Master of Puppets: Teaching Storytelling and Culture through Interactive Chinese Puppets

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ABSTRACT
Museums, while a great place for learning, often have difficulty engaging children past surface-level information about artifacts. Our observations at the China Hall exhibit at the Field Museum in Chicago, IL, showed that visiting children often did not read the text information about the Chinese art and culture for most artifacts. One notable exception to this was the video of Chinese shadow puppets. Thus, there exists potential for introducing children to Chinese culture through interactive storytelling using traditional shadow puppets, through which we can promote creativity and collaboration. We propose a system that allows children to learn (1) the art of puppetry, (2) the art of storytelling, and (3) important aspects of Chinese culture or history through the utilization of a physical puppet controlled by the user via whole-body gesture recognition. In this paper, we showcase a physical Chinese Shadow Puppet controlled by a Microsoft Kinect that allows users to interact with a digital story.

Author Keywords
Tangible interaction; story; storytelling; narrating; Chinese shadow puppets; body motion.

ACM Classification Keywords
H.5.2. User Interfaces: Prototyping

I.2.9. Robotics: Sensors

J.5. Arts and Humanities: Performing Arts

K.3.1. Computer Uses in Education: Collaborative Learning

INTRODUCTION AND MOTIVATION
"What we learn with pleasure we never forget" — Alfred Mercier [1]

Learning is a continuous process that happens naturally for both children and adults throughout their lives. Childhood is one of the best stages for people to gain knowledge and build on it. While there is no doubt that learning in schools is one of the many sources of knowledge in life for children, researchers are looking for other environments where children learn with pleasure. Museums are one such place for children to discover and interpret knowledge differently than by the structure and curriculum of school-based learning traditions. Children often get a larger degree of freedom in learning at their own pace when visiting museums, whether while on a school trip or with family and friends [6]. Museums have always been a top tourist attraction and they offer extensive knowledge on art, culture, and science along with being a place for fun and enjoyment [14]. Falk et al. [6] explains how shared experiences, knowledge and understandings during and after museum trips benefitted family bonding, information retention, and idea exchange. However, museums often have dense or difficult text to describe the artifacts in the exhibits. Museums also rarely have child-based interaction opportunities that encourage shared learning between individuals. Therefore, engaging museum visitors with the artifacts in the exhibits and creating inviting, inclusive and educational interaction opportunities should be one of the key goals for a museum's design team.

Our observations at the China Hall at the Field Museum in Chicago, Illinois, led us to believe that there are limitations in the ways children interact with the artifacts and learn about them, whether by looking at items through glass, reading blocks of text (assuming the child can read the text), or at best, moving between text blocks using a touch screen. Almost all of these techniques highly rely on visual or just single-touch engagement that does not utilize the visitor's physical presence at the exhibit and with these artifacts to help the visitor learn from them. While the Hall contains many authentic artifacts with rich history and culture, most, if not all, are closed inside glass cases for their protection. The only interaction visitors can have with these pieces is through visual observation and reading an information-dense text explanation, one that most children do not participate in. In contrast, the Hall also exhibits a short shadow puppet show as a pre-recorded video. This section, while very intriguing to children, does not allow children to interact actively and immerse themselves in Chinese history or culture as some of the other artifacts do. Thus, we have aimed to interest children in other artifacts of the exhibit and teach small doses of information about these artifacts. This can be done through the use of traditional Chinese shadow puppetry so that children may be comparably intrigued in the rest of the exhibit while learning.

To support art and culture with the use of science and technology, we propose a design to engage children and their families in the rich Chinese art and culture by technologically enabling interactions with Chinese puppets. We believe that this design would encourage children to engage with the puppets and be a part of the story rather than being a passive participant watching a video of the puppet show. The idea is to have a physical Chinese puppet that can move parts of its body, such as the arm, in tandem with a constrained set of user movements. The puppetry set-up would also involve a background screen as a "backdrop" depicting Chinese locations or imagery, or in our implemented case, images from the China Hall exhibit. It would likewise include a short story of sparse text mixed with prompted interactions for children to practice the storytelling skill as they explore Chinese culture and the Field Museum exhibit.

The paper proceeds as follows. We first describe related work in technological interaction with puppets and learning through storytelling. Next, we discuss the design motivation in terms of learning objectives and theoretical background. We chronicle the iterative development of our prototype.

RELATED WORK

ShadowStory

Lu et al. [11] describe ShadowStory, a system that allows children to design and enact stories with puppets. Motivated to incorporate technology in teaching children traditional arts with special focus on increasing their creativity and collaboration, they created a digital storytelling system that allows children to design puppets, props, and backdrop elements for the story using a tablet computer with pen input. Once puppets are created, children can see all the elements that they designed on the screen and move them using a pair of 3D orientation sensors. As the art of manipulating shadow puppets often requires intricate skills and significant time investment to learn, the authors have simplified this with just two controls: one for moving the puppet in one of the four cardinal 2D directions (left, right, up and down) and the other for bending the puppet up or down. All the other parts of the puppet cannot be controlled and are simulated to match the main motion detected by the sensors (e.g. the arms and legs of the puppet swing as it walks). The system is implemented using a projector, a tablet computer and six wireless WiTilt sensors. The authors tested ShadowStory in a primary school and through semi-structured interviews with the children found that it helped with children's creativity (improvisations to their designs) and collaboration with other children.

One of the most important takeaways was that children were highly interested in the real shadow puppets that were presented to them after they used ShadowStory, which the authors interpreted as more interest in the culture and traditional aspects of Chinese shadow puppetry. While the ideas are similar, ShadowStory is completely digital and our method involves moving actual puppets. Through physical puppets, we believe that seeing real puppets move instead of a projection might engage children more than exclusively screen-based interaction does and we believe the results of heightened interest in learning about Chinese culture also extends to our method.

Puppet Animator

Shadow puppetry has a rich history in Chinese culture, and it requires a special level of expertise to handle the puppets deftly using sticks to control multiple and subtle joint movements. In having to consider the particular movements of the puppets, puppeteers must consider such matters as social conventions within a particular story and its related period and contexts of Chinese culture. That is, in aspiring to a rich and accurate story, they must consider certain aspects of Chinese culture that contribute to how the story would be told and how characters would behave. Being able to create and manipulate these puppets is a very challenging task that may keep children and other non-professional people from trying it. The PuppetAnimator is a system that enables inexperienced users to grow comfortable with shadow plays and animation of puppets with a pointing device, such as a touchpad and mouse. This system enables the user to create a design for a virtual puppet, organize its movement, and record the play as animation clip. Moreover, the system provides various modes of motion that simulate the physical movement of the real-world puppet. The system uses the mouse and touchpad as simple input mechanisms to make PuppetAnimator accessible to all experience levels [17]. We intend to give the user more tangible acclimation to Chinese puppetry in our proposed work as they witness physical puppets moving in response to their movement choices.

iTheater Puppets

Based on the analogy of the traditional hand puppets, iTheater is an interactive, tangible system for children to experience storytelling. The system provides an interactive platform that gives children the opportunity to engage their imagination by creating, editing, and recording computer animations through tangible handling of traditional hand puppets. A first prototype was implemented using the Infra-Red vision system. Two IR components are positioned on the arms of the puppets to interpret their movements as actions for the virtual screen characters. In addition, for this prototype, there are four predefined characters accompanied with special animations and audio effects [12].

The idea in this project is similar to our work from them technical perspective. The primary technical focus of this work is digitizing the interaction with a real puppet, while ours is lowering the effort needed to interact with puppets. This project inspired us to have predefined Chinese characters with brief stories to accompany them so as to introduce the child to Chinese culture. In addition, assigning names to those predefined characters and having brief informative text about them will be an enjoyable way for children to learn about those characters and their role in the Chinese history.

Puppet Wall

Liikkanen et al. try to model a multi-user multimodal system for puppeteering through natural interaction. Puppet Wall tracks the user's hand movements and also has speech recognition to identify emotional cues from the user. The most important part of this system design is the way it accepts multiple inputs from a microphone, 3D tracking cameras and multi-touch screen (projection). The objects that respond to these inputs include puppets, props and also backgrounds. The primary contribution of this paper was their view of how to decode user emotions from their voice and use it in augmented and virtual reality. While our idea will involve motion tracking, our design (ahead of potential future work) will not address multi-sensory input as done in this paper. Puppet Wall is aimed at professional theatre artists and their prototype testing was aimed at seeing how technology could help in improvisation of stories in puppeteering. Our project differs as we strive to keep the technology simpler (single input) and to engage children in guided texts rather professionals in improvisational stories [9].

Kinect-Based Chinese Opera Live Video Mapping

Huang et al. address active media-based participation in Chinese opera as a traditional form incorporating a variety of performance types and that, like puppetry, would face transformation over time and potential new interpretations (and, from there, interactions) in present day. The paper asserts that Chinese opera is "one of the best ethnic arts to express and represent the symbolism of Chinese characteristics. This traditional performance has gone through many changes such as the social changing. Globalization and the modernization of the media area become the biggest challenge for Chinese Opera" (Huang et al.). This paper has brought the art to projection mapping, otherwise known as video mapping or spatial augmented reality, to tell its stories [8].

The paper mentions a previous work for its reference called "Puppet Parade" in which children could move oversized Chinese puppets on a screen by waving their arms. "Puppet Parade" allow users to be not only the puppeteer, but also an actor alongside the puppets by performing such actions as petting a puppet rather than just moving it around and controlling it. This duality of interaction offers "a new way of video mapping where [an] audience can participate into the show, the visual source can be reused, and [the] audience can easily accept the performance" (Huang et al.). The project uses openFrameworks and ofxKinect. Two Kinects track the puppeteer's arms [5]. We likewise focused on Kinect and arm movement rather than just focusing on hands for tracking input and accuracy. This choice augmented our balance of goals between the intricate, particular movements of actual puppetry and a more embedded intention of using the puppets for a larger storytelling goal. We thereby have situated our project's place between puppetry and storytelling in balance as art forms.

Learning Puppet-Capable Motions for Interpreting User Movement

Lin et al. discuss a user-driven creation of shadow puppetry displays based on creating a puppet in the image of the user's facial profile and interpreting the user's movements on the basis of what recorded puppet animations suggest as dominant motions and range of motion for Chinese puppets based on their construction and traditional handling by puppeteers. The paper acknowledges that traditional Chinese shadow puppetry involves use of three rods to control nine parts of a puppet, which has seven joints allowing 12 degrees of freedom (we presume the paper to address a standard human form in describing this puppet, as animals or otherwise may warrant different structures). Of the three rods, the key one is attached at the neck to control the head and upper body, and the other two each attach to a hand. It is important to understand the construction and rod-manipulated jointing of the puppets because, "based on this control model, shadow puppets have their own distinguished pattern of motion" (Lin et al.). Lin et al. utilize the motion capabilities of this construction to identify, smooth, and in some cases, combine and relabel atomic motions of the puppet body, which are smaller stages of motion as identified across five puppet show videos that had been studied. A scripting system handles composite, or repetitive atomic, motions (e.g. breathing while stationary), which can be combined with atomic motions for greater capabilities. Each composite and atomic motion is handled by its own function that also works with time duration and spatial distance in producing animation, where animation generation is prompted by a sequence of atomic and composite actions provided as input by a scripting interface.

Not only did constraining puppet motion as Lin et al. did simplify our task (and the system's in interpreting people's movements), but it also accounted for the unique features of Chinese puppetry and its meticulous joint movement in doing so, benefitting the authenticity of the interactions between the users and puppets. It will be important to keep in mind that we do not want to perfectly mimic human motion; we want to position these movements in the context of Chinese puppetry in producing puppet motion that may indeed warrant looking less smooth or realistic [10].

LEARNING OBJECTIVES

In formulating our learning objectives, we must consider both what we wish to achieve through our design and the audience who will use said design. With our design, we aim to (1) increase engagement with users and the China Hall and (2) provide a way for users to have a greater take-away from the Hall than is currently available now. This design must be accessible to both children and adults (primarily parents) alike. Given that even within each of these two user groups there are varied levels of interest and attention, we must ensure that our design is capable of meeting our set of learning objectives regardless of these variations.

Thus, we propose to have two sets of learning objectives: primary and secondary objectives. Primary objectives are those that we hope any user will be able to take away from our exhibit even with limited interaction time (1-2 minutes) and are essential goals of our design. Secondary objectives will keep users engaged past the two-minute mark and are ones that will be achieved by people who are a little more interested in the exhibit.

Primary Learning Objectives:

- How do we ensure users understand the cultural importance and art of Chinese shadow puppetry?
- Can users get a sense of how and why puppets were used as a storytelling medium?

Secondary Learning Objectives:

- By engaging users on a deeper affective, sensory, and cognitive level, can we successfully teach users about the importance of pieces or themes in the Hall?
- Though our interaction, will users leave with a greater understanding of storytelling in ancient China and appreciation of why puppets were so extensively used to do so?
- Will the use of our system help inspire connections from our user-system interaction to other pieces in the Hall?

THEORETICAL BACKGROUND

As creativity and collaboration among children is important to their learning process, incorporation of technology to assist the process has garnered much research interest. One example of this is the magic brush [15], a project from the MIT Tangible Media group where a physical brush utilizing a camera and sensors can pick up texture and colors from nearly any source and use that to draw on the canvas. This helps children to integrate art with technology, engaging their imagination and resources in unique ways to produce artwork. In addition, Tangible Flags [4] is a mobile technology that allows young children to take notes during field trips and then collaborate with other children regarding those notes. On the field trip, children are given physical Tangible Flags, tablets, and a radio frequency identification (RFID) scanner. They can assign these tags to anything that captures their interest during their trip, then collaborate by drawing a picture or taking notes related to the flagged items using the tablet. The Tangible Flags project thereby enhances learning during and after a trip through the formation of intuitive, self-constructed associations between observations, acquired facts, and item recall. Our primary focus is to involve the art of storytelling through puppets to engage children who come to the museum. It is based on the work of Leslie Bedford who examines the ways in which the narrative or story form generates personal connections between visitors and content and thus is ideally suited to the work of museums. The author goes on to describe a particular approach used by Taizo Miyake in his work "Object Theatre" in the 1980s which embodies the essence of narrative effectively. An example of this simple approach included seating visitors to a science museum (planetarium) in a dark room to watch an artificial night sky while listening to "Twinkle Twinkle Little Star". Miyake showed that combining different technologies to have multimedia and multisensory contexts for the museum objects helps to make connections between the museum objects and their life and memory [2].

Fredericks explains several advantages of incorporating storytelling into a child's life. The author says that as children read stories or listen to them they create mental images, which increases their imagination skills. When children imagine a story with characters and scenes, stronger neural connections form in different parts of their brains, which formation helps in additional learning. The author adds that storytelling improves reading, writing and speaking skills in children, and it also improves critical thinking skills for children as they are introduced to a variety of emotions and moral values [7].

In his work *The Acts of Meaning,* psychologist Jerome Bruner discusses two features of storytelling that directly relate to museums. The first is how humans learn. He claims that people are storytellers by nature. They understand the world around them through narrative. Children integrate their desires and imagination with their family's rules and habits by constructing stories, which in turn helps them acquire language as they try to express themselves. Even after the children become adults, they continue using storytelling to negotiate meaning and express themselves. As a result, storytelling skills support a person's active role in societal construction. Furthermore, in their book *Making Connections: Teaching and the Human Brains,* the authors Caine et al. claim that information presented as a narrative is less likely to be forgotten. Stories enable our brains to organize, remember, and associate information. It is natural for our brains to organize information in the form of a story [3]. Storytelling also helps human to construct a moral position. Stories promote exposure to and reflection upon human values, believes, and faith. Through storytelling, children are able to interpret the moral of a story, analyze it, and build on it. Children experiencing the exhibit might have different moral positions depending on their backgrounds, such as religious values and culture. Miller et al. [13] discuss that this will augment the storytelling exhibit as a family-wide experience for participation and discussion. Questions such as "What did you get out of the story?" or "What did you think about the character's actions?" may arise that help children to specifically think about what they believe in, values they have, principles of morality and ethics, and how their worldview on these matters may differ from that which others hold. Stories have the power to change the moral

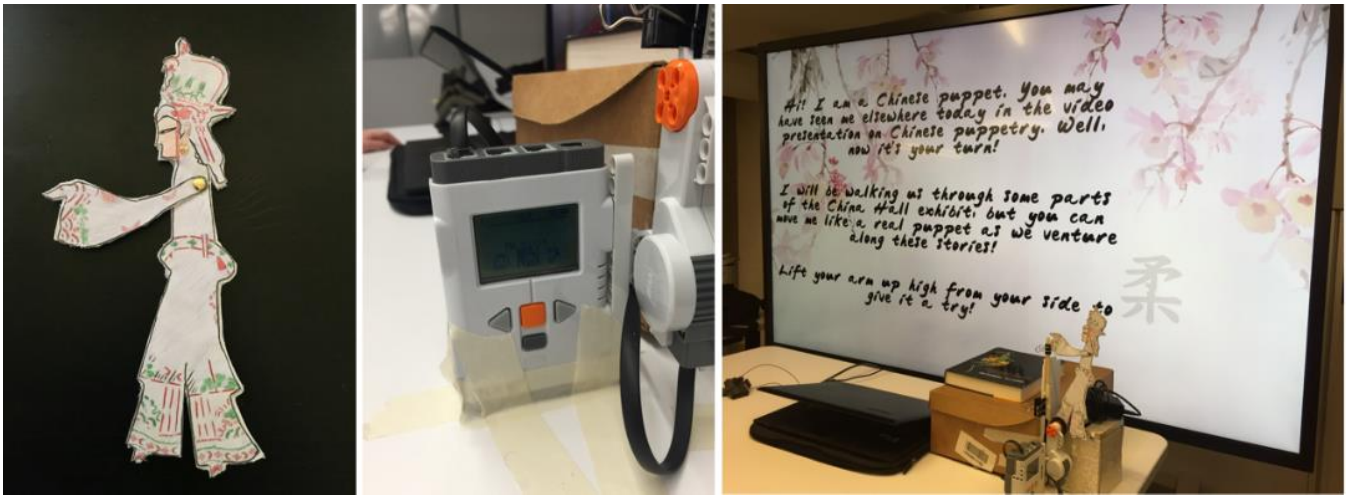

Figure 1. Initial prototype

position of a child. They help children apply this way of thinking in everyday decision-making about what is right, what is wrong and how to react to certain situations [13].

INITIAL DESIGN PROTOYPE

With our primary prototype, our first focus was to create a physical puppet similar to ones used by real shadow puppet performers. We found a physical puppet template on the Chinese Shadow Puppetry website [16], printed it out on A4 white paper, attached it to white foam and attached the puppet's arm using a brad (Figure 1) so we could allow for the user's arm movements to map to our puppet's movement. This approach to puppet design deviates from the traditional paper-only puppets since we needed a material that could support the weight of the motors to control movement. To prototype arm movement, we used a Lego Mindstorms NXT set with a single motor mounted to a rack and pinion gear system to move the arm up and down (Figure 1) and a Wizard-of-Oz technique to handle user input. When the user moved his or her arm, one of our team members would press buttons on the NXT Brick to make the corresponding movement for the puppet.

The second focus was building a story around the puppet's limited range (only up/down arm movement) of motion that showcased both storytelling and aspects of Chinese Culture, while ensuring that our puppet, per appearance, name, dialogue, and otherwise, fit to a proper historical context for more realism. We handled these matters by making our puppet a sort of tour guide for the China Hall exhibit; just as someone may make a variety of sweeping arm gestures in a documentary film or otherwise to present a scene behind them while standing in front of it, our puppet can stay in place while making user-requested gestures relevant to the scene behind it. For example, the puppet asks the user to wave to its friends in a still image from the Chinese Shadow Puppetry part of the China Hall exhibit. In one story slide, the puppet asks the user to raise and lower their arm to control the puppet's arm as the user sees China expanding (raise arm) and contracting (lower arm), in a China Hall video of Chinese border alterations over time. In this way, we help the user feel that they are an active participant in these parts of the exhibit, creating a sense of personal engagement and command or responsibility throughout the exhibit as they move with the video they would otherwise just be watching and form personal connections to the shadow puppets they, again, would otherwise just be watching on a screen in the exhibit. Their learning comes from taking an interactive journey with this puppet to accomplish small, fun sub goals suited to each part of the exhibit visited in our slides projection -- the puppet's backdrop scenery.

SUBSEQUENT PROTOTYPE

With our subsequent prototype, we have focused on capturing the user's motions and reflecting those in our puppet. We used a Microsoft Kinect 2.0 Camera to identify when a user was (1) raising their arm up, (2) lowing their arm from a raised position, and (3) bowing towards the camera. Originally, we had trained the Kinect to recognize gestures like hand-waving and head bobbing, but found that the confidence for the gestures and the overlap between gestures resulted in many unintended motions of the puppet. Thus, we included only gestures that were recognized with high confidence and limited false positives for other gestures.

After capturing the user's motion, we translated the detected arm and torso gestures (raising/lowering and bowing, respectively) into movement for our puppet. While our original Lego Mindstorms prototype was capable of the movements described above, we found the system to be too large to have for both the arm and torso. Therefore, we instead used two small servo motors mounted to the arm and torso. These servos are controlled by an Arduino Microcontroller, which turns each servo to the appropriate angle when it receives instructions from the Kinect to do so (Figure 2).

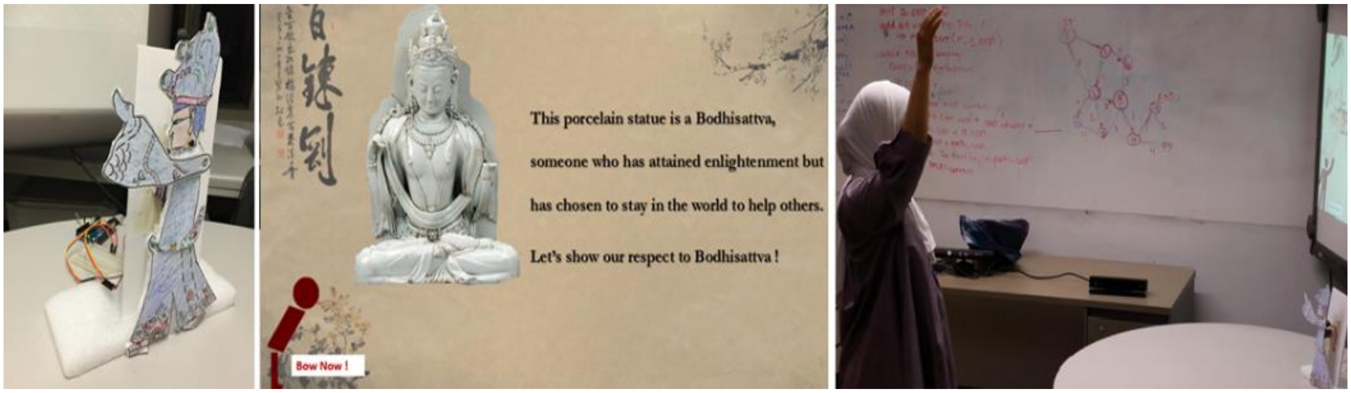

Figure 2. Subsequent prototype

From user feedback on our first prototype, we added more interaction with the user-controlled puppet and reduced the on-screen text, transferring a lot of the story from static reception to active engagement in this way. We first significantly increased the size of the puppet so that it would appear to be at scale with the projected background behind it as its interaction space. We additionally incorporated the bow gesture into our story, giving users another gesture to interact with the story. We then reduced the text for each story to be at most two easy-to-read sentences that would be enough to understand what was currently happening in the story without necessitating users to engage more with the text and less with the puppet. We also added a small icon per background to indicate what action should be performed by the user at each point in the story to further reduce the text needed and clarify what the user must do to progress the narrative (Figure 2).

A video of our current implementation can be found at https://youtu.be/LGFe1n6a090.

FUTURE WORK

As mentioned, the attempts to expand our puppet's set of motions beyond Mindstorms-driven arm movement in the initial prototype faced some difficulties with confidence and accuracy. In the future iterations, we will work to improve motions training and recognition so as to enable our puppet to do more with the two joints it has, perhaps adding more joints as seems fitting. For example, we have not incorporated knee joints but may do so for the user to bend their knees in addition to their torso and to be able to walk in place as indication of the puppet walking if needed in the story.

By adding to the set of motions the puppet can perform, we will better match the puppet to the user's intentions by enabling more complex and accurate mirroring. As one instance, if a user intends to wave in gesturing their arm from the elbow, a puppet that has added elbow joints and is accurately, reliably trained to certain waving patterns will better match the user's intention as opposed to just raising its arm up and down as a wave indication. Furthermore, the motions we currently have in place will be improved to better match the user's motions. The puppet's motion will be made smoother and more timely with the starting and stopping points of a user's movements, countering occasional lag at present.

We will also add more preset stories and, as we add a larger number of reliable motions to the puppet's capabilities, more opportunities for improvisational engagement between the user and puppet to the extent that learning remains central to what our system allows. Additional stories will offer a wider range of insights into the Chinese culture per each story's unique narrative, and these stories will go beyond a tour of the China Hall exhibit itself to include real Chinese tales. For example, we could frame a story about Bodhisattvas (referred to in the China Hall) who hosted Buddha to come to China. Such stories will help to make connections between our exhibit and other pieces in the hall. As we expand our story base, we will also add lights and staging to create the comprehensive feeling of a puppet show that goes beyond merely having a puppet and backdrop. Having a wider range of stories also invites having a wider range of characters; we shall allow for multiple puppet characters in a story, each controlled by a distinct Kinect-detected individual. Collaborative learning will thereby come not only from the user and their puppet "partner," but also occur between users in building shared experience and knowledge.

As relates to the latter goal, we must make technical improvements upon our Kinect motion recognition beyond the gesture base itself. We must determine and set rules for how the Kinect chooses whether or not to include a body in frame as an active participant and how it decides that a particular user is done engaging with it. While such decisions may seem as simple as only considering users in frame as active, the audience our project serves challenges this simplicity. Our audience may include parents standing in frame who do not wish to be controlling a puppet while instead watching their children do so, nor do we want to exclude willing actors despite only a certain number of actors at a time being permitted by our system, the story, and our character base. The latter assumption may itself warrant reconstruction. Our user base may quite likely also include very active children often moving in and out of frame without wanting to be forgotten by our system as the same active participant just in frame moments before.

CONCLUSION

Puppets offer a strong opportunity for bonding and vicariousness so as to immerse their manipulators in the stories and information they have to present. The premise of our work is that children who have fun with puppets will have fun learning what puppets have to teach them. Because the mapping of user movements to those of puppets will matter for keeping users engaged without "breaking a fourth wall," so to speak, we will focus on creating a greater number, accuracy, and smoothness of reliable puppet movements in future development. Nonetheless, our work at present offers users a tangible, fun way of engaging with artifacts and features of the Field Museum's China Hall exhibit that they may otherwise overlook with shallow attention and learning. Through technical manipulation of puppets so as to teach and reinforce storytelling, we leave visiting children, classes, and families with stories to tell of their own as they share all they have learned and newly confronted for introspection or discussion.

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