RECREATING A RARE INSTRUMENT USING VR AND FABRICATION: A HYPERREAL INSTRUMENT CASE STUDY

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ABSTRACT

In this paper, we discuss our ongoing efforts to bridge VR and fabrication to design new instruments for the virtual domain while retaining the tactility of physical objects. As a case study, we use 3D scanning and digital modelling to recreate the geometry and visual texture of a rare drum on loan from the Stearns Collection of Music Instruments at the University of Michigan. We also detail the implementation of a physical augmentation for the Oculus Touch controller that facilitates extending the controller towards bespoke musical accessories. These extensions become co-located with their virtual counterparts and contribute tactile anchors associated with the experience of playing the instrument. Modal Analyses and re-synthesis are used to reproduce the sound of the drum that is then mapped to excitation points on the VR drum model. We discuss the implementation of this case study using our adapter, 3D scanning, fabrication and physical modeling synthesis.

1. INTRODUCTION

Our ongoing research project titled Hyperreal Instruments combines VR and digital fabrication in the design of virtual instruments that are mapped to fabricated physical counterparts [1]. The project explores the relationship between the unique affordances of VR for musical expression [2] and the inherent tactility of performing with physical instruments. We suggested that implausible or imaginary instruments may now be composed within a mediated space with fabrication operating to provide a tactile anchor aligned with the audio visual objects. We constructed a pilot instrument modelled both virtually and physically. This instrument allowed us to observe how performers play a virtual instrument that also provides the kinesthetic boundaries of a real object in space. Our focus was on the versatility of such a practice and how we could even mine musical imaginaries articulated in art and literature and cast them into a computed space. Mythical instruments could now be redrawn, but this time in 3D virtual space with their imagined sounds delivered through digital sound synthesis.

An equally fruitful approach that we report here is to animate instruments that are very much real, but irreplaceable and too fragile to bear the stress of performance. These are the instruments of collections and museums.

As an update on our continued efforts in this project, this paper offers two primary contributions: First, we discuss the design and implementation of an adapter for the Oculus VR System that enables the hand-held controllers to be extended through digital fabrication. These parts can then be tracked in VR without incurring the costs and complexity of adding an additional tracking system. This system also allows us to iterate on different Hyperreal designs, where the visual and acoustics properties of a physical instrument can be virtually redefined and augmented with computer graphics and synthesized sound.

Second, we describe our use of this system to recreate a historical instrument from the Stearns Collection at the University of Michigan. In particular, we replicate a rare Japanese Tsuridaiko using 3D scanning to capture the instrument's geometry and textures. We then use digital physical modeling sound synthesis to simulate its sound. By using consumer-grade equipment and making our designs open source, we hope to enable other researchers to implement not only this particular instrument but also other Hyperreal Instruments, opening these up for modification towards more authentic re-creations on one hand and more experimental inventions on the other.

2. RELATED WORK

3D printing has numerous applications in musical instrument design and prototyping [3]. Early proof-of-concept experiments include Amit Zoran's 3D printed flute and Scott Summit's similarly fabricated acoustic guitar [4]. More recent experiments have included micro-tonal flutes [5] and even toys with identifiable acoustic signatures through the control of interior cavities as modular acoustic filters [6].

More generally this capacity to make precision forms at low-cost inspires a whole suite of projects to restore cultural heritage objects. Scopigno et al. provide a broad perspective on how digital fabrication can be deployed for such historical inquiries [7]. Zoran also explored broken artifacts whose forms were restored through 3D printing scaffolding that filled out the absent component [8].

Musical Examples include reconstructions like that of Koumartizis et al. who made a Greek lyre of Hermes using digital fabrication [9]. The use of 3D scanning in these activities contributes visual textures critical to the identity of an artifact. Point clouds from structured light scanning can be exported to VR as an interactive model on which we can map digital sound synthesis.

3. OCULUS TOUCH ADAPTER

Commercial and proprietary devices are in some respects found objects. They come bundled with the design choices of research teams that work under non disclosure agreements until the product is released. The user is not involved in these decisions other than passively through product reviews. The relatively new capacity to make custom geometries that interface precisely to commercial devices and alter their function puts the user in the role of secondary, if also somewhat reactive, designer. As unwieldy as it can be to build such adaptations, they nonetheless allow us to alter the function of commodities to our own creative ends. This is what we have been doing with several versions of the Oculus touch controller. The device as it stands has been designed to track the hands and accept control data via buttons and small joysticks. The controller has been extended to interface with real world objects that may provide useful tactile feedback, typically very important to musicians. By setting out to fabricate bespoke adaptors that can interface with musical forms, we extend the controller to this kind of application.

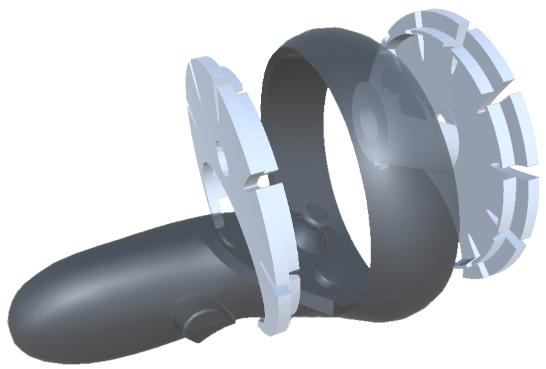

Figure 1. Bracket interfacing with the Oculus Touch.

3.1 Modeling

For CAD modelling we used OpenScad, an open-source text-based software developed by Marius Kintel and Clifford Wolf.[1] OpenScad affords parametric modeling that allows us to home in on the correct tolerances for a perfect fit with the commercial object. The bracket we modelled to interface with the Oculus controller allows us to fasten additional structures to the controller. In this case we attach a mallet with which we can strike the virtual drum, as well as a controller on the drum itself to track its movements. Design constraints for this bracket include the need for an object that can sustain the load of the attached materials while leaving the sensing surface, joystick and buttons unobstructed.

[1] `https://www.openscad.org`

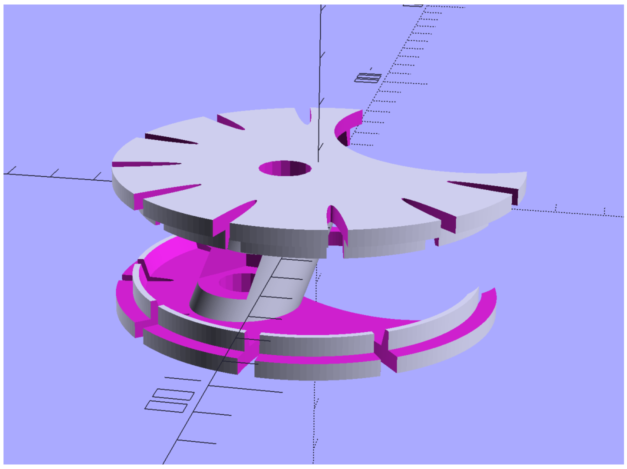

Figure 2. OpenScad model of the bracket for the Oculus Touch.

3.2 Fabrication

The Oculus touch controller has sensors distributed around a flattened torus with a diameter of 9 cm. Given that it houses the IR transmitters, the wide surface of this torus has to remain unobstructed. The design of the adaptor consists of two 3D printed surfaces attached to the outside of the controller that exceed the diameter of the torus by 2mm. Each fabricated surface of the adaptor also has a small lip on the inside edge to hold it in place against the edge of the torus. To attach the two surfaces we considered modelling an inner threaded conduit. Although 3D printed threads work,they often suffer from insufficient strength under load. We decided to adapt the inner conduit such that it would accept two threaded steel bolts, one to hold the two faces together and one to interface with the instrument or accessory. For this we created two cavities in the connecting bar where the fasteners are embedded as seen in Figure 3.

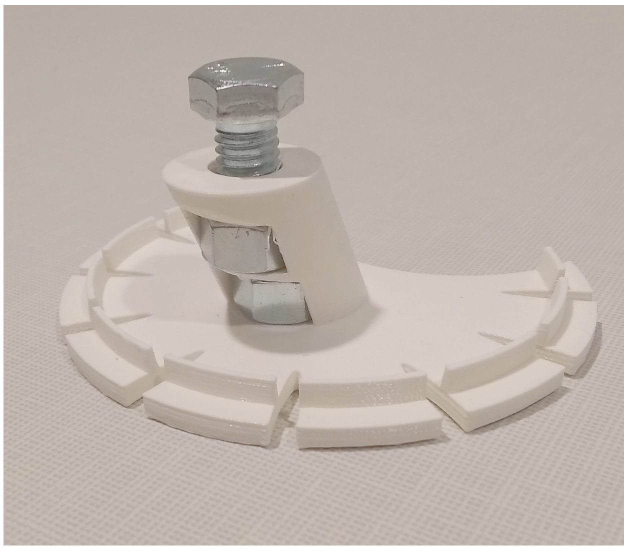

Figure 3. 3D printed Bracket for the Oculus Touch with nut-slots.

4. RECREATING A TSURIDAIKO

As a case study of integrating the Oculus Touch adapter into a Hyperreal Instrument, we decided to recreate a rare artifact from the Stearns Instrument Collection at the University of Michigan. Specifically, we modeled a Japanese Tsuridaiko. Stearns Collection records provide the following information about this instrument:

> Tsuridaiko, Wood, Parchment, Japan.
> The heads are fastened to the body (a very shallow cylinder) by close rows of round-headed nails. The body and heads are elaborately decorated with representations of the three-clawed dragon. The tsuridaiko is generally suspended in an ornate frame of lacquered wood and is beaten with a pair of leather padded sticks. This example is a trifle smaller than the usual "hanging drum." Depth, 9.5 cm. Diameter of heads, 33 cm [10].

4.1 Scanning

To import both the geometry and the texture of the Tsuridaiko into VR we used an Artec Eva and a Spider handheld 3D scanner as well as the bundled Artec Studio software. This toolchain allowed us to take numerous scans of the same drum that were then aligned into a single point cloud representation of the object using automatic texture alignment. The Artec system gives us reliable results, minimizing errors and running algorithms for smoothing and point redundancy detection.

Figure 4. Artec Scanner and Tsuridaiko drum from the Stearns collection

4.2 Fabrication

In order to provide as many sensory anchors as possible in the virtual experience of playing the drum, we also construct an object that stands in as a physical barrier co-located with the modelled audio visual drum. With this in place, a gesture to excite the VR drum is met with the tactile sensation of a mallet rebounding off the membrane of the physical object. To construct this physical place holder for the drum, a laser cut cylinder was produced using kerf bending. This technique introduces a dense array of parallel perforations in thin plywood rendering it pliable and able to conform to the corners of the drum.

For the mallet A narrow oak dowel was threaded to attach to the bolt projecting from the adaptor. This dowel was press fit into a foam sphere to create a light but strong mallet for striking the drum.

Figure 5. Striking the stand in object (top) co-located with its virtual counterpart (bottom).

4.3 Physical Modeling Synthesis

To create an interactive model of the instrument's sound we made several recordings, striking the instruments surface at various points. In general, the drum has a broadband attack with very short sustain. Its lowest mode is at 67 Hz, a resonance that may be lower than expected given the loosening of the membrane over time. The drum also had strong modes at 164 and 271 Hz. The spectra was inharmonic as expected given the nonlinear response of membranes.

Perry Cook, one of the founders of the Chuck audio language has developed tools for modal analyses and resynthesis. In the analyses phase we used chuck to conduct an FFT to evaluate the most important modes that characterise the timbre of the drum. Given that the sound contains broadband transients and other non-linearities, Cook's analyses tool also filters the modes of the drum from the original recording to produce a wave file of the residuals. In the re-synthesis these residuals are superimposed on the spectra of partials to give a realistic attack to our re-synthesis of the membrane's sound [11].

Using Chunity [12], which is a port of ChucK for the Unity Engine, we were able to use collision events to excite the model with its re-synthesized sound. The use of Chunity to run our synthesis code natively in Unity also allowed us to perform a binaural spatialization of the sound with Google Resonance Audio.

5. CONCLUSION

From the Museum of Natural History in Paris to Philadelphia's Franklin Institute, VR is now a common component in public exhibitions. Although this presents ample opportunities to craft informative scenes,it departs very little from the standard visual delivery of information in museums. This "look but don't touch" scenario creates some unease in instrument museums where there is a strong desire to make the artifacts produce sound. To satisfy this urge, the Musical Instrument Museum in Phoenix simply provides a gallery of playable instruments. Yet even with irreplaceable ones that must live behind the glass, we might offer simulated experiences of their virtual counterparts.

Our case study presented here combines a suite of technologies to produce a drum that can be played in VR while still anchored to physical objects that satisfy tactile expectations. Our scan, modelling and re-synthesis of the Tsuridaiko from the Stearns Collection may be viewed as a pilot study for interactive displays at instrument museums. In addition to viewing fragile physical instruments locked behind glass cases and mute, participants can now also experience interactions with a simulated and very tactile counterpart.

6. REFERENCES

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