Meeting the virtual body: Challenges in digital puppetry

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Puppets are constantly mediated and they can gain a lot from mediation: from wider access, to novel forms of expression. Increasingly, these media have become digital and pose new questions. The *Archiving Performative Objects* project, conducted at the Georgia Institute of Technology in collaboration with the archive at the Center for Puppetry Arts, faces a few of these emerging challenges. The project focuses on digitization of existing puppets and the re-mediation of their control schemes. The goal is to learn more about archiving of performative objects through interaction design. This relies on two core dimensions of digital media: procedurality and mediation.

A 3D scan provides detailed views of the puppet's body, texture, and scale from every angle. But performative objects such as puppets differ from other 3D models, such as archeological sites, art pieces, or architectural structures. In the case of puppets, it is not sufficient to digitize the puppet body as 3D model for visualization. It is not just the form and shape but especially its handling and operation by the human hand that define a puppet. If that control is lost, the puppet loses its main function. This human-infused quality provides the meeting point of ephemeral performance and material presence; of physical bodies and immaterial projection through manipulation. As a result of this meeting, puppets have a presence, what Frank Proschnan called "material image" (here cited from (Kaplin, 1999)), that carries elements of life – and even death (Williams, 2015) – through their manipulation delivered by the puppeteer. Virtual puppets, on the other hand, are simulations. How can we provide access to these simulations in a meaningful way and demonstrate the richness of the puppet object through digital means? How can we conserve and present performative objects' functionality through 3D technology and interaction design?

The *Archiving Performative Objects* project sets out to answer some of these questions through a multi-step approach. It will serve as a work in progress example to touch on the question how digital media affect the relationship between puppet and puppeteer. A central point throughout will be the question of mediation in the age of video games, Virtual Reality (VR), and novel interfaces. A second focal point are the procedural qualities (Murray, 1997) in digital media and how they are realized through interaction design. Both will be discussed through challenges faced in the ongoing research project. Because this discussion is built around the project, it is necessarily limited in this reach. Many possible avenues are not covered, from existent digital puppetry examples to historic foundations. However, we hope to provide a sample discussion of the puppet-puppeteer relationship in digital media through the lens of our particular project and its struggles.

New Realities

Researchers in Human Computer Interaction (HCI) recognized their field's connections to puppetry early on. Both practices center on the shared focus on an interpretation of the human action, performed, and realized through some form of technology. Puppets come into being as objects "capable of existence" (Jurkowski, 1990) in their performative moment and this corresponds to Human Computer Interaction, where Drucker argues for such performative

materiality that it “has to be understood in terms of what it does” (Drucker, 2013). The principle of “ergodic interaction” is used by Aarseth to distance video games from other media. It describes a performative movement, “a semiotic sequence, and this selective movement is a work of physical construction that the various concepts of ‘reading’ do not account for“ (Aarseth, 1997). Both, interaction and puppetry, depend on the human performer for the “doing.” Both depend on a technologically empowered translation of these actions.
Especially the tangible and embodied interaction research community experimented with various forms of interface designs in forms of digital puppetry. This ranges from using 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 (Kim, Zhang, & Kim, 2006), to custom-built play objects (Gupta, Jang, & Ramani, 2014), to robotic control mechanisms (Jochum & Murphy, 2015), among other approaches.
A particularly well developed puppetry genre in HCI is that of shadow puppetry. Some of the projects in this field position the puppetry practice in a larger cultural tradition, one they often see endangered by more modern media developments such as video games (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). Projects like these demonstrate that novel interfaces can map effectively onto puppet controls and they often show that these controls work successfully with various audiences or inspire technological advances. However, there are three key problems with HCI-based approaches. First, they focus on the technological challenge. For example, when discussing “guidelines and best practices” for digital puppet systems, Hunter and Maes focus entirely on technological solutions related to computational challenges, not the performance of the puppets themselves (Hunter & Maes, 2013). Second, too few projects include actual puppet experts as consultants to ensure that the digital representation is appropriate. Their primary audiences are other HCI experts, not puppeteers. Third, the majority of projects demonstrate a single innovative mapping approach, as seen in *ShadowStory*, which remains limited to custom-built hardware and specialized software (Lu et al., 2011). Consequently, each project allows for a digital encounter with one kind of control set up only and comparisons between different mappings and effects are near impossible.

Into Media

The *Archiving Performative Objects* project (NEH Research and Development grant PR-253380-17) aims to develop an 3D interactive system to remediate digital operation of 3D scanned puppet objects. In collaboration with the Center for Puppetry Arts, we scanned about a dozen puppets from their archive, integrated a selection of different puppet types into a game engine, and developed different control schemes for these puppets in VR. Each stage faces its own challenges: archiving puppet objects through digital media is a relatively new approach with no set standards, 3D scanning of mixed material objects remains daunting, transfer of these data into a real-time engine depends on lengthy data optimization, and conceptually most challenging: reflecting the unique control schemes of individual puppets in the largely standardized field of game controllers and VR interfaces poses a massive design challenge.

Tillis draws the parallel between puppets and mediated characters "through a site of signification other than actual living beings" (Tillis, 1999). Our project has to define this site for a complex encounter of different bodies defined by action that maps between them. Video games provide a rich and accessible venue for virtual heritage (Champion, 2015) and interactive game technology offers powerful tools to explore this encounter. That is why *Archiving Performative Objects* uses game-based technology and interaction design in a form of virtual heritage. The virtual models are approached not as replacements of the original puppets but as reference copies made accessible through video game technology. The virtual object becomes a playable reference. The notion of such reference objects is not new to puppetry archives. Fred Tickner, a master of Punch and Judy puppets, had suggested to create a "standard set" of Punch and Judy figures for the National Archive (Dixon, n.a.). Likewise, when performances use historic puppets they might have to recreate puppets and objects that are too fragile for active performance settings. In that way, the *Puppet Story*'s performance of *Shakespeare: The Puppet Show* (2014) was based on the puppet collection at the V&A but recreated puppets for the actual performances. Similarly, digital object data provided by this project will not serve to replace existing historical artifacts but to offer an additional layer of reference for scholarship (as seen in the case of Tickner) and possibly performance (as seen in the case of *Puppet Story*). The following sketches the key steps from digitizing physical models to mapping their controls in virtual worlds

Making Virtual Puppets

The Center for Puppetry Arts (CPA) stores more that 3000 objects, puppets, and other materials in their archive in Atlanta. Only a fraction of the collection is accessible to visitors and archived puppet objects are by and large inaccessible to the outside world due to their fragile nature. To create reliable reference objects that might be more accessible, a selected group of twelve different puppets representing different puppet types were selected for 3D scanning. None of the original puppets could be handled by the researchers at Georgia Tech, which led to various scanning sessions first at the CPA and later at the Invention Lab at Georgia Tech. The project experimented with different scanning methods, including a Skanect set up, which uses the widely available Kinect sensor and a Next 2.0 3D scanner, before we settled on the best quality scanner available to us: a FaroArm laser scanner.

These tests quickly showed challenges that puppet materials pose to 3D scanning. Puppets regularly use wide varieties of different materials including metal, wood, cloth, foam, as well as details made of feathers, plastic, hair, and lace. The combination of these materials make up the particular visual identity and performative body of the puppet but they also make scanning the puppet rather difficult.

The FaroArm uses a 7-axis arm that has a laser scanning tip on its end. It offers a much higher scanning density (~ 0.001 in) than e.g. the Next scanner but it is stationary. The device is installed at the Invention Lab at Georgia Tech and all puppets had to be brought from the CPA

archives to campus to be handled by the specialists from the Center, Kelsey Fritz and Kayla Wirtz. Even though it provides a higher level of density, the FaroArm can still struggle with the scanning of the different material types used on a puppet body. In addition, data sets acquired through these high detailed scans are too big and not yet functional for any real-time interactive application. To adopt the puppet models into the underlying real-time 3D engine (*Unity*), we used the scans but re-built polygon geometry around them using the 3D modeling software *Autodesk Maya* and additional digital imagery to capture the textures of the original pieces. This resulted in a multi-tiered data set: the original scan data from the FaroArm, the remodeled real-time model with textures and UV maps, and in specific cases a third data set constructed in *Meshmixer* for 3D printing of the puppet components.
The results set the foundation for what Tillis termed *media figures*: "figures whose performance is made possible through technological mediation" (Tillis, 1999). Tillis argues that such a media figure's presence "is actually created by the medium. They are not media reproductions […] but original productions made possible through media." (Tillis, 1999). According to him, they differ from traditional puppets exclusively in their lack of tangibility. Instead of deconstructing the original's presence - or as Tillis argues in reference to Benjamin: its aura - they create their own through the forces of their set media. But, as noted above, the recreation of the object in 3D addressed only the first challenge of mediation. The second was to map a puppeteer's action onto those digital models.

Figure 1 Monkey King sample puppet: original puppet (left), real-time re-modeled version (middle), 3D scan data (right)

Mapping controls

The project provides two different approaches to implement virtual puppetry control schemes: one is a basic representation built in *Unity* that runs in a web browser. It does not support a “playing” of the virtual puppets but an exploration of different joints and manipulations. Puppeteers can select individual control points with their mouse and keyboard interfaces to manipulate those joints individually. This version uses a plug in available for all main web browsers and does not require any special input devices. It allows for a wide access to virtual puppets as archival objects. Each 3D object can be rotated, zoomed in, and individual joints can be operated. The approach mimics that of existing online archives of 3D objects - as seen, for example, in the Smithsonian’s digitizing project (https://3d.si.edu/).

Figure 2 Prototype in action: Vive system (inlay picture) as it controls a Kasperl body with virtual controllers (larger image)

The second approach uses the same 3D *Unity* engine but is realized for a Virtual Reality environment. The VR set up is designed to allow for a more performative situation, where the virtual puppets can be manipulated in greater detail. This is further supported by a virtual stage modeled after an existing stage at the Center for Puppetry Arts.

The set up uses the HTC Vive system featuring a Head Mounted Display (HMD), a limited sensing area that allows movement within a certain range (the manufacturer suggests 15’x15’), and two special hand controllers as input devices (see inlay picture in fig. 2). To operate, the system also needs a high-end consumer PC (in our case a desktop PC optimized for gaming and VR performance; featuring an Intel i7-6700/ 3.4Ghz and a Radeon RX 480 graphics card). The Vive is commercially available and does not require any unique or customized interfaces. Still, these set ups are rarer than the basic internet browser condition of the first realization. They need powerful PCs, somewhat expensive interface systems (the Vive currently ships for $ 600), and stationary set ups that require a dedicated space.

The main advantage of the Vive system is that it tracks a puppeteer’s head movements, two hand controllers, and various button presses on those controllers. The Vive uses this information to generate the responsive VR environment through the HMD allowing for a highly immersive control environment where virtual puppets follow a puppeteer’s movements and puppet movements can be mapped on the position and orientation of the Vive hand controllers. In that way, the VR installation allows for the control of the whole performing object at once through an in-between puppetry system. One has to play the interface to reach the virtual environment. Because the interface is highly responsive and immersive, this play task is usually easy to pick up but it remains an element of the mapping. For example, the size of the hand controllers, the texture and responsiveness of the buttons, and the weight of the HMD are elements of control that are part of the Vive system - not of the virtual environment. Furthermore, the controllers are standardized, this means that mapping the control mechanisms of the unique puppets onto a standardized VR system remained a challenge.

Playing Different Virtual Puppets

The selection of digitized puppets includes a range of different puppet types: marionettes, hand and glove puppets, rod puppets, shadow puppets, and found objects. Each of these types features its own control scheme: some operate with rods, others through strings, or direct object manipulation. In our case, the remediation of each puppet had to include not just the representational character (the shape, colors, textures) of the puppet in the form of 3D data but also their control mechanisms in the form of equally unique yet accessible interaction design. How to create appropriate control schemes for such unique performing objects within the limitations of standardized digital interfaces?
It was necessary to design individual puppet controls that fit the commercially available digital input systems provided by the Vive system but also relate to the expressive language of the specific puppet. The resulting objects are virtual puppets but they also problematize our relationship to these objects. To conclude, we re-trace and question our two core qualities of *mediation* and *procedurality* to look for the boundaries of digital puppetry and contrast them to existing ones, such as Tillis' notion of "tangibility" as the sole dividing quality.

The virtual puppets in the project at hand were all based on samples from the archive at the Center for Puppetry Arts. Their mediated virtual puppet forms remain an objects insofar as they are defined against other data entities. Each one consists of specific data that can be distinguished from other object data. Within this, it can capture a lot of material or human specifics but re-use them, "transcode" them (Manovich, 2001), on its own terms. But a virtual puppet and its performance do not have to be handmade. The battling armies in *The Lord of the Rings* trilogy came to live not through direct puppetry but through MASSIVE, a software that allows procedural generation of large groups of virtual characters, each with an own "brain" and limited behavioral abilities (Aitken et al., 2004). Other digital environments, like the video game *Spore* (Bradshaw, 2009), contain pre-fabricated virtual body parts that can be assembled either by players or AI driven character generation.
The same game company that published *Spore*, Electronic Arts, delivers regular updates to their soccer game series *Fifa* (1993-). Each *Fifa* game features a huge range of human data - from personal stats to animations to visual appearances of soccer players - often captured from current players. In the game, players control 3D versions of famous soccer stars and direct virtual teams, but the procedural nature of the media also allows unique use of that data. In the case of *Fifa*, it has been a tradition to let the game AI battle against itself before each World Cup Championship to predict the possible winner. The logic of the AI is programmed by humans, but the activation, the performative part, is not in direct human control. This

performance is fully simulated. In an eerie turn of events, the AI competitions correctly predicted both, Spain's win in the 2010 world championship and Germany's win in 2014. It is this non-human capability and its underlying mediated nature that separates the virtual puppet from the traditional one. Even heavily mediated puppet types, such as Henson's *Muppets*, lack this fluent border into the fully artificial.

An AI is already a strong example for procedurality at work in digital media. But procedurality includes a range of other effects that can affect a virtual puppet's performance. Thanks to this flexibility, any mapping of controls is optional and can change, making "hyperpuppets" (Kaplin, 1995) not only capable to perform but turning the controls themselves into variables. The idea of control points might reflect puppetry traditions (Kaplin likes them to marionette controls) but these points themselves do not have to be fixed during the performance of a virtual puppet. Control schemes are just as flexible as the virtual objects they affect. They allow e.g. for Disney's squash and stretch approach and can blend media techniques from animation with those of puppetry.

The entire simulation of a puppet's materiality is conditional as well. A simulated piece of wood can become a simulated piece of metal anytime and this change can be controlled by the puppeteer, the game, or any part of the code turning the virtual character into an ephemeral ghost, a solid statue, or a flexible humanoid - each one behaving differently. Puppet making, puppet playing, and animation effects are fluent. Within any of those stages, the operating rules are more flexible than physical materiality would allow. Expected behaviors such as collision and gravity are entirely optional in virtual space. In the case of the *Archiving Performative Objects* project, the simulation of gravity elements such as the strings of a marionette and the control of collisions of virtual objects with high details, such as the Monkey King's face (see fig. 1 above), pose continuous problems.

We suggest *mediation* and *procedurality* as two borderlines for virtual puppetry that affect the relationship between the puppet's and the puppeteer's body. The examples indicate that these borderlines are not simple binary. They are shifting gradients that lay out a design space along which digital puppetry experiments and stretches its own definition further. For example, a hybrid object - partially animated through human controls, partially by code - can be described through these two qualities as being still a digital puppet. The question, here, would not be whether it is a puppet but to what degree? Mediation and digital media's procedural qualities have opened new possible qualities for puppets. Weighing those contributions with the puppeteer's art remains the shifting borderline of virtual puppetry.

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