Collaborative Musical Performance Practice, Gesture and Interaction in Virtual and Real Spaces

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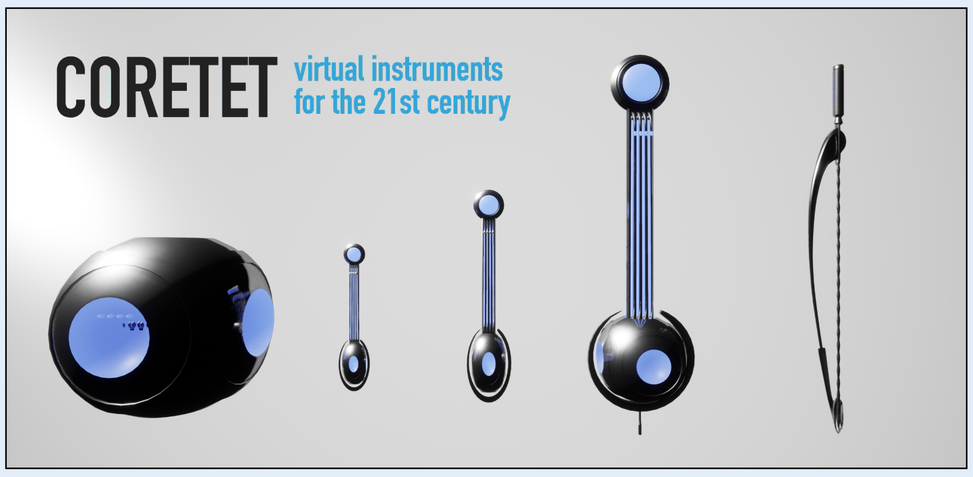
Music making is no longer tethered to our physical world. Where our abilities to perform music together were once limited by the speed of sound and the propagation patterns of sound waves, the introduction of new and pervasive computing and socially focused technologies have both distributed and democratized the music making process. Composers and instrument designers have built fantastical virtual instruments and performance environments, challenging our traditional notions of instrumental playing. Musicians have embraced these new interfaces and instruments, and online and mobile platforms have emerged that allow novice and trained musicians alike to perform and share their music across the internet without limit. But even as technological innovation has allowed musicians to occupy new spaces and surfaces to engage musical production and performance opportunities, our intrinsically human mechanisms for understanding and synchronizing musical expression based on haptic and audiovisual cues remain rooted in our own physiologies.

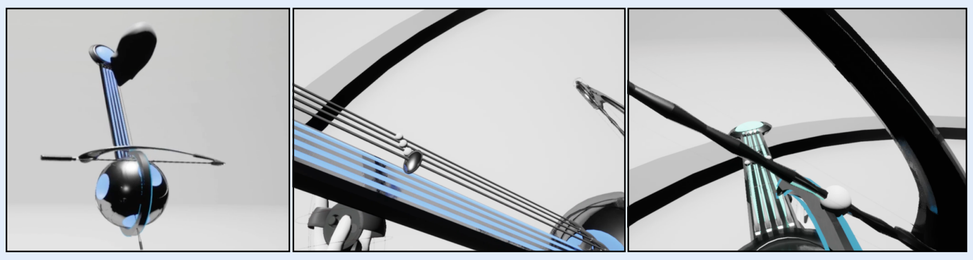
In its **FIRST STAGE**, (1) this ongoing research initiative explores similarities and discrepancies between traditional stringed instrumental performance practices and those explored by musicians playing Coretet — a virtual-reality bowed stringed instrument for networked performance. In our (2) **SECOND STAGE** of research, by observing and tracking player gestures during performance, we seek to better understand how tacit knowledge can transfer between physical and virtual modalities. And in the (3) **THIRD STAGE** of research we seek to train AI performers capable of improvising and collaborating with human musicians.

1 Instruments for Virtual Reality

With deliberate reference to traditional stringed instrument performance practices, Coretet [2] was designed as a futuristic '21st Century' implementation of the core gestural and interaction modalities that generate musical sound in the violin, viola and cello. Coretet's primary design goals focus on the creation of virtual reality musical instruments intended for networked ensembles of expert users, defined here as trained musicians with substantial history playing and tacit knowledge of traditional bowed string instruments. Through the leveraging of performers' tacit learned knowledge of stringed instrument performance practices, Coretet's design aims to allow performers to achieve a high level of skill on the instruments eventually leading towards virtuosity.

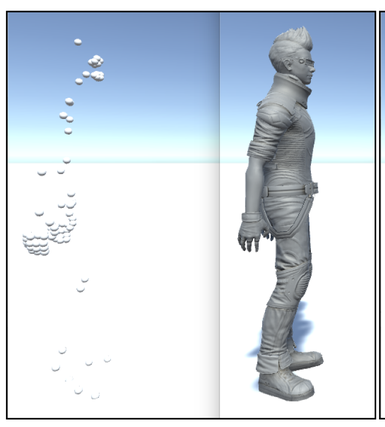


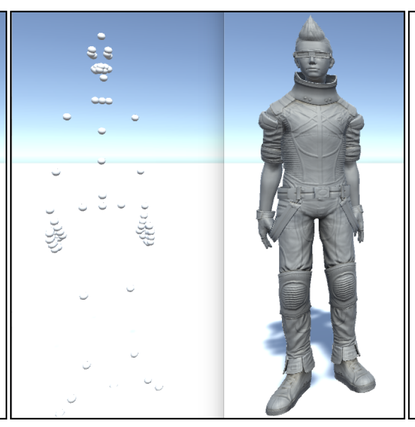
Coretet explores the translation of performance gesture and mechanic from traditional bowed string instruments into an inherently non-physical implementation. Built using the Unreal Engine 4, Pure Data, and the Oculus Rift head-mounted display (HMD) and Touch controllers, Coretet offers musicians a flexible and articulate musical instrument to play as well as a networked performance environment capable of supporting and presenting a traditional four-member string quartet (two violins, viola, cello) as well as a double-bass.



From Left to Right: Server view of a Coretet cello performer; VR view of the left-hand selecting a string to activate; VR view of bow connecting with the Coretet bowing-bar.

2 Motion Capture and System-Generated Performance Data



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/CoretetController
Head 0.007762 1.328696 0.039350 1.329301
Neck 0.009806 1.235983 0.003175 1.236026
Spine2 0.012154 1.107168 -0.001264 1.107236
Spine1 0.013300 0.978401 -0.006912 0.978516
Spine 0.014282 0.830447 0.009966 0.830629
Hips 0.014726 0.785485 0.011275 0.785704
RightForeArm 0.172839 0.932919 -0.077421 0.951948
RightArm 0.140891 1.166153 -0.005672 1.174647
RightShoulder 0.035827 1.236429 0.003519 1.236953
LeftForeArm -0.154153 0.926173 -0.047451 0.940113
LeftArm -0.122271 1.167123 -0.008800 1.173543
LeftShoulder -0.016215 1.235500 0.002957 1.235610
LeftHand -0.170301 0.765394 -0.045942 0.785456
LeftHandIndex4 -0.149006 0.604980 -0.022231 0.623
LeftHandIndex3 -0.163311 0.621646 -0.023048 0.643
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Open Sound Control data streamed from game engine representing three-dimensional avatar joint locations

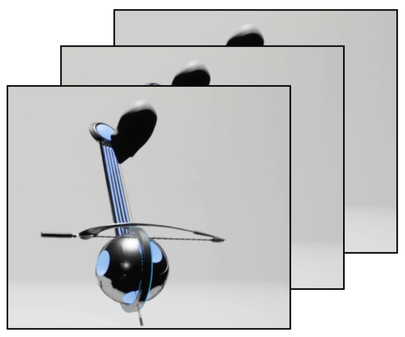
Within Coretet, data points representing user performance gesture are captured in real-time using Open Sound Control (OSC) tracking performer hand, head and bow movement as reported by the Oculus HMD and Touch hand controllers. In this Second Stage of research, a user study is being conducted comparing bowing, left-hand and posture data from Coretet performers. A second set of data is simultaneously being collected from subjects using a Vicon motion-capture system.

Subjects of interest for this study display varying levels of tacit knowledge - not only with regards to bowed string performance practice - but also with regards to experience using gaming or VR hand controllers. As Coretet is controlled using commodity VR game controllers, we hypothesize that both trained musicians and gamers will exhibit and be able to leverage tacit knowledge from performance and gaming respectively. Novice musicians and novice gamers are also included in the subject pool.

Each subject is presented with a set of simple musical examples - for instance, a single-octave major scale - presented initially on a paper score, and subsequently within the Coretet engine as on-neck note markers. Subject note accuracy and timing are assessed as metrics for successful performance (*Co-ordination of Content)* [1]. Communicative ensemble gestures such as head, bow and hand cues used in ensemble performance examples will also be analyzed (*Co-ordination of Process*).

3 AI Performers Trained on User Data

With a goal of transferring parameterized performance gesture from musician to AI agents, the Third Stage of this research will focus on training AI musicians on data collected in the Second Stage. The focus here will be on control data chunked as gesture, used to train bowing gesture and note contours. Coretet provides a platform on which AI training and performance systems can be prototyped and tested, initially using TensorFlow running within the Unreal Engine.

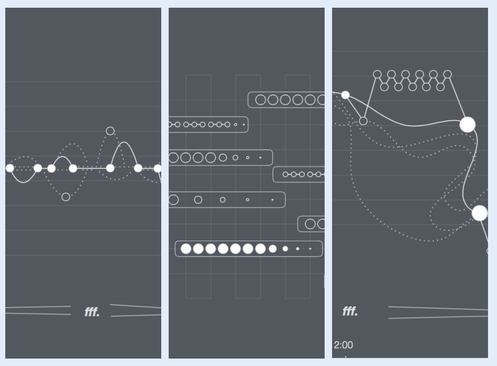


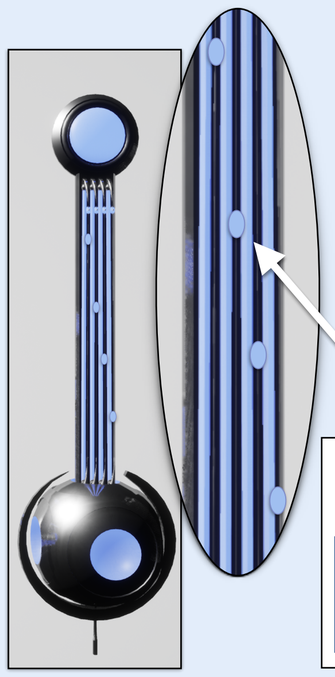
Trois Machins de la Grâce Aimante: a Virtual Reality String Quartet

Coretet was initially designed and developed to support the composition of *Trois Machins de la Grâce Aimante* [3], a virtual reality string quartet. The three-movement work has been featured in ensemble and solo concert performance in Graz, Austria (IEM / Mumuth), Mexico City (Ecos Urbanos Festival), and the United States (ISB).

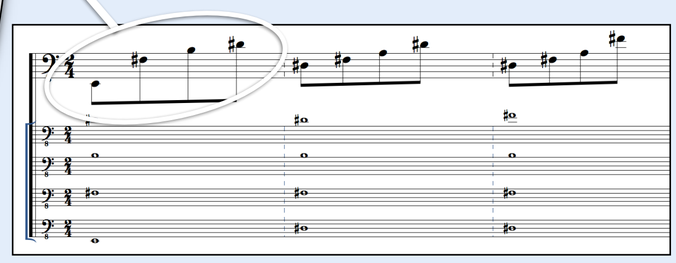
Notation Systems for Virtual Instruments

Movement II of *Trois Machins de la Grâce Aimante* consists of six sections across which ensemble gesture and planned improvisational parameters are notated in a graphic reference score. Performers practice and learn the movement using this printed score.





For scoring situations wherein performers need to follow notation in real-time, Coretet features an on-neck scoring system in which note markers display desired pitches as finger locations along each instrument's neck. Data for each instrument's part is loaded into Coretet as a MIDI file with separate staves representing each string. Movement III of *Trois Machins de la Grâce Aimante* uses this technique.



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