The XT Synth: A New Controller for String Players

ABSTRACT

This paper describes the concept, design, and realization of two iterations of a new music instrument called XT Synth. The development of the instrument came from the desire of maintaining the expressivity and familiarity of strings instruments, with the flexibility and power usually found in keyboard controllers. There are different examples of instruments that bring the physicality and expressiveness of acoustic instrument into electronic music, from DIY products to largely commercially available ones. However, the market lacks of an instrument with the characteristics of the XT Synth. In this paper, it will be discussed the process and the challenges faced on making a DIY music instrument and in the attempt of making a commercially available instrument.

Author Keywords

Synthesizer, midi controller, strings, Human Computer Interaction (HCI)

1. INTRODUCTION

The XT Synth is a new music instrument with continuous polyphonic pitch control, augmented with force resistive sensors, potentiometers, accelerometer and rotary encoders. It's a synthesizer and a midi controller. The instrument has a familiar technique, which can be translatable from string instruments, like the guitar and violin family. Its visual ads a new level of expressivity, where not only sound is generated, but also different light patterns. The XT Synth is an ongoing project, now on the design stage of its second iteration. In this paper it will be discussed what the XT Synth was, what it is, and where it's going. Several changes were made, and it will be pointed how the process of going from a DIY product to a commercial product affected those decisions.

For our purposes, we can divide instruments into two categories, instruments with a translatable technique and instruments with a no translatable technique. Traditional instruments are known for centuries and have a well-established technique, instruments like piano, violin, or guitar, can have their technique translatable to others, like a guitar to mandolin, or a piano to a harpsichord, while, instruments like the theremin can't really translate their technique to any other instrument. Novelty comes with a price, the more novel ways for expression one add to an instrument, the more distant it gets from other instruments. One of the staying power factors for new instruments is the balance between novelty and how it translates from well-known instruments. The XT Synth stays somewhere between those extremes, while its technique can be translated from string instruments like guitar and violin, it ads a new level for expression on controlling electronic music that's usually just found in novel instruments which translate only for keyboard instruments.

While there are countless controllers for keyboard players, it's hard to find controllers for string instrument players. And, for example, midi guitars are just for guitar players, while the XT Synth intends to be a familiar instrument to other family of players too. In the last years there were successful novel instruments with continuous pitch control, like the Continuum [5] and the Roli Seaboard [7], or augmented guitars, like the Sensus, from Mind Music Labs, but not a continuous pitch controller with augmenting sensors for string players.

The XT Synth came from a personal project to the idea of making it a commercially available product. This process affected in many ways the design of the new iteration. Some features had to be added and others excluded, and not only artistic aspects had to be considered. Besides being an interesting instrument for me, it also needed to please others, be resistant, and be easy and cheap – as possible - to build.

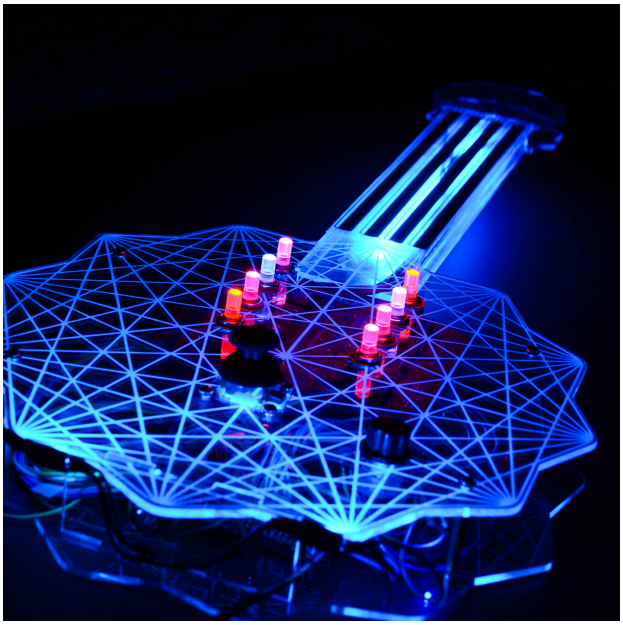

Figure 1. The XT Synth.

The creation of novel interfaces for musical expression might come from the personal desire of the artist to create a new tool for expression, or as merely for the learning and experimentation experience; or it might be to fulfill a market, or client's needs. Both products might share the same conceptual goals, but they might differ drastically in its whole production process, from the first sketches to fabrication. The XT Synth was born as a personal project and shifted to become a commercial product.

It seems to be clear to tell what is "DIY" and what is a commercial product. We all making instruments are part of the maker, or DIY culture. But, some of us also are, or are trying to be, in the commercial side of the business, monetizing the art of making NIMEs. There isn't a well-defined line between what is a DIY product and what is a commercial one. One product can be born in the DIY side, and in each iteration can be considered to be more in the commercial side of business. Both sides might share the same concepts and differ on how finished a product look, but their culture also differs. So, how do you go from a personal project to a commercial one? What considerations to take on a DIY product and on a product that you want to take as much profit as possible? The intention of this paper is far from giving these answers, but to show my perspective on how I'm approaching the creation of the XT Synth, from the DIY to a commercial product.

It's necessary to say that this an ongoing project, and when I say commercial product means: "as finished as possible, aimed to sell as much as possible". In any moment I'm stating that it's going to

become a successful product on the market. There will only be my personal point of view of what it might make it successful.

2. BACKGROUND AND MOTIVATION

My main motivation for building the XT Synth, as a multi-instrumentalist, was to be able to get the best from different instruments that I play into just one. My main instrument is the electric guitar, where I feel more comfortable, and happy, playing. However, I also play the violin and the possibilities of expression, mostly on envelope and vibrato, always fascinated me. On top of that, I also play the keyboard, and I always loved to play old analog synths. Playing Pink Floyd's Richard Wright's solos is always a joy. My intention was to be able to translate my left hand guitar technique to an instrument that could have the expressivity of a violin, which could control any electronic sound I wanted.

The XT Synth was built from this desire and as a challenge: The challenge was building it in two weeks, in time for a competition. Thanks to the deadline was able to finish it in two, exhausting, weeks. However, it was made in the most DIY way possible. All the components were soldered with wires, in solderable breadboards; the enclosure was laser cut in acrylic; and some things were even glued with super glue. It sounded ok, with some glitches, and looked great in the dark, enough for being accepted for the competition. However, it's still had some glitches in the sound, which will be discussed later, and it was really fragile, I could never let any other person play it without the fear of it breaking a part. Besides, on an illuminated environment all the DIY aspects were standing out, Figure 2.

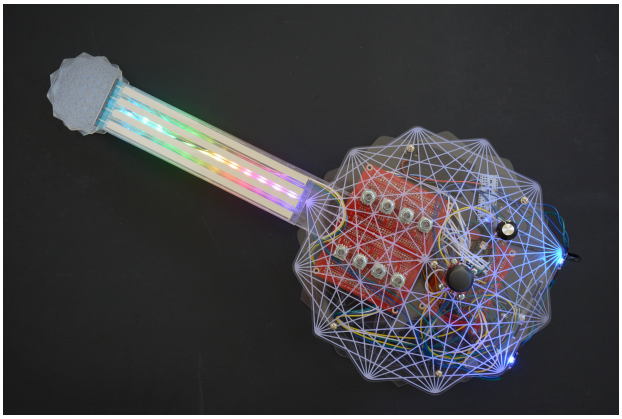

Figure 2. The XT Synth in the light.

For my surprise, after posting one video on my Facebok fanpage, it went viral and I got a lot of people asking me where to buy it. I thought it would be worthy making it a commercially available product, even not having experience with mass produced products at all.

For making it a product that can be sold to others the making process needs to be drastically faster, it needs to be much stronger, have its features, design and components rethought and needs to be as cheap as possible, maintaining its quality.

There are several instruments on the market that uses continuous sensors for controlling pitch, like the Korg Monotron, or the Roli Seaboard, but most of them are intended to play with keyboard techniques. Also there are instruments that use the traditional instrument technique with extra sensors, augmenting them aloowing it to generate and control electronic music, like the Dan Overholt's Overtone Violin [4], or instruments that are inspired in the violin technique but use a different actuators, like the Suguru Goto's Super Pal [6], and Charles Nichol's vBow [2]. However, all of these examples are not suited for string players. Perhaps, one of the closest examples of an instrument that that can be translated from a guitar technique is the David Vorhaus' Kaleidophon, invented in the 70's. The Kaleidonphon has for ribbons that can be played as a string instrument with the same left hand technique, which can control a synthesizer. However, forty years later, we don't have any popular controller for string players yet. There are also MIDI guitars, and MIDI pickups, which basically give MIDI capabilities to a standard guitar, lacking any other type of control, present in many of the keyboard controllers.

That XT Synth comes as a candidate to a new controller for string players, with continuous pitch detection, allowing slides and vibrato, augmenting sensors, and with great visual appeal. The XT Synth was not only thought to be an instrument with extended capabilities with continuous controllers, with soft potentiometers, force resistive sensors, accelerometer, etc., but also thought to have some qualities and challenges that traditional instruments also have. The instrument has a learning curve, it's non-tempered, like a violin. Like a normal instrument it doesn't have an instant gratification, however, it allows an infinite level of virtuosity with time. If in one side we have controllers where the software makes most of the work, where the live performance is not the focus, in the other side we have the XT Synth, where the physicality and performance is in the first place.

3. DESIGN

The initial design of the XT Synth had the concept of being a mix of guitar, violin, synthesizer and midi controller, with visual feedback. Besides its concept, it had to be feasible within two weeks, with the material that was readily available. For tracking pitch it was used four soft potentiometers; and for changing the synth and midi parameters it was used eight RGB rotary encoders, one joystick and one rotary potentiometer. In its core, everything was soldered in solderable breadboards and a Teensy 3.2, an Arduino compatible board, was used as the brain. The enclosure was laser cut in acrylic and engraved, and it was used addressable leds for the light effects.

The second design, still in development, included some features and excluded others. One of the main differences is the redesign of the enclosure to a 3d model, the addition of some other sensors and the fact that XT Synth is not a synth anymore, but a midi controller. It needs a new name.

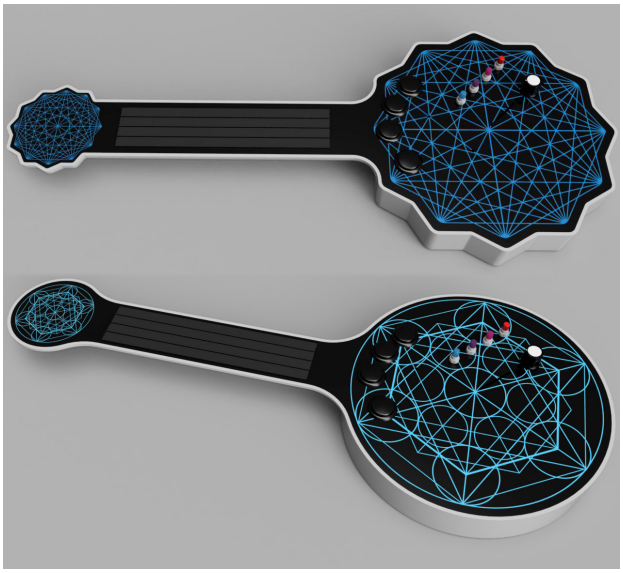

Figure 3. 3D models of the next iteration.

3.1 The Synth

The first idea was to use an affordable microcontroller as the synth engine. The Teensy 3.2 is an Arduino compatible board from the PJRC Company. It has a Cortex-M4 microcontroller, with enough power for moderately complex synthesis techniques and it contains one 12-bit DAC. It can generate

audio at a 44100hz sample rate. The Teensy 3.x family has an audio library, which has a GUI that resembles the software Max. After laying out the synthesizer in the visual workspace (Figure 3), one can export a piece of code that can be used in the Arduino IDE, containing objects that represent the parts of the synth.

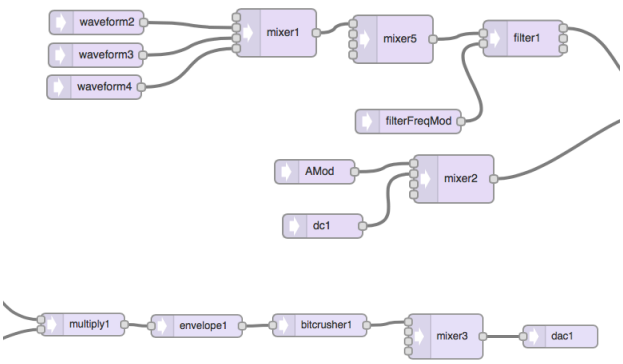

Figure 4. Teensy audio library GUI.

The synth contains three different waveforms – sawtooth, square and triangle – filters, modulation, envelope and a bit crusher. The amplitude of the waveforms, as the other parameters, can be changed through the rotary encoders and potentiometers.

One of the downsides of the Teensy audio library is that the waveforms are not band limited. After the first prototype, it was made an effort for migrating techniques for creating band limited waveforms, such as "polynomial transition region" [3], using the Teensy audio call back. One waveform was successfully made, a sawtooth wave. For the square wave it was used the technique of using two sawtooth waves with one wave with its phase flipped, being delayed by a delay line. However, after many tries, it didn't work and further investigation on the Teensy audio library is necessary. The other problem, and the biggest downside, was the lower quality of its DAC. Glitches happened from time to time and the floor noise was pretty audible.

A better DAC could be used, or even an analog system could be built, but I decided that the amount of work and money that would need be to be invested was not worthy to spend. I, then, decided to focus on its MIDI capabilities. Not needing to use all the power of the Teensy 3.2 for synthesis, I decided to use the Teensy LC for the next version, which is less powerful, but cheaper. The LC (low cost) model is less powerful, but powerful enough for MIDI and can be recognized as a MIDI device, just like the 3.x.

3.2 Pitch Control

The XT Synth should have its pitch controlled as a violin, or a fretless guitar. It should allow tiny vibratos variations, slides, etc., being a microtonal instrument. However, it also needed to be easy enough to be played as a traditional controller, in order to be perform simple to complex melodies.

The sensors used were four soft potentiometers. A soft potentiometer changes its resistance accordingly to the position of the finger on the ribbon, this way, it can be read in an analog pin of the Teensy. Because the analog pins have a 10-bit resolution, a soft potentiometer is able to produce 1024 values. So in a 200mm ribbon, there is a resolution of 0.2mm. Every soft potentiometer can be tuned differently, and in the new prototype there will be a display that will allow the player to change the tuning easily, using the rotary encoders.

The soft potentiometers require a pull down resistor to avoid its floating behavior output. Using a 1k resistor as the pull down resistor, without touching the soft pot, the output was always around 2-5 – in a 0-1023 range. This way, it was set a threshold, and every time that this threshold is exceeded a MIDI "note on" is sent, or the synthesizer envelope is triggered.

On the synth part, every soft potentiometer value was mapped into a range of frequencies. Each of them has one octave and a half, and they were tuned or in fourths, like a guitar, or in fifths, like a violin. Playing the instrument using the embed synth was quite pleasing, since the response was virtually real time, no delay was felt. The Teensy board is quite fast, and since it doesn't have many layers of abstraction, like a computer, it's faster than playing with MIDI.

On the MIDI side, to achieve the same vibrato and glissando effects, pitch bend had to be used. Unlikely midi CC, which has 7-bit of resolution, pitch bend has 14-bit resolution. However, the Teensy analog ports just supply 10-bit analog ports, so it still had the same resolution of the synthesizer portion. The challenge was how to translate the pitch bend to a correct pitch, since pitch bend is not global, it can go from one half step to many octaves, depending on how the external synth is configured. The solution was sending just one "note on" per soft potentiometer and change its pitch bend accordingly to the finger's position. For example, first soft pot will always send a D, second a G, then a B and E, plus the amount of pitch bend that corresponds to the finger position. What needs to be done is that in the synthesizer the pitch bend amount needs to be always the same, like -8 and +8 half steps.

Another important aspect regarding the use of pitch bend is that there's only one per MIDI channel, so every "string" needs to be sent to a different channel. This way, it's possible to do polyphonic glissando, which is impossible in common keyboard MIDI controllers.

3.3 Controllers

3.3.1 RGB Rotary Encoders

One of the ways of controlling the XT Synth parameters, or just sending MIDI CC, is using the RGB rotary encoders. Rotary encoders are digital components that don't have an absolute position like potentiometers, however, one can tell if it was turned counter or clockwise. An advantage of a rotary encoder is that it can be used for controlling several different parameters, using it in different banks, since it just increments to plus or minus, instead of giving a number related to its position. The tricky part is keeping track of which number it's outputting at the moment, since it doesn't have a visual feedback. That's why RGB encoders were used, so I mapped values into colors. In one bank they would go from blue to red, and in next bank from green to red. This way, I could tell about where they were and if I really changed the bank. Those encoders also have push buttons, which were used for changing banks, and octaves. In the next version, the encoders will be used in conjunction with a display to control more features of the instrument, like tuning, light behavior, etc. With the display its gained more flexibility with the encoders, so I decided that eight encoders were not necessary, four would be enough.

3.3.2 Potentiometers

In the first prototype it was used one rotary potentiometer and one xy joystick. The joystick has a spring that always pulls it to the middle. I divided the x-and y-axis in two, 0 being the value in the middle. However, the chosen joystick didn't have a satisfactory performance, it just seemed to work fine near the zero position, leaving me with not much room to work with. Due to this reasons the joystick was excluded from the next version.

The rotary potentiometer worked like it was supposed to, giving me all the 10-bit desirable resolution, which was then converted to 7-bit MIDI. However, my intention was to use it mainly as a low pass filter, controlling its cutoff. With 7-bits to represent a range of approximately 18k hertz, there is not

enough resolution for having a smooth transition between frequencies, mostly in the lower spectrum. This way, I decided to use pitch bend with the potentiometer too, having a 14-bit resolution – which is really 10-bit – due to the Teensy analog pin resolution.
In the second version a slide potentiometer was added. The idea behind the slide potentiometer is that it can me used in a familiar way for guitar players. One can move it up and down, like he/she was moving a guitar pick. Although it can be mapped into anything, controlling volume seems to be the most idiomatic gesture.

3.3.3 Other sensors

While the next XT Synth was not yet built, some other sensor that will be present on it are already being tested. In the first version notes are triggered every time one touches the soft potentiometers. The second version will have 4 force resistive sensors, in the place of the buttons that can be seen in Figure 3. Each will be able to trigger notes and control after touch, bringing another layer of expressivity. There will be a switch to change their mode, allowing them to "play the strings", or to just send individual notes to a computer, to trigger samples, for example.
The other sensor will be an accelerometer. The accelerometer, besides the addition of more control over the sound, it also ads another level to the physicality of the instrument. Some common movements of string players, mostly guitar players, like raising and lowering the neck of the instrument, will be also used to change parameters of the sound.

3.4 Aesthetics

How the XT Synth looks, for me, is as important as how it sounds. Aesthetics in musical instruments have always played a big role. The performance is as visual as an auditory experience [1]. Having a visually interesting looking instrument greatly contributes to our appreciation of the performance.
"Sacred geometry" was used as the inspiration for the shape and pattern in the top acrylic layer. There are several different patterns, but they all have in common a mathematical ratio, which makes them visually pleasing. We electronic musicians are constantly looking for relations between numbers and music, looking for to understand how numbers can relate with aesthetics. Using this type of geometry seemed to be a great match for this instrument.
For enhancing the geometry and to make it more visually interesting, I added addressable leds, adding a mutable aspect to the instrument. The leds will respond to the musician's gestures in the next model.
The first version was made all in acrylic, as a quick prototype, but the next one will be 3d printed. All the design was made in 2d in the software Inkscape. The acrylic, when engraved, shines when light is projected on its sides. The challenge is positioning the leds in a way that it stays in the right position, as close as possible to the acrylic. In the first version they were glued in the acrylic, and one led strip was put inside the neck. In the next version, the 3d model will accommodate the leds in way that they will just fit correctly in the enclosure.

4. WHERE IT IS GOING

In order to make a commercially available product, one of the biggest challenges is how to build it fast. Using wires, like in the first version was out of question, this way I'm designing Printed Circuit Boards for every necessary part.
The next step is 3D printing the models and evaluating their flaws and strengths and proceed iterating until I have the "final" product.

5. CONCLUSION

The XT Synth is an ongoing project that still has a long way to go. It was born with the desire of being just a personal project and changed its path, with the intent of making it a commercially available product in the future.
The XT Synth uses continuous controllers for controlling pitch and for modulating other parameters of the sound. It can translate left hand techniques from instruments such as guitar and violin, making it a good candidate for a novel controller for electronic music for string players.
Making an instrument that is meant to be used by others added several challenges to its design. From the first prototype to the second several things changed, and in future works it will be discussed how those changes were successful or not and what other improvements might be done next.
Although I'm working to make it available to other people, it was born as an instrument that I want to use on my own music. Its first public appearance will be at the *(hidden to guarantee the anonymity of the paper)*.
Videos and more info about the XT Synth can be found at the following webpage: *(hidden to guarantee the anonymity of the paper)*.

6. ACKNOWLEDGMENTS

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