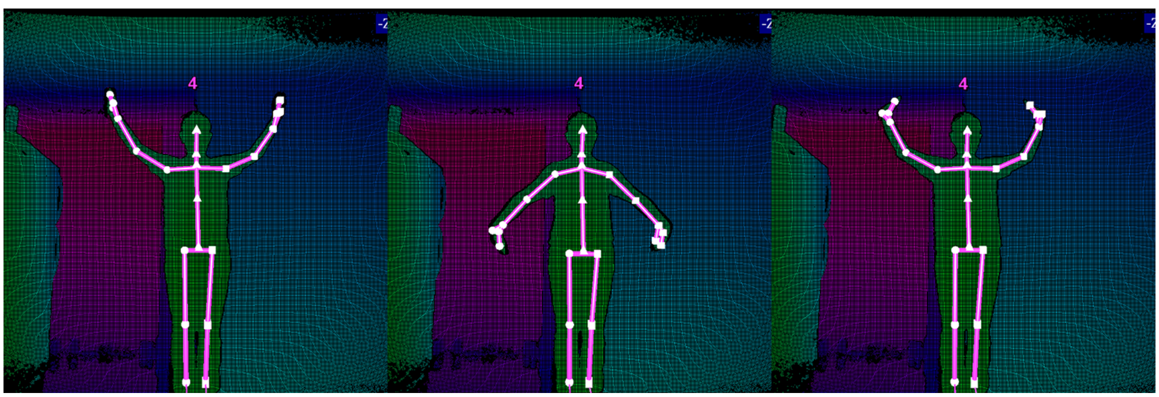


**Figure 4.14:** A screenshot of the gestures for transforming into a bird

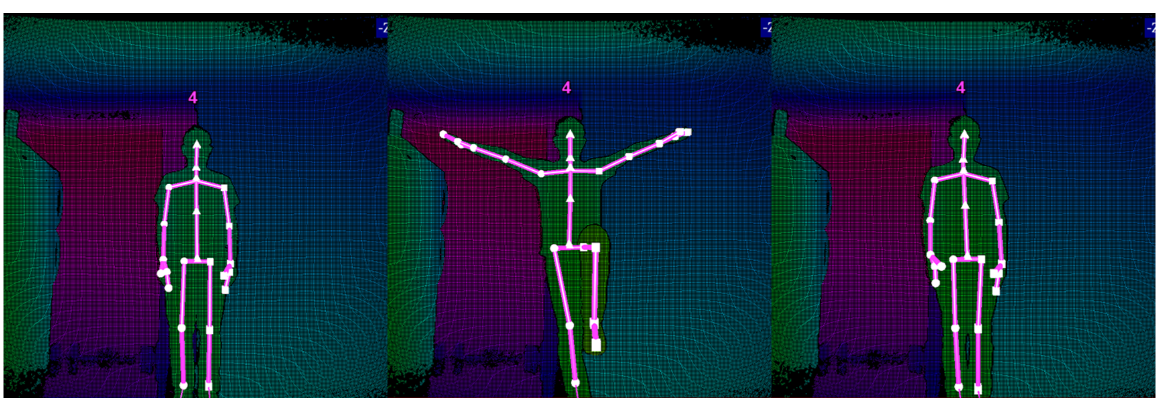


**Figure 4.15:** A screenshot of the gestures for transforming into a crane

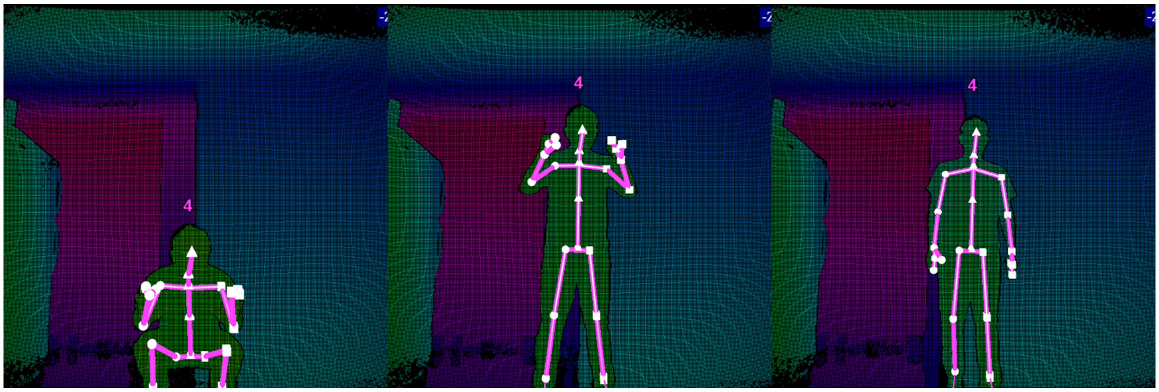


**Figure 4.16:** A screenshot of the gestures for transforming into a tiger

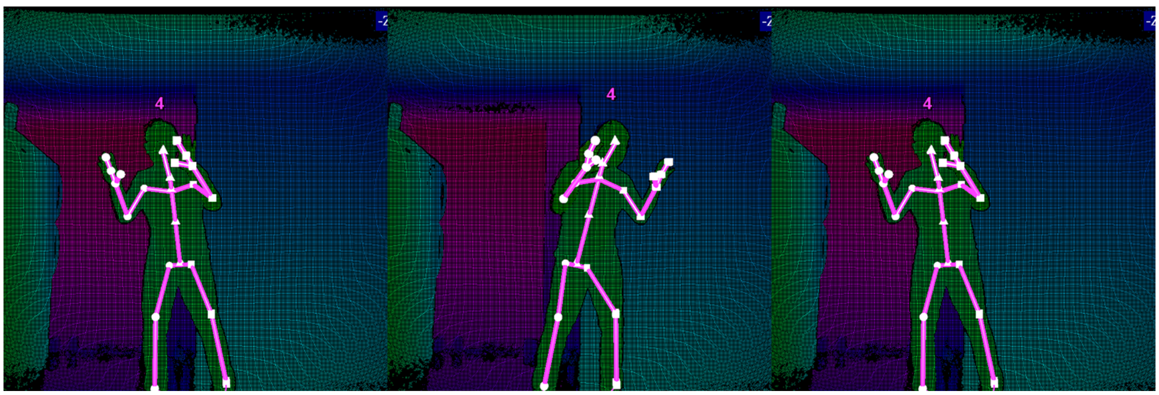


**Figure 4.17:** A screenshot of the gestures for transforming into a dragon

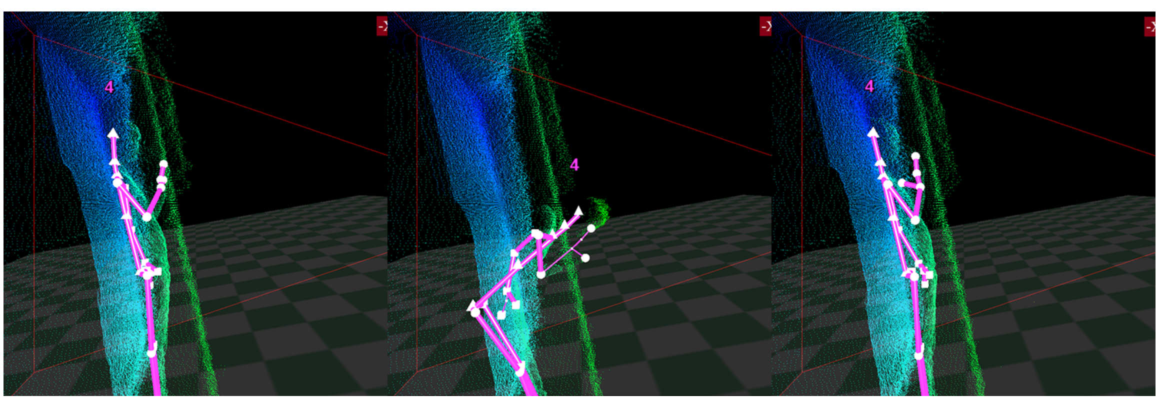


**Figure 4.18:** A screenshot of how Xuanzang transforms back to normal shape

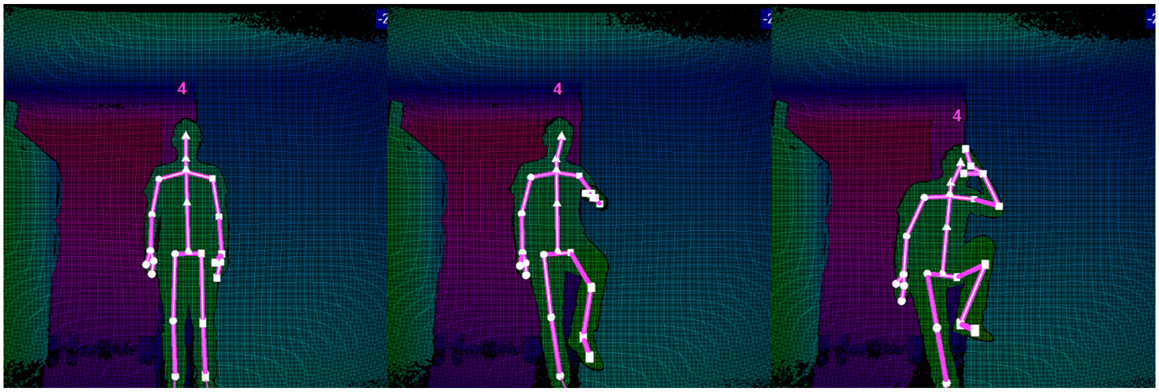


**Figure 4.19:** A screenshot of how Monkey King transforms back to normal shape

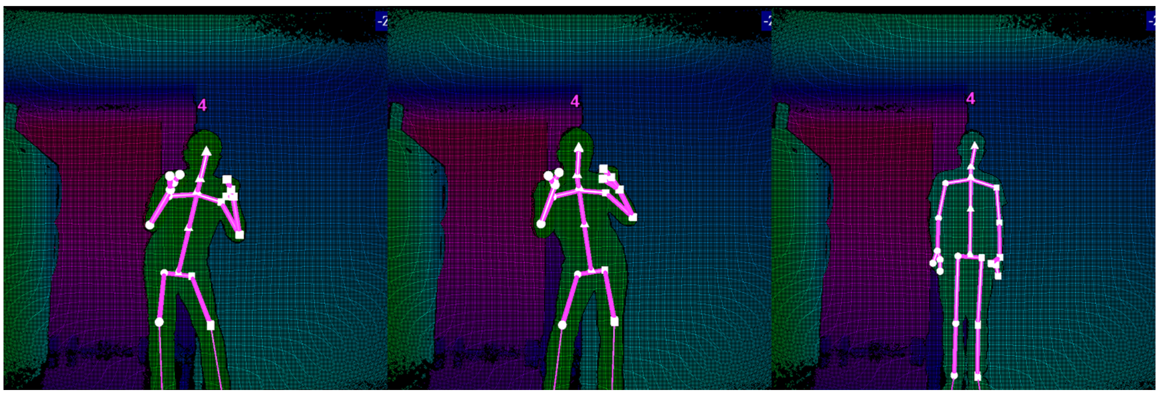


**Figure 4.20:** A screenshot of how Pigsy transforms back to normal shape

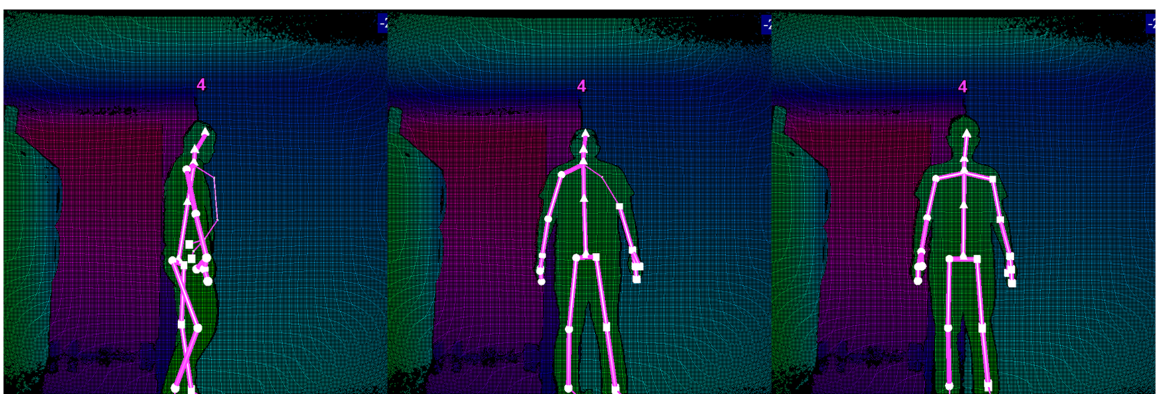


**Figure 4.21:** A screenshot of how Sandy transforms back to normal shape

Now we have figured out all the gestures we need in the system. It's time to record people performing the gestures by using Kinect Studio. All this raw data will directly affect the functionality and efficiency of the gesture database. Microsoft recommends that a diverse variety of people should be included for generalization and it's more important to record the target audience of the application. Besides, the lighting condition, sensor tilt angles and even the clothing may also influence the accuracy of the machine-learning results.

Next, raw recordings were imported to the visual gesture builder, in order to tag or label all of the frame which define a gesture. Tagging recorded data is the most time-consuming part of creating a gesture detector with VGB, but it is the most important step, because it directly affects the results. So it's worth the time to tag all the right gestures precisely and carefully.

Once the tagging is complete, VGB will generate a database using machine learning. Before using the database in the application, it's better to test it using the Live Preview tool (see Fig. 4.22), which enables us to view the results of a gesture database without having to integrate the database into an application. For example, in the Fig. 4.22, we are able to see signals generated by a current pose on the left window. It's super handy for determining whether a given gesture creates interference with another.

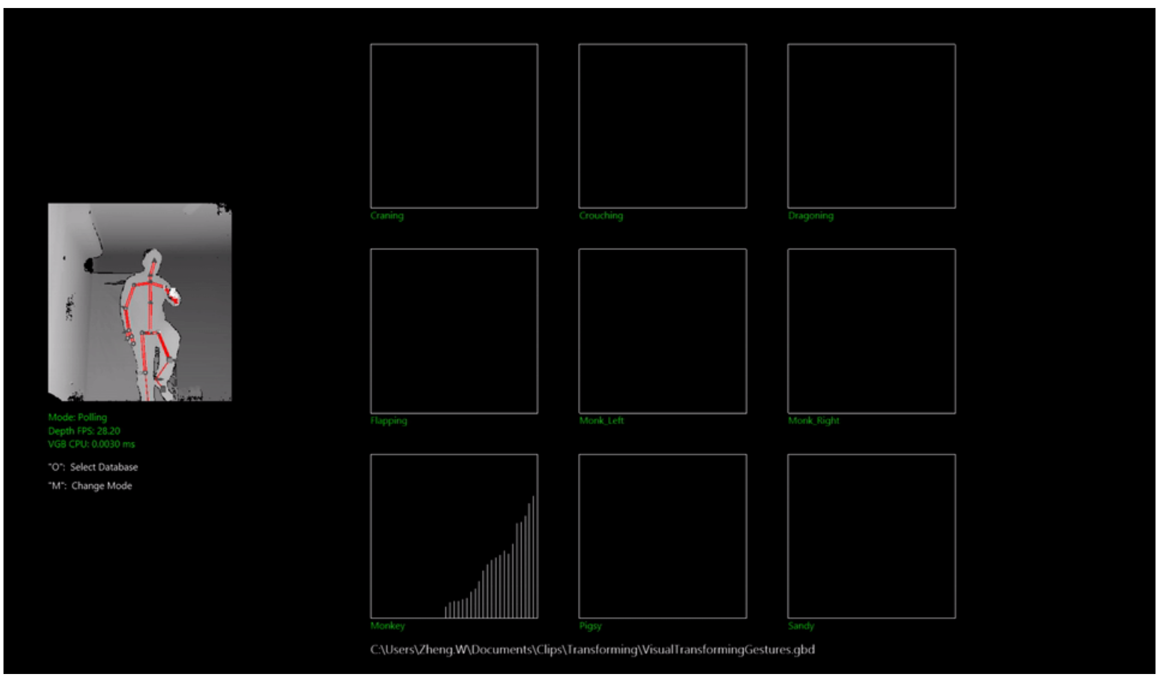



**Figure 4.22:** A screenshot of live preview using gesture database built in VGB

If there does exist interference, that multiple gestures send signals when one performs, then it's better to redo all the previous steps again and tag the right gesture carefully until we get the perfect database.

Finally we can use the gesture detector in our own application. Since all the gestures are discrete gestures, we used the confidence value to determine whether the gesture is happening or not. The Fig. 4.23 presents an example of the confidence value in our *Virtual Puppet* system, and from the results, we can see that the average confidence value is around 40 percent, which means that our gesture detector does not work very well. One possible reason for this result is that we recorded just one adult performing the gestures, while our target audience is children. However the reason is much more complicated in this case, because when recording the raw data, many factors have to be taken into consideration, such as the lighting condition, the clothing, and the sensor tilt angles, as we have stated in the previous sub-section. Overall, our system responds correctly to the gestures performed by the audience right now. So more improvements will be done in the future.

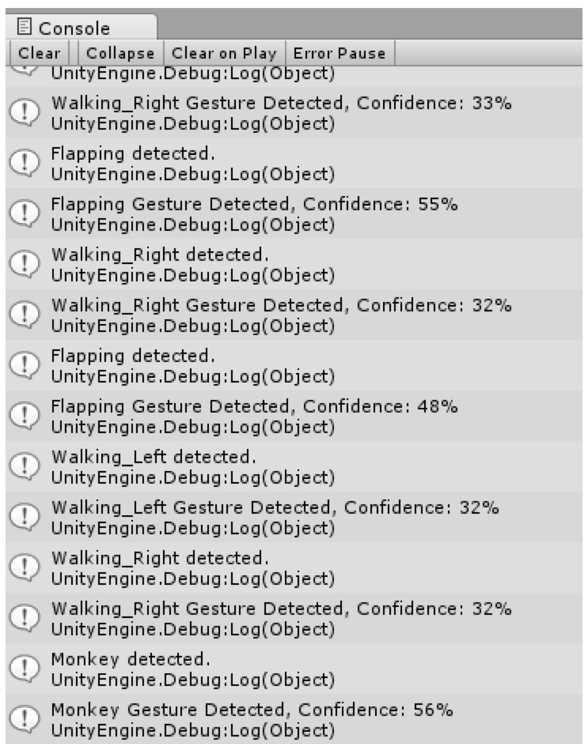



**Figure 4.23:** A screenshot of an example of confidence value in the system

To conclude, using the VGB saves us great amount of time in building the gestures, and we can still achieve high accuracy for detecting gestures even in cases where skeletal data is very noisy. While the disadvantages are that tagging the right gestures requires large amounts of time and lots of disk space for storing raw recordings. However the pros of using VGB still outweigh the cons, since more creative gestures can be implemented and the quality of Kinect applications can be raised in terms of better gesture detection.

# Chapter 5: EVALUATION

In order for the teachers' evaluations of our *Virtual Puppet* system, we had the children play-test the system first. The play-testing took place at the Buddhist Tzu Chi Foundation in Philadelphia. Kids at the center participated actively in this experience and found the contents really enjoyable. The expert panel consists of teachers from Buddhist Tzu Chi Foundation and University City Art League. All the members have rich experience with children education, and they are all teaching Mandarin and Chinese culture to the kids born and raised in the United States. After their observations of children's performance in *Virtual Puppet*, both positive and negative feedback are provided for evaluation and future developments.

## 5.1 Observation from Play-testing

In order to play test our system, targeting American-born-Chinese children, we searched for awhile in Philadelphia area and finally found the Buddhist Tzu Chi Foundation. It's located in Chinatown, Philadelphia, where children can learn Mandarin and Chinese culture only on Sundays. After a long conversation with the directors of the foundation, they agreed the research in their center and showed great interest in the project based on the fact that they wanted their children to learn something closely connected to their culture and identities.

Unfortunately we could not obtain any qualitative or quantitative feedback directly from the children in the center. Instead we were able to have them play-test the system, and our conclusions were drew from the observations of both the researcher and expert panel members.

Children in the center, aged from 7 to 15, were truly active participating in this experience. Here are the observations from play-testing.

- Initially they found it confusing how to operate the system. While as they got accustomed to the interface, they became very excited and active.

- Most of the children chose to perform as the Monkey King, which was exactly what we had expected, because Monkey King is regarded as a hero among Chinese children.
- They were intrigued by the transforming features. When they were told that they could transform into animals by mimicking the features of a certain animal, all of a sudden they became very interested and started to do all kinds of weird gestures, which from another perspective, showed children's rich creativity and imagination. Of all the four animal puppets in the system, most of the children can transform into the bird and dragon successfully without hints. While for the crane and tiger, it might be a little difficult for the children to figure out.
- Most of the children participating in this experience are actually boys, while girls did not show much interest in.
- Most of the children just passed the 'History' section in *Virtual Puppet*, which also as we expected, because it's their nature that they want something animated or fun.
- Because of the large number of children standing in front of the Kinect device, *Virtual Puppet* crashed a lot, which affected the experience in some way.
- The system did not detect children very well, due to the fact that we recorded adults perform the gestures.

## 5.2 Expert Panel

When children were interacting with *Virtual Puppet* system, expert panel members observed their performance as spectators. Of course, they would not rate or grade how the children performed in the whole experience. In order to evaluate the system more fairly and completely, the expert panel members were also given a chance to go through the experience by themselves. After all the play-testing time, expert panel members participated in an interview with the researcher. Several questions in terms of the efficiency, educational benefits and future add-ons were discussed, and answers were recorded as written notes.

### 5.2.1 Expert Panel Members

We have three members in the expert panel, and all the members in the expert panel are instructors who teach Mandarin and traditional Chinese culture in Philadelphia. All of them have rich experience in practice with children of all ages. Two of the panel members are from the Buddhist Tzu Chi Foundation, and the third one is from the University City Art League. Panel members include:

- Sue-ling Wang, Director of Buddhist Tzu Chi Foundation Philadelphia
- Ying (Margaret) Yu, Chinese teacher at Buddhist Tzu Chi Foundation Philadelphia
- Ke Xu, Chinese teacher from University City Art League, majored in Human Development, University of Pennsylvania

### 5.2.2 Expert Panel Results

Sue-ling Wang, who is the director of Buddhist Tzu Chi Foundation Philadelphia, showed great interest in the idea of using body movements to control the traditional puppets. She acknowledged that during her previous experience, there is no connection between the audience and the puppets performed by the masters behind the backdrop. Now with the help of Kinect device, the kids themselves are the puppets, so it has gradually blurred the lines between who is the puppeteer and who is the audience. In addition, the characters in the system, such as Monkey King and Pigsy, are extremely popular in the Chinese communities, since their adventure to the west has been told and adapted into films or TV series so many times. The kids would love to role play as these characters, especially the Monkey King, who serves as a hero among Chinese cultures. From her observations, the children were truly having a great time playing through the system. While on the other side, there are many limitations within this prototype. First of all, traditional Chinese shadow puppetry is all about lights and shadows, and that's why it is named as 'Shadow Puppetry', or 'Pi Ying Xi' in Chinese. So what *Virtual Puppet* lacks now is the changes of lights and shadows, which are important features that should be taken into consideration during the digitalization of traditional shadow puppetry. In addition, when multiple players control the puppets at the same time, there should be a function allowing them to record their movements and the show generated by the system. By doing that, they can appreciate their very own puppet show later, and even share through social networks, which in return, may help disseminate the charms of shadow puppetry to more people. Overall, the instructor believed that *Virtual Puppet* is successful in increasing kids' interest in shadow puppetry at this stage.

Ke Xu, who studied Human Development at University of Pennsylvania, now is teaching Mandarin and Chinese art at University City Art league. She also agrees that it is significant and beneficial to combine traditional culture with new technologies, especially at this age, when urbanization is all around in China, and people have gradually forgotten about the beauty of their own cultures. In this case, the obvious benefit is that the digitalization of traditional shadow puppetry has made the ancient art techniques more accessible to the younger generations. She pointed out that the practice of shadow puppetry requires time and effort, which can not be mastered within a short of time. However, with your body movements as controllers, it would be much easier to bring those puppets to life and perform some complex gestures, which would require advanced skills when controlling an actual puppet. In addition, Ke Xu also provided some cons that can be improved in the future.

- The system is not sensitive enough, and many gestures cannot be detected instantly, which may affect the overall experience.

- There should be some goals or achievements at the end of the experience, otherwise, the children may get bored if all they can do is stand and swipe. From her perspective, children love games more than experience. They love to compete with each other, and finally gain a feeling of achievement.

- In the history part, it would be better if there were audios telling the stories. Thus, it can make the experience more immersive and help children get focused.

- Ke and her students really liked the transforming feature. She could try this all day in order to figure out what she could transform into by mimicking other animals. In this instance, she would love to see more puppets and possibilities in *Virtual Puppet*.

Margaret Yu, who teaches Chinese and Chinese culture at Buddhist Tzu Chi Foundation Philadelphia, had a slightly different opinion on this issue. First of all, she agreed that the visuals of *Virtual Puppet* look amazing and inspiring for the kids. Initially, the system may raise their curiosity to play something new, but finally the effect did not last very long. During the play-testing, she noticed that a boy went back to playing his video games, after making some interactions with puppets for five minutes. Overall, she thought that the system may not help children raise the interest in traditional arts. On the contrary, they seemed to be more attracted by the Kinect device and how this machine works. There is something missing in the system, that could help children be more focused. So honestly this experience may help kids obtain a certain knowledge of Chinese shadow puppetry, but only very basic understandings. Chances are that when they come across these puppets later in their life, they may recognize these things as shadow puppets. In addition to this feedback, Teacher Yu also offered some improvements.

- The interface is a little difficult for kids to figure out how to operate for the first time. Besides, the machine seems not to detect very well. Some kids were holding a gesture for a certain of time, but the system did not respond immediately, which may lower their interest and get distracted by something else.

- The background image should also be changing when the puppet is moving. For example, when puppet is walking, it would be better if the landscape is also changing. So one can see houses, trees, mountains, temples, just to mention a few. By changing that, children can get more immersed in the experience and as if they were the character and walking within the environment.

- Similar to Teacher Xu's feedback, Yu also believed that there should be some game mechanics in the environment, such as fighting the monsters in order to save and protect their Master. So in the end, the kids may raise a feeling of achievement.

To conclude, all the members in the expert panel had provided me with many valuable feedback, which help me understand how to better design the experience for the children, both visually and technically. Most of their positive feedback gives us the confidence that it's worth of the time developing *Virtual Puppet*, which attempts to preserve traditional Chinese cultures.

# Chapter 6: CONCLUSION

The goal of this research was to find out what can be learned in observational research from direct observation of children interacting with the Virtual Puppet System and from interviewing cultural experts who have observed the children's performance. In addition to the insights gained from the observation and interview, we want to use those information to further develop our Virtual Puppet System. So in the future it may help the new generations of China to raise the interest in and appreciation for Chinese shadow puppetry and traditional folk arts of China. To answer this, we developed *Virtual Puppet*, an interactive learning experience for ABC from 10 to 15. Visually the virtual puppets inherited the beauty of traditional puppets with vivid colors. Technically, children can use their whole body movements, with the help of Microsoft Kinect V2, as the controllers instead of rods or sticks to control the movements of 2D virtual puppets. Finally, *Virtual Puppet* was tested at the Buddhist Tzu Chi Foundation Philadelphia. The results were collected from direct observation of children interacting with the Virtual Puppet System and from interviewing teachers who have observed the children's performance during the testing.

## 6.1 Implications

Overall, the expert panel and observations from the play testing yielded both positive and negative results relating to the effectiveness and efficiency of disseminating traditional cultures to children, who are culturally connected.

### 6.1.1 Positive Feedback

From the observations, we found that most of children showed willingness and interest to participate in this project, and as a result, the majority found the content enjoyable and got intrigued by the transforming mechanics, that they can transform into other animal puppets by mimicking. On one hand, children became super excited by the technology, and many children were curious about how Kinect worked so the 2d puppets could be controlled simply through body motions. On the other hand, children at this age took great interest in the characters in *Virtual Puppet* system, especially the Monkey King, just as we expected before the play-testing. In the Chinese communities, many parents would love to use the Monkey King and his adventures to the west as bedtime stories for their children. So Monkey King is regarded as a 'hero' among Chinese kids and teenagers since he is so powerful and possesses immense strength. In addition, we found that children were truly amazed by the transforming features because transformation is Monkey King's special strength, that he knows 72 transformations, which allow him to transform into various animals and objects. Under this circumstance, the transforming feature should be further improved in the future, so there will be more possibilities for the children to explore, which on the other side, may help them become more immersed and focused in the experience.

From the expert panel, we also got some positive evaluations in terms of whether the system can help raise the public's interest in traditional folk arts. First of all, all the three members from the expert panel agreed that *Virtual Puppet* made Chinese shadow puppetry more accessible to the ordinary people since now puppets are controlled through our body motions. While in the old times, mastering this skill requires years of practice, which may scare many beginners away. In addition, when handed an actual puppet, most of the visitors would have no idea about how to control it, let alone perform some complex gestures. However *Virtual Puppet* has made the process much easier, that many complex gestures can be achieved through data-driven solutions. To some extent, new emerging technologies have shortened the bridge between ordinary people and traditional performing arts which require complex techniques. One member from the expert panel also pointed out that with the implementation of *Virtual Puppet*, the lines between the audience and the puppets on the cloth have gradually faded away. In other words, now the audience themselves are the puppets, and the puppets will follow whatever the audience do in the real life. In this way, they would feel much more connected to those puppets instead of watching them in the traditional way.

### 6.1.2 Negative Feedback

First of all, during the game play, some experts pointed out that *Virtual Puppet* system was not sensitive enough. Sometimes, it took a long time for the system to recognize the children's gestures.

While sometimes the system did not respond at all, which had affected the overall experience. This low sensitivity can be improved through more gesture trainings in Visual Gesture Builder. As we discussed in chapter 04, in order to get the perfect gesture detector, many factors need to be taken into considerations, such as the variety of raw clips, the clothing, lighting conditions and sensor tilt angles. For the purpose of an ideal gesture detector which can be used in a variety of environment, for a variety of participants with a variety of lighting or clothing situations, we need to record raw clips as much as possible, so that we may have enough data to train the gestures again and again.

While more importantly, knowing you target audience is another key to a successful gesture database. Microsoft has suggested that, you'd better make sure the target group is well represented when doing gesture collection. *Virtual Puppet* targets at children, but instead we mainly used gesture recordings of adults, which in this case is the researcher. This may also explain why the detector did not work very efficiently and correctly at Tzu Chi center.

Secondly, *Virtual Puppet* system crashed a lot during the game play, which was another technological issues that interfered with the experience. At this stage, our systems failed to handle a large number of children simultaneously.

Thirdly, we found that only a few children chose to take a look at the 'History' part of our system, which tells the legend behind Chinese shadow puppetry. One expert suspected that perhaps it was not appealing or interactive enough for the children.

Last but not least, several experts pointed out the missing of some important elements within the system. As they stated, Chinese shadow puppetry is all about changes of shadows and story-telling. While unfortunately, none of these elements are presented in the experience. So this may not help children deepen their understanding of traditional Chinese shadow puppetry.

## 6.2 Future Works

Based on the feedback from the members of expert panel, more improvements and works may continue in the future.

First of all, for the development of the project itself, many new changes can be added based on the feedback from the expert panel. First, the sensitivity and gesture recognition should be improved. Once we have the approval, we could record children performing gestures in various environments wearing various clothes, so that we could train and obtain the gesture database from the right targeting audience.

During the game play, we found that many children showed no interest in the history of Chinese shadow puppetry. So secondly, we could add audios to this experience, that they can hear the legends. On the other hand, we could also combine the game mechanics and the story behind shadow puppetry, in order to help them become more immersed in the experience. For example, children may need to fight with the monsters in order to protect their master, which may help them understand the story better. At the same time, the background images could also be improved, so when the character is moving, it would be better that the environment is also changing as if they were actually in the puppet world. In terms of the enjoyment, every character in the experience should have their own abilities, while right now, all of them can transform, which actually only belongs to the Monkey King.

One expert also pointed out that except for the puppet itself, the system does not look like the traditional shadow puppetry. Things missing in the system are the changes of lights and shadows, which are regarded as the essence of Chinese shadow puppetry. So Last but not least, changes of lights and shadows should be added as the main characteristics of the experience. Under this circumstance, children may then have a better understanding of traditional puppet shows.

Furthermore, *Virtual Puppet* could be expanded to explore more possibilities. Chinese shadow puppetry is only one of the endangered intangible cultural heritages. With the help of new media technologies, many similar projects could be carried out to revive the past beauty of human traditions. For example, with the new release of Microsoft Kinect v2, it can detect facial expressions, which is a great chance for the public to experience the Face changing in Sichuan Opera.

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# Appendix A: Definition of Terms

This section provides concise definitions of terms used throughout the thesis that the reader might be unfamiliar with.

**Intangible Cultural Heritage (ICH):** Intangible cultural heritage, also known as 'living cultural heritage', includes traditions or living expressions inherited from our ancestors, which should also be passed on to our descendants.

**UNESCO:** UNESCO stands for the United Nations Educational, Scientific and Cultural Organization. Its responsibility is to promote international collaboration through education, science and culture.

**Chinese shadow puppetry:** Chinese shadow puppetry, or shadow play, originated during the Han Dynasty, is a form of theater acted by colorful silhouette figures made from leather or paper, manipulated by puppeteers using rods.

**Digital Puppetry:** Digital puppetry means the manipulation and performance of 2D or 3D figures in a virtual environment.

**Microsoft Kinect:** Microsoft Kinect is a motion sensing input device, which enables its users to control and interact with their computers with their body motions and gestures, instead of a game controller.

**Microsoft Kinect SDK:** Microsoft Kinect SDK stands for the Kinect for Windows Software Development Kit, which enables developers to create applications that support gesture and voice recognition, using Kinect sensor technology.

**Machine Learning** Machine Learning refers to the ability of a computer to automatically learn to recognize complex patterns in data.

**Visual Gesture Builder(VGB)** Visual Gesture Builder is a tool that provides a data-driven solution to gesture detection through machine learning, which turns gesture detection from code writing into a task of content creation.

**Discrete Gesture** A discrete gesture is boolean in nature in that it is either happening or not with an associated confidence value, such as SwipeLeft, SwipeRight, Jump, and Squat, just to mention a few.

**American Born Chinese (ABC):** American Born Chinese, also known as Chinese Americans, are Americans of full or partial Chinese, particular Han Chinese, descent.

**IRB** IRB, or Institutional Review Board, is a type of committee used in research in the United States that has been formally designated to approve, monitor, and review biomedical and behavioral research involving humans. Its purpose is to assure that appropriate steps are taken to protect the rights and welfare of humans participating as subjects in a research study.

## Appendix B: Legend of Chinese Shadow Puppetry

This section provides the legend of Chinese shadow puppetry, which can also be read in the history part of the 'Virtual Puppet' System. Due to the fact that 'Virtual Puppet' is designed for kids from 7 to 15, the legend was written in a way that kids can accept and understand. Most of the contents were written by Lin Donn and Don Donn, who dedicated to write stories and legends around the world for children.

Once upon a time, a long time ago, there was woman in one of the many kingdoms that made up ancient China. She was a very special woman, because she told the best stories.

She was married to the emperor. She was, in fact, his favorite wife. The emperor loved her stories. He loved his wife.

Sadly, one day, the emperor's wife became ill and died. The emperor was very sad. He spent more and more time in his garden, and less and less time caring for the needs of his people.

Everyone in the kingdom wad worried. One day, a priest passed some children playing with their dolls. The dolls made dancing shadows on the wall.

This gave the priest an idea. He knew the stories the emperor's wife used to tell. What if he could bring those stories to life? The priest made and painted a puppet to look somewhat like the emperor's wife.

When the puppet was finished, the priest slipped into the emperor's garden, carrying his puppet, a candle, and a curtain, waiting for the emperor to appear.

The dancing shadow drew the emperor's eyes immediately when he walked into the garden. He was entranced. He know the priest was there. He knew the puppet was there. But it seems as if the shadow was telling the story, as if his wife was spending time with him.

The emperor was no longer sad. At the end of each busy day, the emperor went into his garden, eager to visit his shadow wife and hear her stories once again.

So that is how Chinese shadow puppetry first began.