Convolin: A Novel Digital String Instrument

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Abstract

The Convolin and attached performance system were developed as a novel digital string instrument. The concept is based on pitch tracking and manipulation combined with convolution as a means of altering timbre and spatial sonic qualities. The system allows the musician to play expressively via bowing technique, while the digital fingerboard allows even novices to play the intended notes and chords.

Keywords: new musical instruments, musical controllers, string instruments, pitch manipulation, convolution

1. Introduction

1.1 Concept

The idea of the Convolin project was to take experiments conducted using convolution and apply the same concepts to an easily-playable string instrument. The convolution is used to change the timbre and overall spatial quality of the string sound, and the ease of playing comes from keys used to pitchshift the input signal of the instrument string.

1.2 Background

The Convolin began with an exploration into the use of real-time convolution. The basis for this exploration was a paper by R. Aimi of MIT's Media Laboratory entitled *Percussion instruments using realtime convolution: physical controllers.* [1] The paper explored different manners of physical controllers and methods used to convolve the signal from those controllers. The intention of the convolution in this case was to create a seemingly natural sound without the natural input, utilizing a combination of impulse response and various processing parameters. The same technique has been used in other projects for similar reasons, such as the Sound of Touch [13], in which a controller can be used on any surface. However, after various experiments it was decided that in order to develop the Convolin project, the convolution, in this case defined as the resultant signal of two sounds (the input and impulse response) combined [8] [10], would not have the intention of sounding natural, but rather create a new, unnatural dimension to the natural string sound.

The convolution patch used in Max/MSP for the development of the Convolin project is called TconvolutionUB [21]. It requires a userdefined input response sample and has preset buttons that load files, select rates, and trigger the overall calculations.

The area of augmented string instruments has seen many designs, from augmented electric guitars [11] and cellos [8] to digital violins [14][15] and bows containing sensor apparatuses [6]. These projects focus on either utilizing an existing instrument as the basis and physically augmenting it, or in the case of the Overtone Violin [14][15], creating a physically new digital instrument based on an existing instrument. The Overtone Violin consists of the string setup and playing modality of the violin combined with both numerous onboard digital controls and a user motion sensing apparatus. In the case of the Augmented Violin project [6], a traditional violin was pared with a bow containing various sensors with the goal of capturing the movements of the musician in order to use the data as a means of creating a new dimension of sound. The Augmented Electric Guitar [11] and Augmented Cello [8] both take the approach of modifying the traditional instrument to allow the signals to be obtained and processed.

Unlike the majority of existing augmented string instrument designs [16], the Convolin is intended to be a novel instrument. While the basic concepts of traditional string instruments are incorporated to some extent, such as the reliance on tuning pegs, a bridge, and a bow, the playing method and control of the instrument will be unique to the Convolin. The idea behind the physical development of the Convolin was to create a hybrid of the sound of a classical string instrument and the functionality of a musical video game controller, specifically that of the popular game Guitar Hero. The Guitar Hero controller is shaped like a guitar. It contains a number of buttons on the fret board and a plastic lever that serves as a 'string'. To create a sound, one holds down at least one button and strums the lever to play a preset note or chord.

1.3 Goals

The intended result of the Convolin project is to create an instrument utilizing bowed strings, digital pitch control, and convolution to create a unique, easy to play, sonically versatile string instrument. The final product should be fully playable to even a novice user, and usable in the musical and performance context of a typical string instrument.

2. Development and Implementation

2.1 Early Experiments

The first experiment run with the convolution patch involved the sound of a snare drum being run real-time into Max/MSP and combined with the sounds of other percussion instruments. When combined with a sample of a cymbal, the processed snare hit took on a bright, reverberant quality. Combining it with a wood block sounded like a tinny, sharp knock on a door. Various combinations were tested, and with each combination the resultant sound was unlike either original sound. One would not listen to the sample and instantly be able to decipher it as a snare and cymbal combined. Instead, the resultant sound becomes a basis for aural metaphor - “like a snare drum with a heavy reverberant metal plate inside” - as it is difficult to define a sound that has never before existed.

After experimenting with various combinations of percussion instruments, the idea arose to attempt the same experiment with a string instrument. A guitar was used in place of a drum, and the same experiments were repeated. The result was that transient sounds, such as plucking a guitar string, gave similar results to the earlier percussion experiments. However, bowing the strings gave a rather different result. Bowing the strings created a unique effect similar to a pitched reverb, changing the timbre and spatial quality of the instrument based on the sample with which it was being convolved.

2.2 Mechanical Design

The design for the final instrument was constructed as a solid model in Google SketchUp. It began as an oblong acoustic shape, using a hollow body and soundhole similar to that of a lute. The body itself grew progressively longer with each reworking of the design because with the neck intended to be a fingerboard of buttons, the strings would not be running the length of the neck. Instead, the body itself had to be of adequate size to have strings tuned in the lower octaves. The body shape became progressively oblong.

Upon experimenting further with strings and the convolution patch, it was decided that the input sound functioned better through body vibration than through acoustics. At this point the overall body shape changed greatly in structure. As acoustics were less than vital to the final sound, he oblong shape of the back of the instrument was kept but the front of the instrument was completely removed. This resulted in an open bowed shape, similar in appearance to a bow and arrow when viewed from the side. It was decided that the entire body would be made from metal, so as to allow the greatest resonance of the string vibrations for ease of signal pickup.

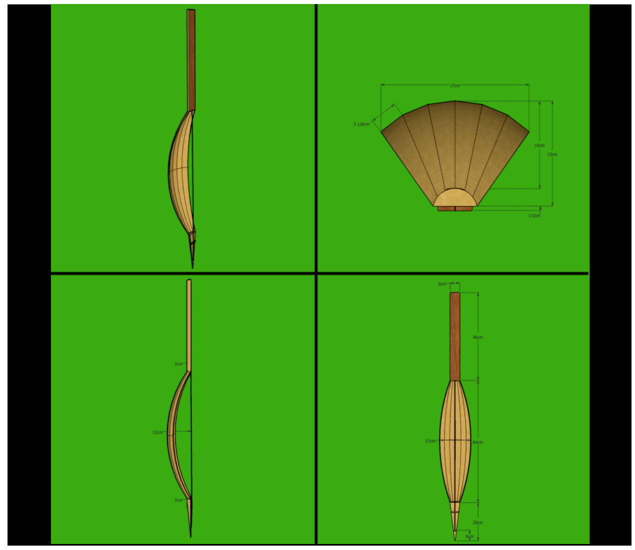

Figure 1. Mechanical Drawings of the Convolin

The neck was designed in the traditional form of a string instrument, with a curved back and flat front. The button positions were originally arranged in a single line, with the lower pitch nearest the body of the instrument. Upon trial of this arrangement, it was found to be both counter-intuitive and difficult to use to play chords. Discussions with string players as well as non-musicians led to two important insights: the pitch should be arranged as that of a string instrument wherein the lowest pitch is farthest from the body of the instrument, and the keys would be easiest to play arranged as a piano with semitones physically above tones. This resulted in the creation of the left-handed piano concept, which caters to both of the aforementioned insights.

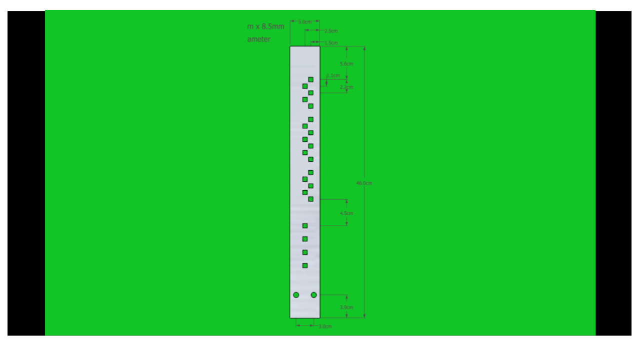

Figure 2. Convolin Neck and Pitch Keys

Various bridge designs were tried and tested. The first bridge tried was a prism shape sculpted out of polymorph plastic, and from there progressed to a low, sturdy bridge of layered wood. The final bridge was carved out of solid pine, similar in size and shape to that of a cello bridge with a thicker top. The tension of the strings became an issue with a thinner bridge, as attempting to adjust the bridge position even slightly resulted in damage to the bridge itself. The bridge sits on the upper face of the triangular apex at the base of the body, which is hollow.

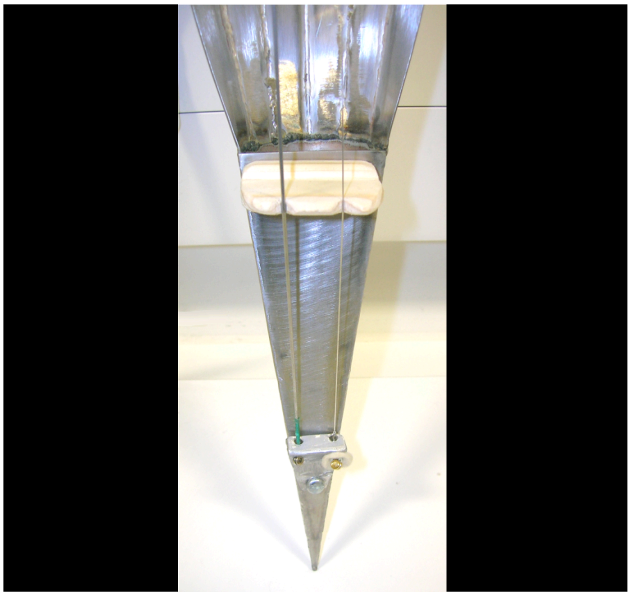

Figure 3. Apex and Bridge

2.3 Strings

Originally the Convolin was intended to be a single-string instrument. When it came to deciding the actual range of the instrument, it was discovered that one could only achieve approximately an octave and a half before running out of room for an adequate number of pitch keys. Because of this, it was decided that using two strings pitched an octave apart would allow a larger range. The strings of the final instrument are tuned to A2 and A3. When pitched using the keys, he lower string ranges from C2 to E3, and the higher string from C3 to E4, or the E above middle C. This gives the Covolin a similar range to the cello minus an octave in the higher range. The actual strings used are from a cello and guitar.

2.4 Pickups

Three different types of pickup were experimented with. The first used in the string experiments was a small cardioid microphone, placed over the soundhole of the guitar. The microphone worked adequatedly, however it was decided that the additional acoustics picked up by the microphone were unnecessary.

The prototype featured an electromagnetic (humbucker) pickup from an electric guitar. While aesthetically pleasing, the humbucker created far too much noise in the form of buzzing to be very useful.

The final pickup that was settled on for the instrument was a piezo pickup, or contact microphone. This was ideal when joined with the concept of a metal body used to resonate the vibrations of the strings. Originally the sound from the piezo was rather shrill with unwanted buzzing, however this problem was solved by the application of blue tack between the piezo and instrument as well as on opposite edges. The ideal placement for the piezo was found to be either inside the triangular apex of the body, opposite the bridge, or centered on the rear of the body itself.

2.5 Controls

The main controls of the instrument are the strings themselves, as any vibration in the strings creates the input to be processed. One can play in the same manner as any string instrument, with the same variance in bowing technique.

The digital controls include three separate controls: pitch, convolution, and reset. The pitch controls are the buttons arranged as a left-handed piano along the upper portion of the neck. They can be used individually, or multiple keys can be played simultaneously. The keys themselves are arranged sequentially in semitones from the top of the neck, from C through E.

The convolution controls sit below the pitch controls. There are three buttons allocated to convolution control, and they are intended to allow the user to change the sample with which the signal is being convoluted without having to refer back to the program running on the computer. The samples triggered by the buttons can be changed within the program itself.

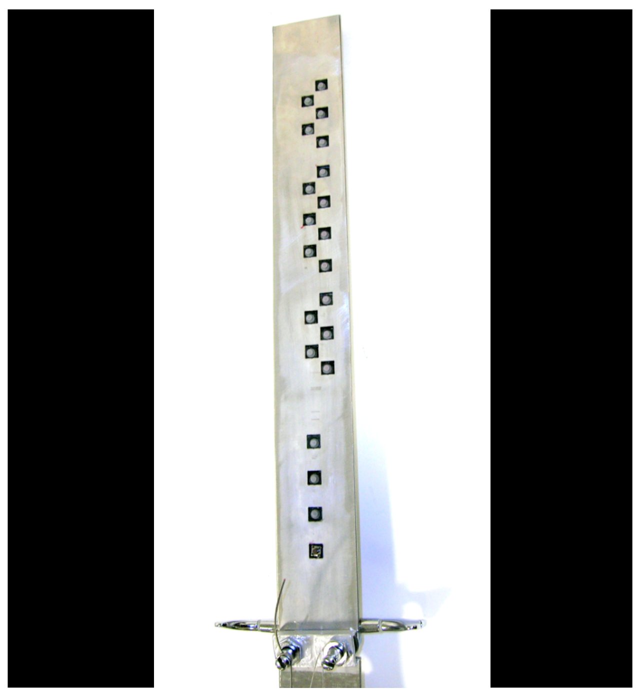

Figure 4. Digital Controls

Below the three convolution controls is the reset button. The reset button is intended to be used in case of sonic emergency, such as signal overload or a feedback loop. The reset button will instantly set the input and output for the convolution section of the patch to 0, to allow the user to either refer to the program to fix the settings or to continue playing without the use of convolution.

2.6 Processing

The programming for the Convolin was created in Max/MSP. The first important aspect of the patch is the section controlling input, which is run through the pitch~ object [20]. The pitch object has the capabilities to assess the incoming signal in various terms of pitch, frequency, and amplitude. For the purposes of this patch, the input is assessed for frequency in Hz. This frequency is then sent to the pitchshifting portion of the patch.

The pitchshifting section of the patch was originally written using Max/MSP's freqshift object. However, freqshift requires very precise values for the frequency to be shifted, and this can cause difficulty if a string is slightly out of tune or if the musician plays in a manner so as to create a tone higher or lower than intended, and makes it nearly impossible to process two strings without twice as many copies of the object. A solution to this was found in the object shifter~ [21]. Shifter~ allows one to pitch a signal by multiple means, including frequency, midi note number, and semitones. Using the shifter~ object requires one to utilize pitch~ to ascertain the information needed to perform the transformation. In the final Convolin patch, shifter~ is given the frequency in Hz from the pitch~ object, and shifter~ then pitchshifts the input in semitones based on the respective pitch key. Since both strings are tuned to A, the A key is set at 0 semitones, Bb is +1, B is +2, and so on. The keys below A are negative semitones. The structure is such that if one bows the string in a manner that creates a note different from the tuned A2 or A3, shifter~ will process the semitones relevant to that note, and as such one will still receive the correct pitch relevant to the note they have played.

The third section of the patch is the convolution section. The convolution patch utilizes a tool called tconvolutionUB (henceforth referred to as the convolution object). The convolution object takes the input and combines it with a chosen input response sample. The input sample can be any sample at all that is ideally under 7 seconds in length. Convolution, by means of its process, can create a very powerful signal in a very short period of time, and as such has a separate, fully controllable input and output from the rest of the patch.

The final application features a user-friendly interface combining adjustable levels and the respective level meters, an input section to accept the input from the arduino controller, a section to manually change the convolution settings, and two oscilloscopes: one showing the signal output by the convolution patch, and one showing the overall master level.

2.7 Prototypes and Design Progression

All designs for the Convolin were produced in Google SketchUp. They were originally produced as solid models, and the final design was broken down into components and rendered as proper mechanical drawings.

The Convolin prototype was hand-built out of a wire frame coated with fiberglass.

Figure 5. Wire and Fibreglass Prototype

The dimensions were not to the final standard, and as such the overall tuning and sound were not as expected, though it served the purpose of creating a pitched and convolved sound. This prototype featured both an electromagnetic pickup and a piezo pickup, though the electromagnetic pickup was proven not to be particularly effective.

The prototype lent itself to be the basis on which changes and improvements were to be made. Physically, the first change would be the overall size. The final instrument would need to be exactly to the intended dimensions in order to be tuned properly. Based on the poor performance of the electromagnetic pickup, a piezo pickup would need to be used, and this led to the instrument being made out of metal, as the reverberance of the metal would amplify the signal. Finally, the neck would have to be scaled down, as it was too deep for comfortable playing.

In terms of the programming, once the working prototype was created, it was realized that the pitchshifting (using the freqshift object) was not going to work as was intended, and that the program required some means of assessing the frequency of the input signal in order to properly pitchshift it. These problems were eventually overcome by completely rewriting the programming using the aforementioned pitch~ and shift~ objects.

The final instrument was machined out of stainless still by the Queen's University engineering department, based on the mechanical drawings. While the fabrication process took far longer than intended, causing some difficulty, the final product was nearly flawless.

Figure 6. Fully Assembled Convolin

This design takes into consideration the problems encountered in the earlier prototype, including a body precise to measurement, a narrower neck, and a piezo pickup mounted with blue tack on the rear of the metal body. The strings on the final instrument were able to be tuned to a perfect A2 and A3 which, when combined with the new programming, produced the desired pitchshifting effect. The instrument on its own produces more of an acoustic effect than would be expected from an open shell, but upon working with the instrument and final program, it was discovered that the tiny bit of acoustic-ness actually contributed to a more full-sounding final effect.

3. Operation and Experience

3.1 Usability

The final Convolin instrument was found to be particularly intuitive, especially to those users who have experience with musical video game controllers. The concept of holding down a button with one hand while playing the string with the other was a concept easily grasped. Some users found it surprising that more than one button could be triggered at once, allowing the instrument to create chords, but found it an area to explore after their initial discovery.

3.2 User Expression

The topic of user expression in digital instruments is one that is frequently addressed [2][3]. The Convolin is somewhat unique in terms of expression in a digital instrument, as the sound is not simply a triggered or manipulated sample, and the user input can be extremely varied.

The main aspect of the Convolin that allows user expression is the use of bowed strings. The concept of bowing a string in itself is a manner of expression. A string can be bowed in many ways, and a musician can vary the pitch and tone based on their respective means of bowing. The pitched keys will precisely change the pitch of the instrument, but the signal being pitched is taken directly from the signal that is received from the bowed strings. In essence, the musician has the majority of the expressive control that any musician would have with a typical string instrument.

3.3 Sonic Properties

Sonically, the Convolin can vary greatly based on the impulse response with which it is convolved. As an unprocessed signal, the Convolin sounds like a typical bowed string instrument with a more metallic timbre. Once processed through the convolution patch, it can sound like anything from a moderately reverberant classical instrument or electric guitar to a sparkling pad or even a set of bagpipes. The heart of the sonic quality of the instrument lies in the creativity of the user.

4. Reflection

4.1 Achievement

In creating the final Convolin instrument, the original plan of developing an easily playable string instrument with a user-customizable sound was fully realized. Some physical features could be improved to make the instrument more ergonomic, and the programming could potentially be improved to allow less room for user mistakes, though at the same time altering the program in such a fashion could detract from the available sources of expression.

4.2 Sonic Review

The sonic properties of the Convolin are nearly limitless, but could potentially be given more user control. When utilizing convolution, the overall length of the notes played will not be less than the impulse response sample with which it is being combined, as the impulse response is played in its entirety. In order to offer more sonic control, it would be possible to augment the programming with a section of envelopes based on amplitude that would control the attack, decay, sustain, and release of both the impulse response and the convolved signal.

4.3 Physical Review

In terms of the ergonomics of the Convolin, some improvements could be made. The first would be the overall scale of the instrument. The design was made to the scale of its creator, who happens to be very petite. If the Convolin were to be produced for the public, it would be necessary to create additional sizes of both body and neck.

The key placement, while intuitive, could also be more ergonomically designed. Attempting to play chords with the current placement can prove difficult. Ideally, the keys need to be placed closer together and possibly in a nonlinear fashion. The keys would also benefit from some manner of cover similar to the keys on a computer keyboard, to make them easier to trigger and give a more satisfying tactile response.

The body itself could benefit from better support. At the moment any downward pressure on the instrument can cause a change in pitch. The effect is noticeable even when switching from playing in a seated position to playing whilst standing. However, depending on the intentions of the musician, the bending of the pitch could actually be used as an intentional effect.

4.4 Potential Development

There are many ways in which the Convolin could be further developed. The first and most likely future development would be that of a wireless instrument. This would allow for much more dynamic use of the Convolin, as being tethered to a control box and computer requires one to stay in a relatively stationary position and be careful not to disconnect the cabling.

Another development along the lines of convenience would be the creation of an embedded system. An embedded system would rid the user of the necessity of having a computer on hand, and would bypass the problems of freezing programs and crashing systems. This idea could involve having a built-in impulse response sample bank as well as onboard controls for each input and output.

5. Discussion

The Convolin project resulted in the successful creation of a novel digital string instrument. It is easily playable even with no previous knowledge of string instruments or of the Convolin itself. The processing is adequate and allows user control of the timbre and spatial qualities of the sound. As an instrument, the Convolin is entirely usable in a standard musical context and could easily take the place of a classical string instrument, especially that of a cello, which is similar in range with the current tuning. The strings and tuning could be changed to octaves higher or lower to cover the range of other string instruments, and the programming would function properly as is so long as the strings are always tuned to an A, regardless of octave.

There is currently no plan for commercial production, though several enquiries have been made as to how one might obtain a Convolin. While the Convolin may have commercial potential, any further instruments developed in the near future will be made independently.

Given the opportunity, a wireless or Bluetooth version of the Convolin may be produced, as well as full designs for scaled versions of the instrument.

With the successful development of the Convolin, the potential for easily accessible, versatile string instruments has been brought to fruition. While not an attempt to replace skilled musicians, the Convolin opens a door to the creation of musical instruments that allow immediate access to the composition and performance of music even to those with little to no musical background.

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