The Overtone Violin

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ABSTRACT

This paper describes the concept, design, realization and evaluation of a radically augmented musical instrument named the Overtone Violin. The rationale behind the development of the instrument is to preserve the expressive elements of the expert violinist, while incorporating the added benefits of gestural controllers via embedded sensors. There have been many examples of idiosyncratic alternate controllers in electronic music, as well as quite a few hybrid controllers that typically use sensors to capture the motions of playing a traditional instrument. However the Overtone Violin crosses these boundaries by retaining the original violin techniques and sounds as well as extending/enhancing the instrument with new methods of expression that are not inherent to the conventional technique.

1. INTRODUCTION

The pursuit of novel interfaces for new music performance is a very interesting angle from which to approach the design of a musical instrument, but without the proper perspective the result can be hard to differentiate between a musically useful device and a simple gadget. There is of course the typical industry approach of building electronic instruments in the likeness of an existing (acoustic) instrument, and while this can be useful, such imitation lacks the creative effort that can lead to new innovations. However, ignoring the background and not building on an existing tradition can be hazardous as well, as it can either be too far ahead of its time or end up being merely a gimmick. Although the evolution of most acoustic instruments has stagnated, there are recent examples of hybrid instruments [1, 2, 8] that augment traditional instruments with additional gestural capabilities. The Overtone Violin fits into this category.

Any instrument can be augmented to different degrees through the addition of extra sensors. Hybrid instruments offer musicians the familiarity and expressivity of their chosen instrument along with the extended control afforded by the sensors. There are two ways, however, in which the Overtone Violin differs from most hybrid instruments. First, the extra sensors are used to capture a new, separate set of gestures; many hybrid instruments use sensors just to acquire techniques that are part of the traditional skills of the performer. And second, it is custom designed and built from scratch to be an entirely new, specialized instrument that continues the evolution of the violin (rather than adapting or retrofitting an existing instrument with some sensors tacked on).

The philosophy behind this approach is to use gesture sensors to add completely different functionality to the instrument rather than capturing playing techniques that already have their own outcome—in this case, the sound of the strings. In fact, the Overtone Violin can be viewed as two components tightly integrated into one: it is both a traditional (electro-acoustic) violin, and a gestural computer music controller.

Figure 1. The Overtone Violin.

As can be seen in Figure 1, the violin itself is improved though the addition of extra strings (six strings instead of four, extended downwards into the cello range) and the tuning machines are located at the bottom in order to allow gesture sensors to be placed at the head of the instrument. A custom optical pickup system provides independent audio signals from each string, plus there is a monophonic audio output using a standard ¼" guitar jack. Details of the optical audio pickups and sensor electronics implementation are included in sections 3.1 and 3.2 respectively.

2. MOTIVATION AND BACKGROUND

One of the primary motivations behind the Overtone Violin is to put real-time signal processing under direct expressive control of the performer, thereby pushing the envelope of violin performance and composition into completely new areas. Through the combination of violin performance technique and gestural control, employing a virtually unlimited number of synthesis possibilities and mapping strategies, the Overtone Violin can be used for a wide range of musical purposes.

Trained violinists are able to pick up the Overtone Violin and play the strings fluently. However, there is another gesture vocabulary beyond that of acoustic violins in dealing with the extra sensors that requires the development of new skills to master. While this necessitates new playing techniques, the process of learning is facilitated by similarities to the older technique. For example, the 16-button matrix at the head of the instrument is fingered with the left hand, as are the violin strings themselves. It is by design that there is no direct overlap between the two types of instrument manipulations, because if they were synonymous the instrument would be incapable of controlling new sounds independently. For instance, using sensors to obtain gesture data from established violin technique may be interesting from a strictly engineering or pedagogical point of view, but the artist who wishes to have technology do more than reflect their old gestures should expect to spend time learning a new vocabulary just as they spent years practicing traditional technique.

However, there are countless possibilities for using signal processing to mirror/modify the string sounds from the Overtone Violin—in fact the independent audio signals from each string are intended to help in this process by providing clean signals for pitch detection/feature tracking, and allowing different algorithms/spatializations to be applied to each string. Signal processing is a very powerful way to enhance the violin without having to learn a new gesture vocabulary [6, 12], as it preserves the nuances and subtleties of a skilled performer. But traditional instrumental techniques are not well suited for the parametric control of signal processing (e.g., audio effects or synthesis algorithms), so gestural controllers are needed as well. The Overtone Violin is a powerful research tool to investigate innovative approaches to combining signal processing of traditional violin sounds with gestural control.

There are many people who have worked on augmenting the violin in different ways, some of whom have directed their efforts exclusively towards signal processing [6, 12, 14], and others who focus more on the input device (a classic example is Max Mathew's Violin [9], which used piezoceramic bimorph pickups with resonant equalization). However, there have only been a few true hybrid bowed string instruments that incorporate gesture sensors with traditional technique. Chris Chafe developed his Celleto [3] and has used accelerometers and the Buchla Lightning IR tracker to measure the dynamics of the bow. Camille Goudeseune measures violin position and orientation using a SpacePad motion tracker and the relative position of the bow and violin with magnetic sensors [5]. Some instruments though are actually alternate controllers which were only inspired by the violin, such as Dan Trueman's BoSSA [15], Suguru Goto's Super-Polm [11], and Charles Nichol's vBow [10]. These keep some violinistic traditions but do not have real strings, and drop genuine violin technique entirely in favor of analogous control methods. Peter Beyls IR-violin [4] also fits into this category even though it is built into a conventional acoustic violin. Related also are the Hyperbow by Diana Young [17], and Jon Rose's MIDI bow [13].

3. DESIGN OF THE OVERTONE VIOLIN

The development of the Overtone Violin was a complicated process, and involved quite a few different disciplines. One of the first decisions encountered was the choice of material to use for the construction. While this one uses curly violin maple, the design could be built using many different woods or other less traditional materials. The neck and body were hand carved and machined using a milling machine. While it is possible to purchase pre-made violin fingerboards, the use of six strings called for a wider fingerboard, so a viola fingerboard was used with the extra length removed from the narrow end. The electronics in the Overtone Violin are powered by a 10-Volt rechargeable NiMH battery pack located in between the two ribs along with all of the circuit boards and wiring. A trickle-charging circuit is built in, and there is a DC-input jack on the left side of the body—the violin can be used while charging, or the battery will last 3-4 hours with everything powered on.

3.1 Optical Audio Pickup

The pickup system used on the Overtone Violin is an adaptation of an electric bass/guitar pickup made by Lightwave Systems [7].

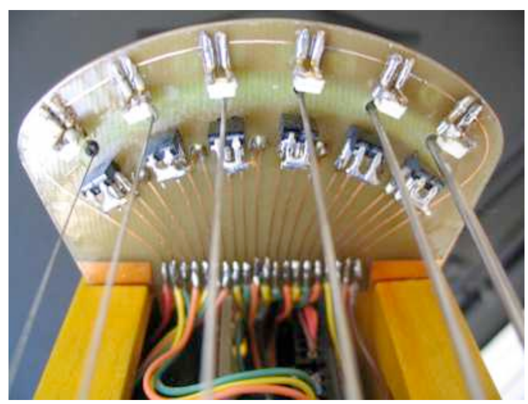

Figure 2. Overtone Violin bridge/PCB with optical pickups.

As seen in Figure 2, there are six IR LEDs above the strings, and a pair of IR photodiodes below each string. These are mounted on a custom circuit board that doubles as the violin's bridge. In this manner, infrared light is directed across each string in order to cast a moving shadow on the photodiodes. The instrument does not need a resonating body, as the optics sense the string's vibrations directly and very precisely through differential occlusion, and the resulting sound is quite good.[1]

[1] Tone is a matter of personal preference, but the author is quite pleased with the timbre quality of the optical pickup system.

The optical pickup system was developed in an attempt to improve the quality of sound as compared to other violin pickup systems, and is unique to the author's knowledge. The bridge circuit board is made from a sheet of epoxy fiberglass laminate using the common process of developing and etching PCBs. Making the bridge this way allows for optimal placement of the pickup optics, and minimizes interference with bowing techniques such as "sul ponticello" (near the bridge). But because there is no easy way to modify the height of the bridge (conventional violin makers simply shave wood from the bridge to adjust the action of the strings), the angle between the neck and the body of the instrument is adjustable using a set screw underneath the instrument. In this way, the height of the strings above the fingerboard can be changed.

A monophonic audio output is provided on the left side of the instrument, and a 13-pin DIN connector with individual string outputs is available as well on the underside of the violin, following the standard pinout used by Roland on their Virtual Guitar (VG-8 series) and MIDI guitar converters. The Overtone Violin can be plugged directly into either of these, or used with a commercial breakout box to get access to the string signals independently. The three rotary potentiometers on the left side of the body of the instrument are connected to the Lightwave active electronic pre-amplifier, and control volume, tone, and 'MIDI-volume' (used with Roland gear) respectively.

3.2 Gesture Sensors

The sensor system on the Overtone Violin includes 18 buttons, 3 rotary potentiometers, 2 linear potentiometers, 1 spring-loaded slider-type potentiometer, 1 miniature joystick x/y, a 2D accelerometer x/y, 2 channels of sonar (one in direct and one in echo mode), and a miniature video camera. The majority of these sensors are located on both sides of the head of the violin (see Figure 3).

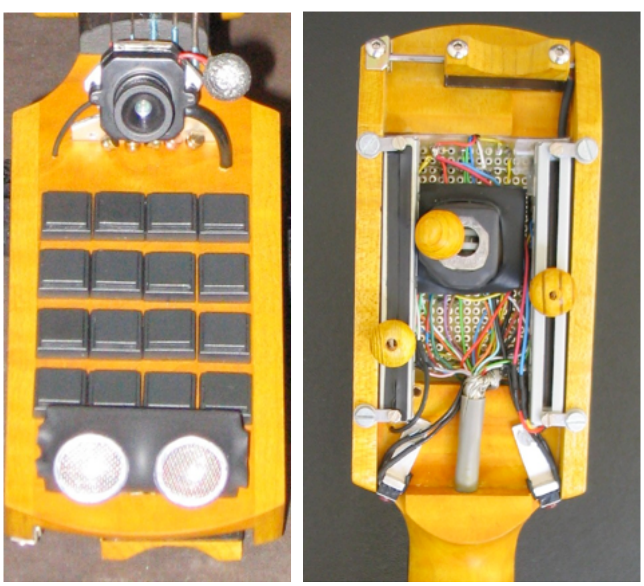

Figure 3. Sensors on the head of the Overtone Violin.

There is a channel inside the violin's neck for the sensor wires to run through in order to connect to a microcontroller (Microchip PIC16F877) located in the body of the violin. This PIC converts all of the analog and digital sensor values to a serial stream that is sent to an RF transmitter also in the body of the violin (Radiometrix TX2-433). With this wireless link, a performer can walk onto the stage just as an acoustic violinist does—all the electronics can be left off-stage. The miniature video camera also has it's own built-in RF transmitter, and the audio from the violin strings can be transmitted to the computer for signal processing via a commercial wireless guitar system.

Figure 4. The USB RF receiver and glove with sensors.

The sensor data is received through a USB-powered RF receiver (see Figure 4) that uses another microcontroller (Microchip PIC16C745) to translate the RF data into USB. For ease of use, the sensor data is translated into the USB standard protocol for game controllers (the firmware of the PIC enumerates as a multi-axis, multi-button game controller with the device name "Overtone Violin"). This makes the task of communicating with software such as SuperCollider, Max/MSP/Jitter, Pd, etc. much simpler, because these programs already have built-in support for game controllers through the HID (Human Interface Device) drivers. The use of USB has several advantages over MIDI, such as lower latency, bus-power (no need for batteries or a power adapter), and simply not having to carry around a MIDI interface.

The top side of the head of the violin includes the miniature video camera, the 16-button matrix, and one of the ultrasonic sonar sensors. The video camera can of course provide content to be manipulated in a multi-media performance setting, but this was only one of the reasons it was included with the sensors. One gestural attribute that is unexploited in normal violin technique is the direction the violin is pointing—the video camera (as well as the sonar) are included for this reason, in order to capture information about whatever the violin is pointing at. This can then be analyzed in the computer and used to control different aspects of the sound. The sonar sensor determines the distance from the end of the violin to any solid object such as a person or a wall; it does this by sending out 40kHz bursts controlled by the PIC16F877 and waiting for the echo to return once the signal has bounced off something. It calculates the distance based on the speed of sound, and has a range of about 10 feet.

The back side of the head of the violin has one spring-loaded slider, a miniature joystick, two linear potentiometers, and two buttons. All of these can be thumb-controlled, except for the two buttons that are mounted in such a way that they are accessible with the knuckles while playing the violin strings—these are useful for changing modes without having to switch hand positions. Any sensor may be assigned to any parameter on the computer of course, but they are interconnected such that the left linear potentiometer controls an offset for the spring-loaded slider, and the right linear potentiometer changes the scaling factor for both axes of the joystick. This does not preclude using either of the linear potentiometers independently, but it does allow the sensitivity of the joystick to be fine-tuned, and the base level of the spring-loaded slider to be set so that it doesn't always go all the way back to zero; these interdependencies can be very useful while performing.

The Overtone Violin is played with a normal violin bow, as the performer wears a glove with embedded gesture sensors (see Figure 4) on the right hand. This glove connects to the violin via a 5-pin mini-XLR jack located on the right side of the body of the instrument. It is actually a fingerless nylon biking glove with a small circuit board sewn on consisting of an accelerometer and a sonar transducer. The accelerometer is an Analog Devices ADXL-203, which can sense both acceleration and tilt (with respect to gravity) on two axes. This gives the performer a virtual x/y joystick and captures relative gestures of the bowing hand / arm. The sonar transducer is used to capture absolute movements between the glove and the body of the violin. Like the sonar sensor on the head of the violin, the glove sonar senses distance but it is set up for direct instead of echo (reflection) mode. It has a range of 3 feet, corresponding roughly to the distance from the glove to the violin when the right arm is fully extended. The ultrasonic pulse is sent out from the glove transducer, and there are three receiving transducers mounted on the body of the violin (just behind the string support) in order to widen the angle of reception. The glove sensors provide the performer with a set of gestures that are similar to bowing, yet can be used in a completely different way (even without holding the bow). The performance technique employed while using the gesture glove is actually more in the vein of Michel Waiswiz's Hands [16] than traditional violin practice. This is the main reason the sensors were put into a glove instead of being attached to the bow, but they can in fact be used as an approximation of bowing gestures while playing on the strings if so desired.

4. CONCLUSION

The Overtone Violin is an ongoing project that will keep evolving. While this paper outlines the technical development of the violin itself, current research has focused on the development of new performance practices with it. The first public performance with the Overtone Violin was at the Dutch Electronic Art Festival (DEAF '04) in Rotterdam, the Netherlands. The composition *Duet for Violin + Violinist* uses the SuperCollider 3 audio synthesis language to process sounds from the violin strings as well as generate completely new sounds through a mixture of different synthesis algorithms. It was inspired by the idea of creating an improvisation environment with oneself, and trying to get away from the division between accompanist and soloist. The Overtone Violin represents a significant step towards formulating an integrated approach to new violin performance; given the versatility and expressive performance possibilities of the instrument, it is impossible to foresee the far-reaching effects it may have on violin performance and composition.

Video clips of the Overtone Violin can be found at the following web page: http://www.overtoneaudio.com/violin/. The Overtone Violin is Patent Pending 2004.

5. ACKNOWLEDGMENTS

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