A Character in Your Hand: Puppetry to Inform Game Controls

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ABSTRACT
As VR platforms such as HTC Vive and Oculus Touch enter the gaming market with high fidelity motion controllers, they call for a re-thinking of our game control design schemes. We present a bottom-up design exploration of traditional puppetry controls in VR and the design spaces such an experimental mapping opens up for VR gaming. We argue along 3 steps for a critical return to puppetry as a reference to design and analysis game character controls. Based on existing background research that largely emphasized puppetry as metaphor, we briefly touch on the use of puppetry in current games, before presenting our own design approach and implementation of existing puppet schemes in VR. Three initial controller mappings for virtual rod puppets, marionettes, and hand puppets serve to highlight opportunities and challenges in this approach. The overall goal is to re-establish a puppet-based perspective to character controls for VR and to highlight the emerging design space for games.

Keywords
Game interface, tangible, puppetry, HCI

INTRODUCTION
Puppets are “alien others.” Objects, into which we project ourselves when we play or when we watch them at work. “They are ‘not me’ and also ‘not not me’” (Cohen, 2007) in these moments. Tillis draws the parallel between puppets and virtual characters “through a site of signification other than actual living beings” (Tillis, 1999). Like game characters, puppets are objects in-between the imaginative and the factual world. It comes as no surprise, then, that puppetry shaped the development of digital worlds and their interfaces since the beginnings of interaction design as a field (see e.g. (Hayes-Roth & van Gent, 1996)). Their history spans from The Character Shop’s *Waldo* to Disney’s *Turtle Talk with Crush*. Likewise, once video games were established as a distinct field of study, they quickly were associated with forms of puppetry and character control. Notably this connection was made from Games Studies scholars (Westecott, 2009), HCI scholars (Calvillo-Gamez & Cairns, 2008), and puppetry scholars (Kaplin, 1995) alike.

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Puppetry offers a critical perspective to the connection between the player and the game character through a well-developed mapping of human controls onto object expression. This dynamic connection between a player's own body and that of the puppet through immersion and agency combines key game criteria that have been debated in theory, design, and practice. In practice, these debates manifest in a collection of projects on virtual puppetry and game interfaces. These range from Wii-motes (Shiratori & Hodgins, 2008) to input gloves (Bar-Lev, Bruckstein, & Elber, 2005), to Leap motion detectors (Oshita, Senju, & Morishige, 2013), to Kinect puppetry implementations and haptic feedback devices (S. Kim, X. Zhang, & Y. J. Kim, 2006), to custom-built play objects (Gupta, Jang, & Ramani, 2014), to robotic control mechanisms (Jochum & Murphy, 2015), among other approaches.

Underlying these experimental setups is the importance of mappings controls in a way that positions the player in relation to the game content. Players literally project their bodies into the virtual world through these mappings (Mazalek et al., 2011) and they have been used to explore players' game-self perception (Birk & Mandryk, 2013). The role of the controller and the interaction design in this projection opens up a challenging design space for Virtual Reality (VR). It becomes more pressing, as the body-character relationship grows ever more complex in VR through effective immersion and agency. This invites us to re-approach video game play as personal expression through projected embodiment onto an object - in other words: as puppetry.

This essay follows this turn to puppetry through a hands-on experimental design exploration following Human Computer Interaction practices. Its goal is to open up the design space for VR gaming through the practical challenges and opportunities provided by traditional puppetry. The argument builds on three steps: first, it traces connections of puppetry to the fields of Human Computer Interaction (HCI) and a selection of video game examples leading up to an overview over the challenges and opportunities of such an approach; second, it looks at the underlying design approach and implementation of the *Archiving Performative Objects* project, which aimed at a remediation of puppet objects and controls in virtual spaces; third, it discusses three key mappings that were implemented as part of *Archiving Performative Objects*: rod, marionette, and hand puppets as examples for traditional puppet controls and their operation in VR.

PUPPETS IN VR

Puppetry in Games

As Aarseth established more than two decades ago: during the play activity, the "user will have effectuated a semiotic sequence, and this selective movement is a work of physical construction" (Aarseth, 1997). Since then, new interfaces have helped to shape this player's "physical construction" in countless novel ways.

The principal connection between puppetry and the emerging experiences has been traced by Calvillo-Gamez and Cairns (Calvillo-Gamez & Cairns, 2008) based on the "double-vision" of effects in puppetry wherein the puppet negotiates between the "real" and the imagined worlds. But their work offered a largely preliminary conceptual connection based on the phenomenological similarities. Building on the same "double-vision" effect - which originated in Tillis (Tillis, 1992) - Westecott positions the player as bound to the game experience through sign systems that can be understood through puppetry (Westecott, 2009). These semiotic approaches make it clear *that* puppetry can play an important but they do not identify the specific practices *how* to implement this approach. Nitsche/

Mazalek/ Clifton's work on puppetry in machinima production (Nitsche, Mazalek, & Clifton, 2013) attempts such a connection. They continue Westecott's turn to puppetry as performative play-practice but look into different interfaces and their expressive ranges. Their goal is to position machinima as another form of puppetry but they offer no framework for VR interaction. These critical and theoretical approaches encourage the inclusion of puppetry in video games. But this connection emerges not only from theory and scholarship.

Video games have established a range of performative interfaces ranging from genre specific forms, like the guitar controller for *Guitar Hero* (LoPiccolo & Kay, 2005), to the variety seen in the steady output of Konami's *Bemani* division, to the standardized input variants of whole console generations, like the Kinect or the Wii controllers. Particularly the release and subsequent hacks of the Kinect and Wii controllers led to a wave of puppet-related projects that mapped control on objects (Held, Gupta, Curless, & Agrawala, 2012) or one's body (Zhang, Song, Chen, Cai, & Lu, 2012). The Wii controller was even described as interaction device to support a "virtual puppet for the self" (Burrill, 2010) by performance scholars and applied to various puppet-like game designs in single user as well as collaborative settings (Bottoni et al., 2008).

At the same time, games continue to draw from puppetry in their design and mechanics. Video games include puppetry as an aesthetic setting (*Puppeteer* (Sato, 2013)), optional control schemes (*Little Big Planet* (Healey & Smith, 2008)), or gameplay mechanism, as seen in *Octodad: Deadliest Catch* (Zuhn, 2014). Because this argument focuses on the interaction design, the actual gameplay mechanics in titles such as *Octodad* stand out as most relevant and will be discussed in more detail.

Octodad casts the player in the role of a father and husband desperately trying to hide the fact that he is an octopus from all humans. While the game uses this narrative conceit for humorous purposes, the conceit also informs the gameplay. The player must push and pull on Octodad's limbs to give him some semblance of human movement, lest he be discovered. To do this, the game offers the player direct control of Octodad's limbs. This control is split between control of his two legs and control of one of his two arms. What differentiates this game is that players do not activate discrete animation states in either of these stages of the game. Rather, the player influences the position of the limb, and the body as a result, through forces in the game's physics system when affecting the limbs. The closest resemblance of natural motion is achieved in the game's multiplayer mode through cooperative play. In cooperative play, each player controls a single limb, or a set of limbs if there's only one player controlling the legs. In this specific case, Octodad can move and grab objects at the same time, giving him more of a sense of coherent behavior then he has in any situation during the single player mode. Notably, this re-creates the classic puppetry control scheme of *Bunraku*, which is a type of puppet typically operated by multiple puppeteers. The chief puppeteer, omozukai, controls the head and the right arm, while one additional puppeteer controls the left arm and another the legs. In that way, *Octodad* provides a *Bunraku*-inspired mapping and its gameplay focuses on the continuous practical challenges this mapping provides.

Fig. 1. *Octodad multiplayer screenshot. Each color indicates a different player*

The challenge in *Octodad* comes from the puppet-control scheme itself and dealing with this mapping constitutes the main game mechanic. It is a novelty and humorously posed challenge but it clearly demonstrates the applicability of puppet control schemes in game design and the challenges it poses.

Currently, VR game design is limited to the physical space defined by the range and setup of the tracking cameras and by the number of tracked objects in this space. This poses a number of challenges to emerging control schemes. How to control individual body parts, character position, and character movement? How to map the limited physical player's space to the less confined virtual world? On the one hand, important information is completely missing to solve these challenges. For example, the player's legs are usually not tracked. On the other hand, the range of navigation is often too restrictive. For example, the player can only navigate an approximately 5x5 m zone with the HTC Vive. This causes multiple problems for the player-avatar control mapping. One of them is navigation through space, which is hindered by the limitations of the tracking in physical space but near boundless in the virtual world. A number of VR games incorporate some form of teleportation for movement to address this problem, such as *Robo Recall* (n.n., 2017), or *Arizona Sunshine* (n.n., 2016). In those games, players "throw" themselves around an environment larger than the physically mapped space by selecting a new space to shift the virtually mapped physical space too. However, some of the games that forgo confronting the problem of player-directed locomotion have instead, like *Octodad*, used the mapping of the body (*Superhot VR* (Iwanicki, 2016)) or the mapping of the hands and head (*Job Simulator* (Schwartz, 2016)) to instead derive challenge and engagement for the player within the limitations of a more fixed space. The examples present early stages of VR game controls but they also call for more exploration. Unlike other control schemes, such as the single and dual joystick game controllers or the WASD keyboard mappings, no standard has been set for VR, leaving the field open for experimentation.

Opportunities and Challenges of Puppetry in VR

Puppet control mechanisms come in countless forms and are usually specialized for particular expressions. They include trick puppets built for unique effects, giant puppets controlled by multiple puppeteers, found object puppetry, as well as more abstract material performances. To add more dimensions to the plethora of approaches, it is furthermore common for puppeteers to control many different puppets - often of different nature - during a single performance or even simultaneously. Other puppets - such as the oversized puppets of the *Bread and Puppet* theater - require multiple puppeteers to work. Some puppetry controls are intricately connected to their performance situation and stage design. Black Theatre uses UV lighting of specially prepared puppets playing on a black stage and controlled by puppeteers clothed in black, thus invisible to the audience. Hand puppetry, as seen in traditional *Judy and Punch* shows, often uses a simple portable proscenium frame under which the puppeteers hide. Marionettes are operated from above, requiring a particular stage setup that can include multiple bridges. This indicates a rich design space of countless possible opportunities in video games but also a challenging variety to deal with.

The *Archiving Performative Objects* project followed distinct puppetry traditions as guiding practices to distinguish within this wide field. While each marionette remains unique, they all share the concept of strings as controlling devices. Every rod puppet operates in a singular way featuring unique joints or body structure but they share the form of pole-like extended control mechanisms. We initially focused on these specific control relationships of player/ puppeteer and puppet/ object and investigated a basic range of different approaches: rod, shadow, glove, and string, as well as direct object controls. These basic conditions include a widely shared basic puppetry repertoire. They provide a varied yet established range of character controls to learn from but they also offered us the necessary focus. Thus, the project's design and implementation followed a bottom-up experimental setup starting from the puppet. It allows us to study control mappings for VR based on puppetry traditions through a hands-on implementation. It 1) started from the traditional control mechanisms; 2) abstracted them from a layered approach to a puppeteer's embodiment; 3) to map them first on a game application with mouse and keyboard for technical representation; 4) and on a HTC Vive VR for experimentation.

Design Approach

The project reaches across three different fields: puppetry, HCI, and game design. Various philosophies and frameworks for interaction design exist across all these fields, following different core principles. For example, in tangible HCI foci reach from social interaction (Hornecker & Buur, 2006), to learning (Antle, 2007), to futuristic concepts of material interaction (Ishii, Lakatos, Bonanni, & Labrune, 2012). In contrast, the key reference for any control scheme in puppetry is performative expression. In fact, Proschan described puppets as "performative objects" (quoted in (Bell, 2001)). Their central task remains clear, yet the means of achieving a successful performative situation differ widely. There is not a single model of how these performances work. For example, Craig's mystical Übermarionette traces puppets' lineage to god-like representations (Craig, 1908) and sees performative action as a form of creationist activity, while other scholars have linked it to psychological approaches (Tillis, 1990), semiotics (Jurkowski, 1990), or a range of educational perspectives (Bernier & O'Hare, 2005)..

At the same time, puppetry remains a popular art practice that constantly produces new pieces, new designs, and new puppets. *Archiving Performative Objects* draws from the critical approaches listed above but its design exploration builds on a collection of historic puppet control designs, their limitations, and material conditions. Its approach to VR interaction design followed existing mechanical control schemes: namely a remediation of historical puppets' gestural, spatial, and technical control conditions. These control conditions derive from - and at times directly embody - larger design frameworks or purposes. For example, one of the marionette-type puppets created for the project was originally built purely as an educational puppet, not for any specific performance. However, our designs did not aim such a targeted usage but originated from the actual mappings at hand and the practices of handling the puppets themselves. This prevents us from attempting novel mappings solely through the lens of new technology. For example, the use of the Kinect or related sensors to map full body movement onto any kind of digital puppet is an extremely effective interaction design and has been explored in a range of projects and video games, such as *The Gunstringer* (Bear et al., 2011). But it is not a reflection of the actual puppet control schemes that our historic puppets use and thus it is not appropriated.

Instead, the most basic control model derives from the relation of the puppeteer to the object of the performing puppet: from the position of the operator and the dependent puppet, to the orientation of the object in the hands of the puppeteer, to the individual control of puppet parts through finger movements in the control scheme. This is motivated by work of puppet scholars such as Kaplin, who suggests to map puppet controls along two axes: distance and controller ratio. As our project in its current state is aimed a single user interaction, we did not include any multi-puppeteer controls (the “ratio” dimension of Kaplin’s model). However, our abstraction of controls relates to his concept of “distance” in puppet control. He defines distance as “the level of separation and contact between the performer and the object being manipulated” (Kaplin, 1999). This level of distance inspired our initial abstraction model to map possible puppet controls. Our model does not favor any single control mapping but the basic level of distance and abstraction served as an underlying logic. Different puppet formats can include additional levels, such as legs or feet, but this model was developed to help our design approaches for the puppets that were digitized from the Center for Puppetry Art’s archive.

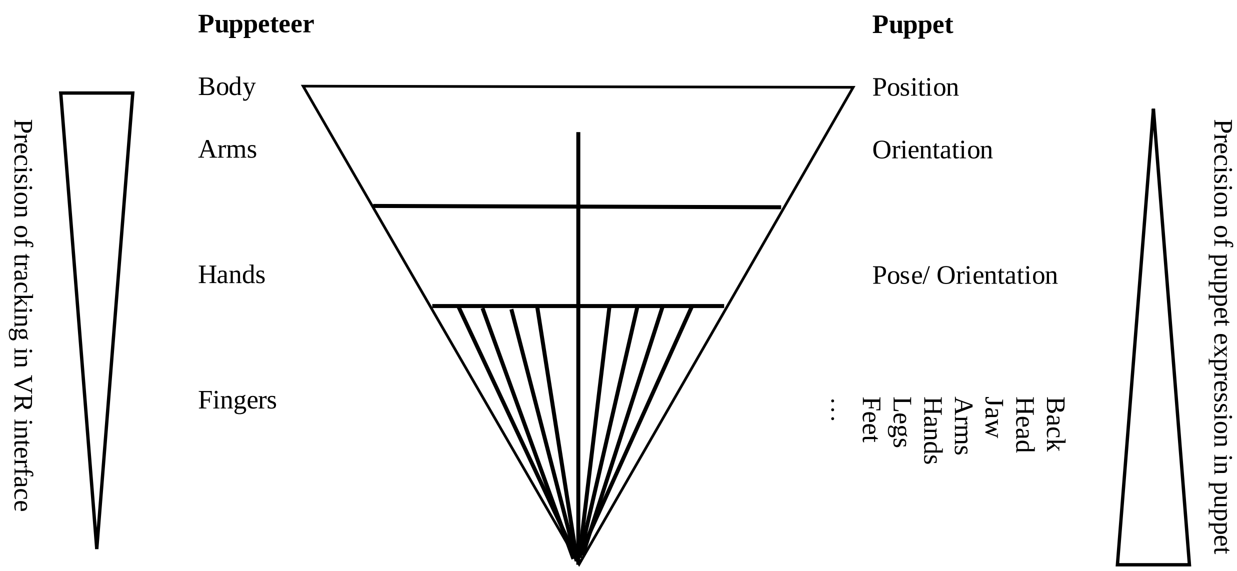

Fig. 2. Basic control dependencies in digital puppetry.

Mapping the strengths of the VR control scheme onto the expressive range of existing puppetry controls shows a principle challenge. The strength of the VR interface is in the precise tracking of the controllers, which reflects only parts of the puppet range outlined in figure 2 above. The more detailed the control of particular puppets get, the more it utilizes finger or finger sections, the less the standard VR controls support them. While the tracking of the controllers supports highly effective positioning and orientation, it does not extend to the same precision of more localized manipulation. For example, the control of marionette's arm or leg is usually provided by individual (or interconnected, as in the case of knee controls) strings. The limitations of the VR controllers pose serious challenges to these manipulation techniques. In the following, we briefly outline three mappings that address these challenges.

Implementation

Archiving Performative Objects is based on existing historical puppets stored at the archives of the Center for Puppetry Arts in Atlanta. The project digitized a number of puppets in order to experiment with their interaction design and explore whether it could be remediated in a digital environment. To accomplish this, we used high-resolution 3D scanners (FaroArm) and DSLR cameras to capture the form and texture of each puppet from its physical shape and form. We then remodeled each puppet using *Maya* using this data, rig the models, and imported them into *Unity*. The focus of this paper will not be on the models themselves or the archiving function of the project but on the design of the puppet-informed interaction mappings and the question whether those might provide workable solutions or new opportunities for game design and interface development. To test this, we had to take certain mechanisms of the existing puppets into account, such as directionality of certain joints, scale of the puppets and their controllers in relation to each other, fixation of control mechanisms and their operation, or simulation of cloth. Some of these will be elaborated further below in the sample discussion of individual mappings.

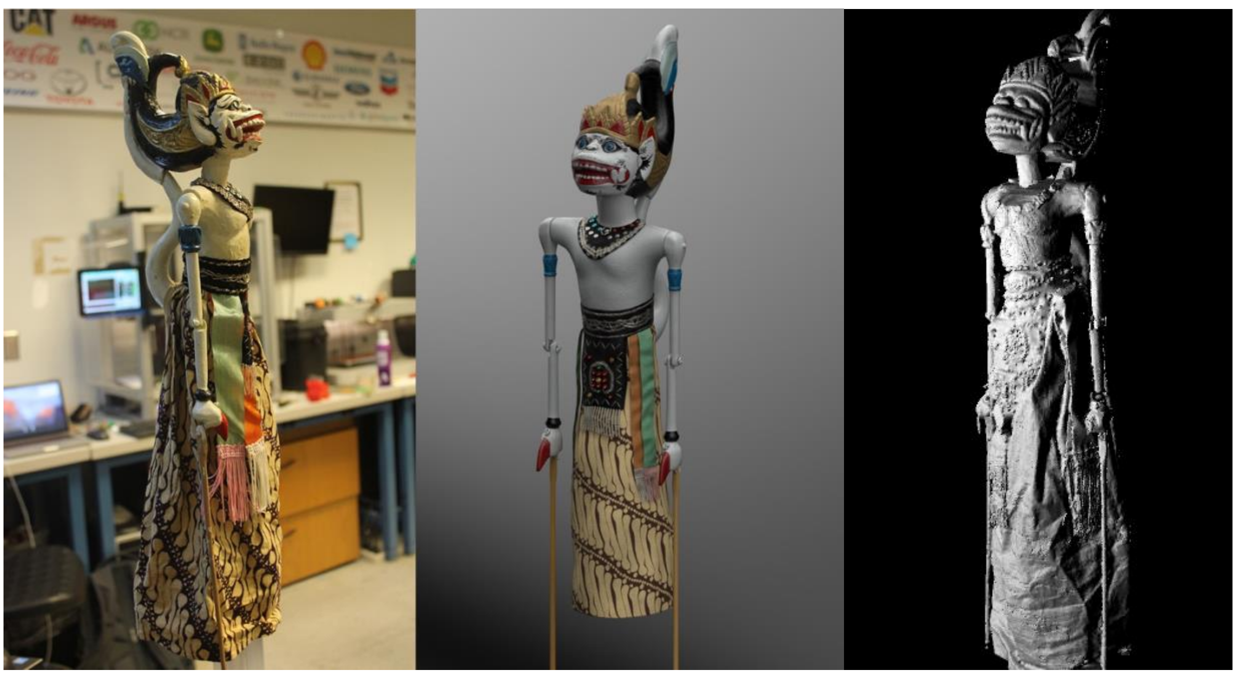

Fig. 3. Sample model acquisition: Monkey King / Hanuman *puppet original (left), final real-time recreation (middle), and 3D scan model (right).*

Archiving Performative Objects utilized *Unity* to create two main digital versions of each puppet: a VR instance and a web-based version. The web versions were simplified versions of the VR models but optimized for mouse interaction. In the web versions, players can grab certain control points to manipulate the puppet object. This control is implemented largely as a form of technical exploration. Because the manipulation is limited to one control point at a time, it does not support actual performance on the necessary level of detail. Instead, these web implementations serve as visualizations of the archival aspect of the project. As their interaction design was much more limited than the VR one, the argument here, will concentrate on the VR version of the puppets which offers a richer palette to the player

We began our experimental setup with our simplest puppet, *Trixie the Brick*. Trixie is an example for found object puppetry: a brick wearing a tutu. Using everyday objects as puppets has a long tradition in puppetry. In this case, it was realized by Ann and David Powell for their performance of *The Brick Brothers* (1981) in which Trixie performed as a trapeze artist. Trixie is the most intuitive virtual puppet to engage with. One has to pick her up to bring her to live and the virtual object reflects the direct control by the player, comparable to existing VR games such as *Job Simulator*.

From this basic point of departure, we explored increasingly complex puppets designs from *Wayang Kulit* shadow puppets, to marionettes and hand puppets. Each puppet's mapping is based off the principles taught by the Trixie mapping: grabbing a key control point to manipulate the puppet object or parts thereof. But different puppets used very different mappings in achieving this control.

The puppets we chose to explore are a sampling of various puppetry practices and we created multiple variations of each based off different puppets from the CPA. The following will outline three key mappings that were adapted in our project to fit the VR setup. Each mapping opened up new design opportunities that often related to but extended existing game setups. We present them here as hands-on examples for further discussion and development of a puppet-based VR control scheme.

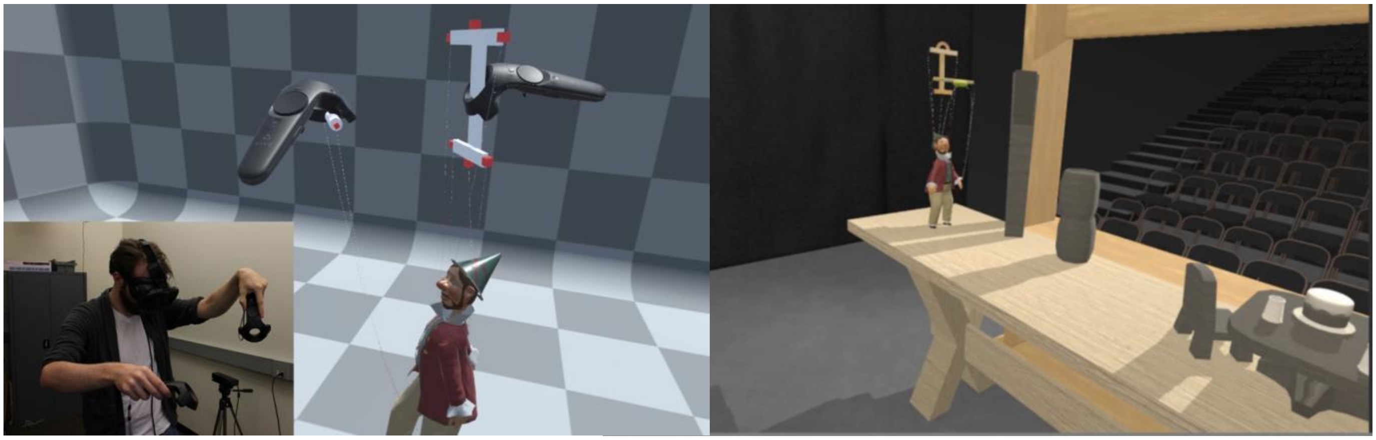

Fig. 4. Sample puppet implementation of a Kasperl *marionette puppet realized in VR with inlay showing the physical control handling of the HTC Vive (left) and realization within the final virtual stage (right).*

Mapping Rod Puppets

Shadow puppetry, a sub section of rod puppetry, is possibly the most developed puppetry genre in HCI. This can be traced to an intense interest in preserving shadow puppetry in Asia. Oftentimes, puppetry is seen as endangered by more modern media developments such as video games (X.-f. Huang et al., 2015; Lu et al., 2011). In response, educational projects like the *ShadowStory* project provide digital interventions to widen access to puppetry practices. The project notes that only 1 out of the 36 participating Chinese school children had ever encountered shadow puppetry as a live art form. To counter this, Lu et al. implemented a project where students can design own virtual shadow puppets and control them via customized sensors to develop and share stories (Lu et al., 2011). But the provided solution remains highly customized. In contrast, Zhang et al. re-use the more standardized Kinect interface (Zhang et al., 2012) but here the challenge is that the rod controllers are reduced to a direct mapping on the Kinect-tracked player skeleton. The rod controller as defining element of the puppet itself is neglected. Equally driven by a heritage-based digital approach, Lin et al. include an automated construction of Chinese-style shadow puppets in their work (Lin et al., 2013). But the animation of these puppets is left to a computer-controlled system that triggers selections from an “atomic motions” system. It does not utilize direct human manipulation.

Fig. 5. principle rod puppet control scheme (left) implemented controllers and pick up functionality (middle) controlling the Wayang Kulit *puppet with different hand controllers behind a projection screen (right).*

Our system remained close to the challenges of actual sample rod puppets. A particularity of rod puppets, such as the depicted *Wayang Kulit* sample puppet, is the fact that puppeteers do not necessarily control only a single rod with one hand. They regularly hold more than one rod in one hand for manipulation. None of the systems we encountered took this into account. In our case, the principal mapping allows players to pick up the puppet at the rods and manipulate it through them. Holding the “trigger” button on the Vive enables the player to pick up another rod with the same controller and manipulate more than one rod with one Vive controller if so desired (see fig. 5 above middle). Players can let go of them and/or pick up an another one to continue play (fig. 5 above right). The concept of simultaneous but separate character control systems has been realized in the video game *Puppeteer*. Players in *Puppeteer* can control two different puppet characters moving across a 2D plane at the same time using one joystick of the Dualshock’s controller each. This loosely mirrors a shadow puppet approach even though the puppets in *Puppeteer* are full-bodied characters on a visually three-dimensional stage. However, it does not support dynamic changes between these mappings.

The sample *Wayang Kulit* puppet is performed in relation to a projection screen, which emphasizes the growing importance of a performance situation in the design of the handling. Traditional *Wayang Kulit* puppeteers - the *dalang* - use the distance to the screen, the pressure of the puppet onto that screen, and the positioning of the lamp among many other details as elements of accentuation. The current limitations of real-time render engines reduce the variety in the digital domain. But, for example, the flexibility of the rod as one presses the puppet against the screen is a basic measurable control component that could be used for many purposes.

Mapping Marionettes

Marionettes have been mapped on tangible input devices in various ways. Kim et al. mapped the controls on the stylus-like interfaces of an Omni controller (S. Kim, X. Zhang, & Y. Kim, 2006). This allows not only for precise input but also for haptic feedback to the user. The limitations of this system are both in the larger scale controls for the puppet and in detailed control mechanisms. The single access point by the Omni pen-like controller excludes any separate control schemes such as pulling a particular string or two at the same time. On the larger scale, moving the puppet through space or lifting it up are movements limited by the range of the Omni controller's arms. The same limitations apply to mappings directly on hand and finger control when using the Leap controller for marionette-like controls (Oshita et al., 2013). Oshita et al. used the Leap Motion Sensor as main input mechanism for a PC and monitor-based system, limiting the sensing area to the Leap's specifications and battling issues of occlusion within those.

The *Archiving Performative Objects* project uses variable mappings of the VR controllers onto different kinds of marionettes. The typical dual control mechanism of the marionette has been implemented (fig. x). Users can grab each control element in any angle suitable for them, using the trigger button. Once grabbed the controls stay mapped on this device and react accordingly.

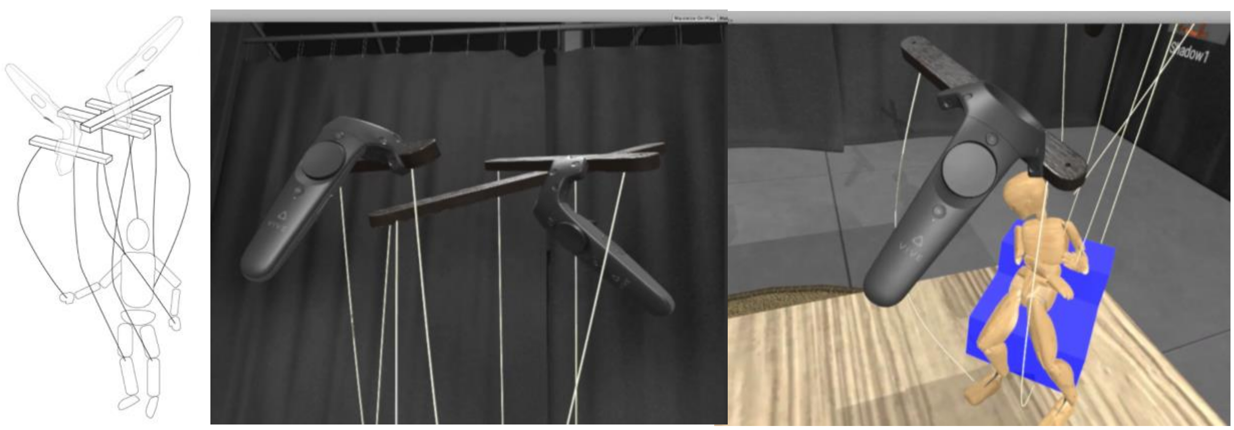

Fig. 6. principle marionette control scheme (left) implemented visible controllers and detaching functionality (middle) controlling the Educational Puppet *with different hand controllers (right).*

Our mapping addresses some of the issues identified above. Most importantly, it allows navigation of the puppet in and through space and it is less bound to local manipulation. This allows for a 3rd-person-like character control in VR. The mapping of the marionette's original controls is replicated in the positions of the two Vive controllers leaving the touch pad and buttons open for more detailed interaction. The most relevant improvement of the mapping, however, is the option of spatial navigation. The marionette control realized in the HTC Vive offers a way to open up spatial navigation through virtual worlds through a 3rd person perspective and the use of traditional puppet mappings.

Another opportunity that emerged from the remediation of the existing controls was the modularity of the controller itself. Our specific puppet features a detachable front controller for the manipulation of the puppet's knees. Such a feature is rather common in puppet and marionette designs. One can re-attach this front part to the main controller at any given time, thus freeing up one hand/ controller to engage differently. *The Gunstringer*, as one example of a marionette-like control scheme in game design, has a fixed association: left hand for directional and jump control (one cannot move backward or outside the prepared rail experience), right hand for targeting and shooting. Including the controller itself as a variable object would open up a wider range of interaction designs and states.

Mapping Hand Puppets

Hand puppets have been modeled in the field of tangible user interfaces. Ralph Baer, pioneer in the development of video game technology, even filed a patent for hand puppet controllers in 1983 (#US4540176 A) to better bridge player engagement "into" the screen. In puppetry, hand puppets are considered "closer" (Kaplin, 1999) to the puppeteer than marionettes. Kaplin argues that the wider the distance to the puppet, the more technology for its control is needed, yet hand puppets as one of the "closest" puppet types to the human performers are challenging precisely because of that closeness. They pose a number of challenges in design and existing sensing solutions are usually one-off prototypes that rarely relate to existing interfaces.

Wang et al. tested individual markers on a puppeteer's hand to track particular hand puppet reactions (Wang, Tzeng, Kuo, & Chen, 2010). Their focus on actual puppet expression is notable but their visual marker approach remains highly individual. Du and He's *VRSurus* project uses a custom-build puppet with integrated sensors in a VR setting (Du & He, 2016). *VRSurus'* approach provides some tactile feedback and accelerometer-based sensing of user input. But the puppet is a single-standing prototype and more a proof of concept prototype. Other work in digital puppetry has struggled e.g. with the accurate modeling of joint physics and cloth behavior (S.-H. Huang, Chi, & Li, 2011), a challenge that our system addresses by optimizing existing animation and cloth systems in *Unity*.

Our mapping reflects the "close" control demands and shifts the control scheme up to the strengths of the VR controller as conceptualized in fig. 2. The Vive controllers are set to control one finger each, splitting the "close" single hand control of the original puppet to a technically more distant, but more expressive manipulation scheme on the controllers. In addition to this dual hand control one of the touch pads operates the puppet's head. The index finger controls the head in the traditional mapping and depending on the user's preferences, this is still possible in our setup. More likely is a use of the thumb, though. Once again, the trigger button is used as a grab function to allow users to define their own best angle and control condition. Spatial control is possible, but not emphasized. Instead, the localized rotation around the closely aligned control points of the hand puppet are pushed to the forefront. The effect relates loosely to the control of one's Sackboy character in *Little Big Planet* (Healey & Smith, 2008), where players can control arm movements with the Dualshock's two joysticks and emotive facial expressions with the d-pad. *Little Big Planet* shows the shortcomings as much as the potential of such a mapping: the interaction is highly engaging but the joystick interface too limited to explore it further.

Fig. 7. principle hand puppet control scheme (left) implemented puppet pick up (middle) controlling the hand puppet with different hand controllers (right).

As with the marionette interface, our hand puppet mappings have limitations. Mapping a finger onto a fixed stick-like controller avoids any bending or twisting of finger joints. Data glove input devices would allow for a possibly more direct recreation of the original glove puppet setup. Yet the goal was not a truthful recreation of the ergodic condition but an experiment in possible mapping. The key design decision, here, was a shift along the strengths of the VR controller's abilities to respond to the puppets' expressive range as sketched in fig. 4 above. Balancing the two components against each other opens up a puppetry-based design space for VR interfaces.

CONCLUSIONS

There are numerous challenges that a standard VR interface cannot fully address. One of them regards the lack of haptic feedback. Currell emphasizes "[t]he essence of good marionette construction is balance and distribution of weight, coupled with flexibility of movement and joints restricted appropriately to allow adequate control." (Currell, 1999). Without haptic interfaces, such weight and balance remain only visually simulated and our system might model physical behavior of the puppet and simulate e.g. its weight but it cannot recreate a fully balanced model. The level of detail in control and feedback are a constant challenge. However, as design approaches the *Archiving Performative Objects* project manages to open up and exemplify new design spaces for VR game interfaces.

The three main sample mappings exemplify different opportunities that open up through bottom-up inclusion of puppetry principles in VR controls. The rod mapping is an example for variable control schemes and emphasizes the relationship of the puppet to the environment. The marionette mapping is equally variable through a changing control mechanism and it offers a possible solution for a 3rd person VR control scheme that might allow higher mobility through spatial tracking of the Vive controllers. The hand puppet mapping demonstrates varying granularity where controls shift between different levels of "distance" as outlined by Kaplin. The brief discussion opened up novel design spaces in all three conditions that expand beyond the related existing game examples.

The project is work in progress. But the above outlined practical design solutions open up possibilities that a theory-driven approach alone would miss. They do not directly map on specific game design challenges, nor were they meant to, but they indicate future questions and design opportunities. A key feature that they share is a particular take on 3rd person controls in VR. As puppets invite a cognitive shift from one's own body into that of the object, they also provide a gateway to design 3rd pov VR controls. This allows for a more nuanced design space than full immersion vs bodily detachment (Black, 2017). Such wider design spaces are much in need for VR. Current schemes struggle with basics such as movement through space and limitation of players' performance areas. Yet, these are challenges every puppeteer masters when performing. The here presented design variations adopt existing control schemes to VR conditions. They build on already established relationships between an object-character and subject-player shaped by puppetry approaches that utilize one's self-projection into the puppet and provide design solutions for effective mapping of this projection in VR. Because puppetry control operates through a personal projection of the operator into the puppet/ object, the proposed 3rd person puppetry approach would open up new designs for game controls in VR.

Another emerging effect is a shift between control accuracy and basic control schemes. The expressive differences between physical puppets and VR controllers can be bridged by shifting control schemes. Even if a puppet in VR might demand highly detailed controls, the VR control mappings can shift - as seen in the hand puppet mapping - to support the required level of detail through the technology available. Or they can be flexible in terms of how many mechanisms are controlled by one VR device - as seen in the rod puppet mapping. Or they can use the modularity of the control mechanism itself to shift variances of input - as seen in the marionette mapping. This emphasizes a possible richness of mappings and their interconnections. The result can be perplexingly complex as the emerging control schemes differ widely.

This complexity increases even further if one includes the role of the surrounding VR stage in the mapping, as hinted at in the shadow puppet example. For the *Archiving Performative Objects* project, we modeled not only the puppets and controllers but also a stage environment and an audience room (see fig. 7, right). Extending the control mechanisms to these spatial conditions would further augment the available puppetry vocabulary. It would not make designing VR controls easier but richer. And this might not be a bad thing. In these early days of VR games, interaction design is in danger to be misinformed by past game controller traditions or build on technical traditions or mismatching game design tropes (e.g. the WASD controls). It might miss the necessary richness of expression that puppetry suggests. We propose to focus on existing puppetry traditions to build Tillis' "site of signification" from specific puppetry traditions. The results will be more diverse and not necessarily easier to learn but it will inherently reflect long-standing encounters with the performed object.

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