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Design & Evaluation of an Accessible Hybrid Violin Platform

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ABSTRACT

We introduce and describe the initial evaluation of a new accessible (easily replicable) augmented violin prototype. Our research is focused on the user experience when playing such hybrid physical-digital instruments, and exploration of novel interactive performance techniques. The goal of wider platform accessibility for players and other researchers is approached via a simple 'do-it-yourself' design described herein. All hardware and software elements are open-source, and the build process requires minimal electronics skills. Cost has also been kept to a minimum where possible.

Our initial prototype is based upon a relatively inexpensive electric violin that is widely available online. This instrument serves as the starting point for construction, to which our design adds Digital Signal Processing (DSP), gestural sensing, and local sound output. Real-time DSP algorithms run on a mobile device that incorporates orientation/gesture sensors as well, with the resulting sound amplified and rendered via small speakers mounted directly to the instrument. The platform combines all necessary elements for digitally-mediated interactive performance; the need for a traditional computer only arises when developing new DSP algorithms for the platform.

An initial exploratory evaluation with users is presented, in which performers explore different possibilities with the proposed platform (various DSP implementations, mapping schemes, physical setups, etc.) in order to better establish the needs of the performing artist. Based on these results, future work is outlined leading towards the development of a complete quartet of instruments.

Keywords

Hybrid Instruments, Augmented Instruments, Electronic Violin, Gestural Sensors, Digital Signal Processing, Evaluation of New Interfaces for Musical Expression

1. INTRODUCTION & BACKGROUND

The primary goal of this project is to provide creative control and augmented expressivity for stringed instrument performers, in this example specifically for the violin. However, many elements may be applicable to other stringed instruments as well. In order for augmented violins to be more broadly adopted, important characteristics must be identified and further pursued. The overall methodology for identifying these characteristics has been an iterative design based approach, where prototype development and evaluation has been carried out in order to identify user needs. As such, the initial prototype development has explored factors such as gesture acquisition, DSP algorithms, amplification, sensor usage, accessibility, new playing techniques, form factor, cost, mobility and

personalization. These factors have then served as the basis of inquiry in a qualitative evaluation where the major goal has been to identify directions for future work within this ongoing project.

Widespread work is ongoing both within and beyond the NIME community towards hybrid acoustic (physical) / electric (digital) musical instruments. Background work specifically related to violin-based research includes many electronic violins enabling extended gestural control, such as those discussed in [4,7,12], amongst others. A more complete overview of the field is described in [9].

1.1 Hybrid Approach

Our research platform, the prototype hybrid violin, was created with provisions for embedded audio processing to enable real-time effects, and simulations of acoustic body models. The DSP techniques used are able to transform from one model into another – including extrapolations beyond realistic models – in order to explore interesting new timbres. Models can include everything from traditional violin bodies to guitars, sitars with their sympathetic strings, and even physically impossible acoustic bodies. The research focuses on augmenting the expressivity of the violin by finding novel timbral possibilities and gesturally controlled effects, rather than attempting to simulate purely acoustic violins with high fidelity (as seems to the be goal of a somewhat related project by Weinrich Labs [14]). The opportunity to control a malleable virtual instrument body while playing, i.e., a model that changes reverberant resonances in response to player input, can often result in interesting and possibly musically inspiring sonic output [10]. Many common audio effects can also be employed, and simultaneously controlled via the performer's movements.

1.2 Gesture Acquisition & Augmentation

Our research also explores several approaches to gestural playing techniques extending normal practices that can be applied to bowed-string and other acoustic instruments, in order to provide inherent creative control over the possibilities offered by DSP. For example, gestural movements of the instrument are tracked via the embedded Inertial Measurement Units (IMUs) in mobile devices, which can be mapped to alter parameters of effects. Mappings can include posture-based control of the wet-dry mix of a simple 'octave doubler' – or other more advanced audio effect algorithms – further augmenting the potential expressivity of the player.

While many interesting opportunities exist for precision acquisition of gestural movements today (e.g., Kinect, LeapMotion, Thalmic Myo), it has been deemed important to avoid external or wearable peripherals, as these make it less practical for a player to simply pick up and play the instrument. We also avoided adding additional weight to the bow (as seen for instance in the KBow [8]) for this reason. Furthermore, it was found that the bow is a rather individualized element for violin players. It is very important for their personal feel of control, and therefore best left untouched. We have chosen to initially explore larger bodily gestures by employing solely the IMU in a mobile device as our gesture sensor (either on the violin

itself or in the case of the evaluation described later, attached on the non-bowing arm of the player).

2. HYBRID PHYSICAL-DIGITAL VIOLIN

In order to initiate the design process choices have been made regarding the following elements:

Mobility – We chose a battery-powered solution in order to free the player from the restraints of having to deal with wires. The design is entirely self-contained, in order to avoid the need for any external peripherals while playing.

Gesture Acquisition, DSP processing, Amplification – Instead of transferring sensor data and audio signals to a computer, we embed all sensing, audio-DSP and amplification entirely in the violin platform. An audio interface for the mobile device (which serves as the processing unit for DSP and sensing) is used to receive the audio signal from the pickup, and send the output to small speakers mounted on the instrument.

User Interface – Besides performing with the violin, the user also has to be able to control settings, monitor the system, etc. This interface is provided by the mobile device.

Accessibility – In at attempt to increase the availability of the platform, it was decided to base it on a low-cost electric violin (as mentioned earlier). Nonetheless, some may wish to use higher quality instruments, depending on personal desire.

In order to accommodate the considerations presented above, we decided to build the platform around an iPod Touch running the Mobile Music Platform app MobMuPlat [5] which is a free, open-source application providing the capability of running PureData (Pd-vanilla) patches on iOS, with access to device resources (including internal sensors, processing and wireless communication). Other software environments are possible as well, including the iOS port of SuperCollider, LibPD, or MoMu toolkit [2]. However, MobMuPlat has the lowest entry barrier, especially for users who may not have a background in programming.
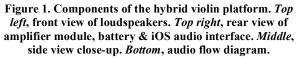
3. Implementation

Implementation of the prototype was kept as simple as possible, in order to achieve better accessibility for other musicians who might like to build one for their own use. The list of materials used in this first version of the prototype include (see also Figure 1):

- Low-cost electric violin (from eBay, in our case), many models available. However, this particular model was convenient, as the form factor allowed mounting the required augmentation hardware with very little to no modification of the instrument, using zip-ties and similar.
- Two Balanced-Mode Radiating speakers for wide sound diffusion, model HIBM130H10-6 'HARP BMR Driver'.
- Stereo Class-T audio amplifier module DTA-2 'Tripath TA-2024' with 15W/ch continuous output power.
- Rechargeable lithium polymer battery: 11.1volts, 850mAh capacity, weight 73grams (charger separate).
- Audio interface for iOS devices (many models available), this prototype uses an AmpKit LiNK HD, which also happens to be compatible with Mac OS X.

The speakers and audio amplification module were purchased at Parts Express (an online component supplier), and are likely the only somewhat esoteric or difficult to find elements. The battery and charger are available online and at local remote control car & airplane hobby shops, and the iOS audio interface is likewise widely available both online and at local music shops.

While overall weight is clearly a concern with this prototype, our choice of components has minimized the contribution from each element, and the design places the majority of extra mass towards the bottom of the instrument, so that the weight rests primarily on the

player's shoulder. The intentional lack of enclosures for the loudspeakers sacrifices a bit of loudness and bass response, for better omnidirectionality of the soundfield. This trade-off seems reasonable, given the low frequency response still extends down towards 100Hz (and all the way up to 20kHz). Beyond full-range response, the choice of drivers is primarily based upon their omnidirectional response, as Balanced-Mode Radiator (BMR) speakers are known to provide superior off-axis response, compared to conventional driver speaker designs. While we have not taken precise measurements, this approach is a simple tradeoff towards soundfield omnidirectionality without resorting to much more complex designs, such as spherical speaker arrays [12] (which would simply be too heavy to incorporate into a handheld instrument directly).

Figure 1. Components of the hybrid violin platform. *Top left*, front view of loudspeakers. *Top right*, rear view of amplifier module, battery & iOS audio interface. *Middle*, side view close-up. *Bottom*, audio flow diagram.

3.1 Audio processing

We tested the prototype hybrid violin with several Pd Patches running on the iPod Touch (via MobMuPlat) – with different parameters coupled to the gestures based on our own intuitive mappings. Several gesturally-controlled patches based upon simple DSP algorithms of well-known audio effects are

described below, as they were used in the initial evaluation session with a group of performers.

4. Evaluation

In order to evaluate the prototype, a qualitative evaluation was carried out in the form of an exploratory focus group session in which three experienced string players (two violinists and one cellist, all female, who played together in an electronic string quartet) were asked to explore various augmentation algorithms based on the same physical prototype[1]. The participants were all classically trained and had at least 12 years experience playing their instrument. During the exploration sessions the participants were encouraged to comment on how they experienced the prototype in regards to musical features, exploratory features, ergonomics and form factor, considering limitations/opportunities regarding the instrument.

The evaluation took place at the home of one of the test subjects and took approximately two hours. Test participants were asked to explore four variations of the same prototype each designed to represent different opportunities and limitations in regards to the aforementioned design factors. They were chosen in order to present a diversity of what the platform had to offer while at the same time encouraging discussion. These included:

Granulation via Munger1~ [3] – The violin was coupled via cable to a computer running Max / MSP. While the munger1~ object is not part of Pd-vanilla (so cannot run in MobMuPlat without porting it), we included this setup in order to trigger discussion about the importance of a wireless approach. The mapping allowed yaw-rotations (turning while playing, which potentially tangles the player in the wire) to control various parameters of the granulation. This led to discussions about extended musical functionalities of granulation-based effects.

AutoWah – here players were able to control the wet/dry mix of the effect by tilting up and down with their upper body, wherein pointing the violin upward made the effect more prevalent. It was included in order to explore an audio effect that was normally used in a genre that was not familiar to the players.

TransposeTilt – here the players were able to transpose notes played by tilting up/down while controlling a wet/dry mix of the effect by tilting to the sides while playing.

Feedback delay – the user was able to control a feedback delay with a fixed delay time controlling the amount of feedback with the up/down tilting motion. Tilting right/left would control a "feedback hold on/off", which when turned on held the last note in a separate feedback delay loop allowing them to play along with the generated feedback. Note that this version was explored using external amplification from a mid-range studio monitor in order to establish the importance of the built-in amplification.

As described above, the session was conducted as an exploratory focus group evaluation. In order to structure the discussion, a semi-structured interview guide was used. For each of the variations the following subjects were discussed:

- General feedback (first impressions)
- Form factor (placement of iPod Touch, placement of speakers, weight issues, importance of wireless)
- Amplification (internally / externally)
- Possibilities of iPod Touch (increased visual feedback during play, input possibilities)
- Gesture acquisition (additional sensing needs)
- Musical potential (synthesis, audio effects, gesturs, etc.)

- Software integration (Live, Logic, Protools, etc.)
- Any other business (traditional classical music vs. experimental, repertoire, acoustic vs. electric, etc.)

Most of the above subjects arose naturally, while others were directly asked for. When test participants would ask about specific features to do with the augmented violin and associated audio processing, the test conductors would elaborate enough to encourage further exploration. In other words, the evaluation was not meant to directly uncover usability errors by deliberately omitting information from the participants.

4.1 Analysis of the observation data

The session was video recorded and notes were taken by one of the two test conductors. Recordings and notes were analyzed using a bottom-up grounded theory approach inspired by Stowel et al. [11]. Themes from the interview guide together with the notes taken during the session were used to initiate the identification and categorization of important statements and performed actions. Additional categories were found during the review of evaluation material. These were then used to group important statements and actions, which were finally compared and contrasted in order to form the following results.

4.2 Results

4.2.1 Form factor and Ergonomics

Test subjects were very pleased that the violin was playable as a standalone instrument. Even though they were used to playing electronic string instruments it increased the accessibility of the violin. The fact that they could use their own bow unmodified was also appreciated.

The weight of the violin was an issue for one of the test participants stating quite early on that her arm began to tire. This statement was repeated each time she played the prototype. Part of this had also to do with the fact that the iOS device was strapped around the players non-bowing arm during the evaluation session. Placing the device closer to the bottom of the instrument was suggested – however, that would make system monitoring through the GUI of the device challenging.

4.2.2 Amplification

The initial impression of the built-in amplification was that it improved the feel of the electric violin making the players feel a closer connection to the instrument. One of the participants found that the emitted sound was too loud forcing her to restrict her playing. After comparing to an acoustic violin it was found that the augmented violin was not actually louder. The perceived loudness was caused by one speaker, which was placed in such a way that it directed sound directly into the left ear. Additionally, this placement partially obstructed bowing close to the bridge of the violin.

When exploring the last prototype, users noticed a large increase in audio quality, as this was tested with external amplification from a studio monitor. They stated that this was of course an important factor and proposed that perhaps the audio could be amplified both externally (for better audio quality) and internally (for improved feel). Traditional mic'ing techniques could possibly be used for this as well.

4.2.3 Gestures and Mappings

While subjects expressed a great enthusiasm for playing the instrument, observation showed that the musical gestures were not explored as much as expected. Additionally, due to the short amount of time for learning the different systems, subjects never got to a point where they played the instrument very expressively. Most gestures were limited to upper body tilting where tilt angle was directly mapped to a parameter of the audio processor. It would have been interesting for the test

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[1] The cellist did not actually play the violin prototype but participated in the discussion, while also having her electric cello present for demonstrating various discussion topics.

participants to control parameters with amount of movement instead of position. Especially for the Granulation patch (which was the more abstract of the implementations), it would seem natural to couple movement with a parameter such as perceived chaos, energy or dry-wet. Not only would this encourage exploration and perhaps ornamental or conversational interaction [6], but it would also fit in the theatrical context.

During the session the discussion fell upon how the functionality of the violin could be extended and the test participants were shown a video of an earlier prototype that implemented sensing of the position of the bow-hand relative to the body of the violin, making mid air gesture-mappings possible. They all seemed very intrigued by these possibilities. Not only could it extend the control possibilities (gestures-to-sound, playing technique, etc.) it would also extend possibilities from a theatrical point of view. In general there was a request to provide more extreme audio processing (especially with composers in mind – see next point.)

4.2.4 Performer and composer

A discussion arose about the importance of evaluating this sort of prototype by including also composer's inputs. The performer can provide valuable insight in regards to usability of the proposed systems, but it is only together with the composer that one is able to assess the overall musical and performance potential of such a system. The test participants would often state that they could only assess what the system provides from a players point of view, but that the composer was needed, especially for assessing the potential of the different audio processing techniques. This aligns well with recent work by Bevilacqua et al [1] where the composition was integral in the way mappings and gesture-following techniques were developed and assessed.

Testing on a different kind of violinist would have definitely produced different results regarding this issue. For example, these performers were not accustomed to improvisation, instead they built their repertoire by playing sheet music.

4.2.5 Soloist versus Quartet

Especially when assessing the nature of the different gestures, there was a discussion regarding the difference between designing gestures for a soloist performance and for a string quartet. This discussion also relates to the earlier point about the importance of including the composer in the design and evaluation process. Experimentation with the gesture-sound relationships in a string quartet demands a more coordinated approach, where musical expression and overall performance issues (including theatrical issues) are considered from higher level. Each approach has it's own opportunities and limitations.

Table 1. Summary of Evaluation Session

	Positive	Negative	Solution
Formfactor/ ergonomics	standalone, non-modified bow	weight	placement of mobile device
Amplification	improved feel	audio quality, loudness	speaker placement, combine built-in and external amplification
Gestures/ Mappings	interest/ enthusiasm	limited explora-tion	more complex mappings, additional sensing
Performer/ Composer	performer - usability issues	info on musical potential	Include composers in evaluation
Soloist vs. Quartet	-	-	establish target group

5. DISCUSSION AND CONCLUSION

Several issues were discovered throughout the evaluation, which we consider worthy of further investigation. The next steps in the project involve working with two overall methodological approaches in parallel. One will be a continuation of exploring and improving the current prototype. Here composer participation will be crucial for informing new design requirements especially in regards to gesture-sound exploration and to implementation of the platform in larger ensembles. The second approach entails a series of more focused usability studies of the issues discovered throughout the evaluation. These are necessary to understand the importance and quality trade-offs of integrated amplification, optimal placement of speakers, optimal integration of mobile devices, analysis of upper body gesture space with special focus on resolution and naturalness of mapping to the audio processing. We believe that working with these two methodologies in parallel will lead to an improved overall platform that can prove more accessible to string instrument performers.

6. ACKNOWLEDGMENTS

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