Mixed-Reality Instrument Design for the Twenty-First Century Musician

As we approach our 18th year in the 21st century, our musical traditions and perspectives continue to evolve, far beyond the musical forms and functionalities explored by our forefathers. Computer-based technologies, specifically the virtual and mixed reality platforms that grow more ubiquitous with every passing day, have afforded digital luthiers a rich multi-modal playground within which to experiment and create. New sensor technologies have evolved, allowing human performative gesture—long the hallmark of physical musical instrumental performance practice—to engage purely digital instruments.

I'm Rob Hamilton, and for this issue of IEEE Computing Now entitled "Virtual Musical Instruments Using Sensor Technologies," editors Roger Dannenberg and Timothy Shih have asked me to share my experiences as a composer, researcher, and performer, designing and developing virtual and mixed reality musical instruments and immersive experiences.

My own practice of building virtual instruments began in an unlikely musical place—namely within the scope of video game design and development. Experienced gamers, much like trained musicians, exhibit characteristics of virtuosic control over multi-modal gaming systems. This ability, coupled with the dynamic creative possibilities and inherent collaborative nature of gaming platforms, led me to begin experimenting with hacking game modifications (or mods) to couple player control over avatar and gaming systems with real-time synthesis and sound-controlling engines.

Some of these works blur the lines between game and musical system, while others, like *Carillon*—created with artist and designer Chris Platz—leverage gaming technologies, VR Head-Mounted Displays, and hand-tracking sensors to create something that we'd more clearly identify as a *virtual reality instrument* or VMI. Human hand gestures, tracked in real time by Leap Motion controllers, are mapped directly to the hands of a humanoid avatar, controlled by the performer through a first-person camera view.

Each player can select one or more rings that make up the instrument interface and set them rotating in three dimensions with the swipe of a hand. The speed of rotation in three dimensions (pitch, yaw, roll) of each ring drives a continuous musical timbre.

Visually, the *Carillon* is realized as a hybrid instrument/structure floating in a virtual space. At the center of the structure is a set of six interlocking rotating gears, surrounded by three circular platforms. The gears represent the core performable interface of the project.

The rotation and speed of each ring is sonified in real time using a synthesis engine modeling Jean-Claude Risset's additive synthesis bell-models, realized using the audio programming language Pure Data. At the same time, hand position and motion is mapped to the controls of a multi-channel granular synthesis engine. The sound is in turn spatialized around a multi-channel speaker array, surrounding the audience—when presented in concert—or around the performer when presented as an installation or demo.

Data representing the motion of each component of the instrument is transmitted using Open Sound Control from the Unreal Engine to Pure Data. In this way, both musical gesture and interaction layer can be programmed in an environment well suited for their respective needs.

Carillon uses the Unreal Engine's built-in networking layer to connect multiple performers, each collaborating by controlling different rings of the same central instrument. The motion and action of individual components—including rotating gears, lights, levers, and sequenced bell-strikers—trigger the generation of musical sound.

Our work on *Carillon* grew from a series of game and VR-based pieces investigating different sonifications of avatar physiologies and game processes, and different roles for virtual performers within the context of live musical performance.

In *Tele-harmonium*, an avatar capable of spawning musical projectiles was paired with a live pianist, performing a mixed-reality duet. In concert performance, the relationship between performers, real and virtual, is enhanced again through the use of human-scaled video projection, letting the audience feel the size of the virtual environment and performer—creating a parity between pianist and avatar.

Tele-harmonium was created using the Unreal Development Kit, the UDKOSC Open Sound Control mod, SuperCollider for real-time audio synthesis, and an eight-channel speaker array spatialize using ambisonics.

In an attempt to better understand the role of performative gesture in mixed-reality and virtual-reality musical performance, our work *ECHO::Canyon* explored the sonification and control over specific portions of avatar physiologies, in this case, the front-wings of a 4-winged bird and the trunk of an elephant-like creature.

Using the dual-analog stick controls of an Xbox controller, players exert nuanced control over each creature's skeletal mesh, the bones of which are tracked and mapped to control synthesis models running in the SuperCollider programming environment.

In *ECHO::Canyon*, every motion of each creature across the landscape is sonified as part of the musical system, using ray-traces cast in each direction to understand the distance to and type of topography near the avatar at any given time. Flying the avatar around and through the environment becomes the performance practice; actor motion and the contour of the environment itself becomes the instrument.

To better understand how audiences watching virtual performances correlate motion and action of visual gesture with procedurally generated sound, we designed and ran a series of multi-modal user studies using Amazon's Mechanical Turk. Users were presented pairwise comparison tasks, rating the perceived coherence between sonic event and visual avatar motion. Details of this study were published as part of the 2015 IEEE 2nd VR Workshop on Sonic Interactions for Virtual Environments (SIVE).