Sensor Technology and the Remaking of Instruments from the Past

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Abstract

Starting from a parallelism between the effervescence of the 1920s in the exploration of new ways of controlling music and the actual revolution in the design of new control possibilities, this paper aims to explore the possibilities of rethinking instruments from the past towards instruments of the future. Through three examples (the experience of the Persephone, the design of the Persephone2 and the 4 strings ribbon cello project), I will explore the contemporary notion of « instruments of the future » vs. controls that people expect from such instruments nowadays.

Keywords: Controller, Sensor, MIDI, USB, Computer Music, ribbon controllers, ribbon cello.

1. Introduction

Are we the future of the past? Let's go back to the early twentieth century and the recent invention of filters and VCA, which has been followed by the invention of many new controls and new electronic instruments. If among these, many are now parts of our cabinets of curiosities, some are worth a closer examination… Sensor technology now enables to recreate some of these forgotten controls with a new accuracy, turning them into innovative tools.

2. Historical Parallelism

A quick historical comparison between the XXth and the XXIst century will lead to the conclusion that both centuries have known, in their early years, a certain effervescence in the design of new controllers. This parallelism can be explained by recent discoveries that have, at both times, opened wide fields of new technical possibilities. May it also find its origins in a particular political and economical environment – this won't be the subject of this paper.

2.1 1920's Effervescence

The creation of the first electronic oscillators, followed by the invention of filters and VCA enabling to play tremolos and vibratos and to recreate the musicality of classical instruments, opened the field of the research for new controls, which would offer more possibilities than generic keyboards. The 1920s remains the most fertile years for the evolution of electronic music instruments with the invention of new controls like dial-operated non-keyboard electronic instruments or ribbon-controlled instruments. In Russia, Lev Sergeivitch Termen developed the Theremin using the body capacitance as a control mechanism, freeing the performer from the keyboard and fixed intonation. He also created the first fingerboard cellos. In France and in Germany, a whole family of dial-operated non keyboard electronic instruments was developed. Among them, René Bertrand and Edgard Varèse's Dynaphone or Jörg Mager's Electrophon and Spharaphon. At the end of the 1920s, a family of the fingerboard instruments –or ribbon controllers- appeared. In France, les Ondes Martenot, designed by Maurice Martenot, included both a seven-octave keyboard and a ribbon controller that allowed pitch inflections like a voice or stringed instrument. It allowed for a wide glissando when the player moved a finger ring attached to the metal ribbon that controlled frequency. Hundreds of symphonic works, operas, ballets, and film scores were composed for this instrument by Varèse, Honneger and Maessian.

In Leipzig, Peter Lertes and Bruno Helberger developed the Hellertion. This fingerboard was a flat metal resistance strip covered with leather. Depending on where the strip was pressed, a different resistance in the circuit was created altering the voltage sent to the oscillator and thereby producing different pitches. The force of the pressure controlled the volume of the output signal. The fingerboard was marked to help the performer find the correct pitch on the strip and had a range of approximately five octaves. The original instrument had just one fingerboard strip which was gradually increased to four and then on the later models, six aligned in parallel horizontally at the height of a piano keyboard. The four and six strip models allowed four and six voice polyphony.

The Trautonium was the first instrument to ally position and pressure control. Created in 1931 by Franz Trauntwein, it used filters to modify the timber of the note and a keyboard. The Original Trautonium had a fingerboard consisting of a resistance wire made of a tube of graphite stretched over a metal rail marked with a chromatic scale and coupled to a neon tube oscillator. When the performer was pressing the wire, it would touch the rail and complete the circuit. The Trautonium had a three octaves range that could be transposed by means of a switch. The Sonar, developed by N. Anan'yev in the USSR in the 1930s also had a fingerboard continuous controller to vary the pitch of the oscillator.

2.2 The Supremacy Of Keyboards

After the 40s, the general use of keyboards (and the war) slew down the research of new types of controls. Ribbon controllers were back in the 1960s with Moog ribbon controllers which Keith Emerson was famous for attaching to a pyrotechnics control. The Theremin-like sound in the Beach Boys' song "Good Vibrations," was played by a ribbon-controlled instrument called the Electro-Theremin, which the Beach Boys have later replaced by a Moog ribbon controller with a Moog synthesizer.
Only a few synthesizers from the 1980s had ribbon controls: Yamaha CS80's ribbon controller, Kurzweil synths and the Korg Prophecy.

3. The XXIst Century and the Emergence Of New Controls

The 2000s offered new possibilities with the development of sensor technology and new computer controls. Today, new controllers designed by the gaming and communication industries are much more innovative than the controls developed in the music industry. The general use of these new controls necessarily has a deep impact on the demand from musicians for new controllers as well as on the invention of a new approach for making music. Will brands like Apple or Nintendo be at the origin of a new musical gesture? Communication & game new controllers, such as Apple IPod, IPhones, ITouch, Nintendo Wiimotes, or DS with Korg D-10 for example, are commonly used by musicians as new tools for controlling music -first advantage being the low prices of these new tools. Though they offer a choice of innovative controllers, their low sampling resolution remains a barrier for making music (the number of values being insufficient for a musical gesture). On another hand, new controllers made for musicians are often limited to a closed non editable environment. Some artists and circuit bending specialists modify these new controllers to have a higher sampling resolution (12 bit allowing a resolution of 4096 values), but this approach is rare for a larger public. In general, the re-appropriation of control tools, which have not been thought for musicians and are not designed for musical applications, is limited in terms of use. Though it is possible to imagine that these new controllers could be at the origin of a new intuitive control gesture? The question of intuitivity in musical gesture must refer to an acquired gesture, but not necessarily to a musical gesture. The analysis of this intrusion of new control gesture into the music area is fundamental for all music industries and controller new designs. The « learning limit » is another important aspect for the design of new instruments. Among the forgotten controllers from the past, many have disappeared because their play required to be learnt. The past experiences with controllers tell us that a controller must be intuitive. The fact that most of the non-keyboard instruments using new controllers required a new play explains why they remained unpopular with musicians who had little time to practice on unusual keyboard, the Telharmonium 36-note-per-octave keyboard designed by Cahill for example.

4. Remaking Ribbons: the Persephone Experience[1]

In 2002, we decided to work on a contemporary version of a fingerboard instrument, using sensor controls today's technology would offer but preserving the best of analogue sound generators. Beyond a vintage look, the Persephone allies sensors technology and digital controls to a pure analogue generation of sound. Its analogue oscillator can generate notes with a range of 10 octaves, which goes from a deep and resonant cello tone to a nearly human voice [2]. And on the highest pitches, it can reach very high frequencies. The oscillator waveform can be set between triangle and saw tooth for a more or less brilliant sound. Its ribbon sensor technology allows all kind of glissando a Theremin or Les Ondes Martenot would allow, though the sensor ribbon is much more precise than the tube full of graphite used as a variable resistance in the Trautonium.

fig. 1. The Persephone

The way the Persephone is played creates the instrument personality. The Persephone follows the traditional play of the first non-keyboard electronic instruments with the right hand controlling the pitch and the left hand controlling the velocity. Control gesture is very intuitive, expressive and accurate enough for playing scores – not only sci-fi effects. Like on the Trautonium, the Persephone's ribbon is sensitive to pressure and position. The ribbon is a linear potentiometer that generates different control voltages depending on where it is touched. These changes in voltage are applied to the voltage-controlled oscillator and the filter. A 12 bits converter samples analogue signal from the ribbon to send them in MIDI or control the oscillator. In the 5 octaves mode, the 12 bit sampling enables a resolution of 68 cents per half tones –the average human perception range being of 8 cents. This avoids scales effect and it is possible to switch from mode A to the other modes without hearing the analogue/digital switch. An expression key controls the filter. This kind of key was also found on Les Ondes Martenot. With the Persephone, it is controlled by an optical sensor able to reproduce vibratos.

Four play modes A,B,C,D offer different hierarchy of control between the pitch, the velocity, a filter modulation and a LFO. An expression pedal can be connected to control the volume (modes A and B) or the LFO speed (modes C and D).

5. Designing Persephone markII

Three years after the first release of the Persephone, comments from users and suggestions for new features illustrate how important is the influence of new controllers developed by the game and communication industries (e.g. multi-touch surfaces and Nintendo Wii games) on the perception of new musical interfaces. A growing demand called for a polyphonic ribbon and stronger integration into the computer music environment by adding a USB I/O to the MIDI and CV I/O.

5.1 Designing Persephone II: A duophonic ribbon [3]

The Persephone II has two analogue oscillators (low wave and hi wave) both generating a sine to saw waveform. Making the ribbon duophonic extends the instrument sonorities spectral to play simple chords. With ribbons, the resistance is usually measured where at the stimulated position (the ribbon is pressed). Here, the resistance is measured at each extremity of the ribbon.

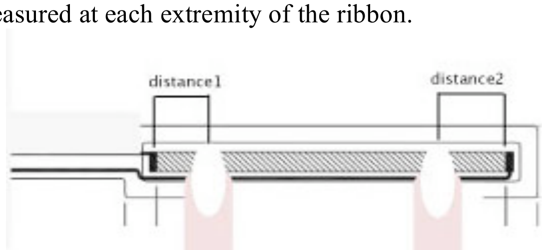

fig.2. Duophonic ribbon

The Uc switches alternatively the voltage at the two ends of the ribbon. Measuring the voltage at the stimulated position will alternatively track the right and left positions. and left positions.

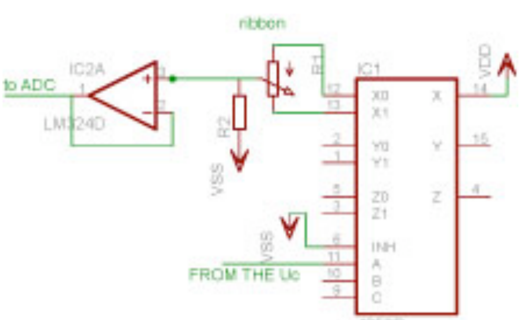

fig.3. Circuitry for a duophonic ribbon

The duophonic ribbon allows modulation capabilities like frequency modulation of one oscillator by the other one. Each oscillator has a dedicated 12dB low-pass filter to adjust the low and hi sounds separately.

5.2 The hierarchy of controls

16 presets enable to select different routing architectures. 8 presets are fixed and 8 are users presets configurable thru a software application. Users presets will be stored in an internal memory.

5.3 Compatibility with computer music environment

The A/D conversion is made with Eowave ESS DSP [4]. This process assures a 12 bits resolution (4096 values) conversion for an accurate musical gesture. It's 100% MIDI compatible and uses USB full speed 12 Mb/s. This compatibility makes the Persephone II compatible with all MIDI compatible softwares. It reduces the latency at less than 1,5ms. ESS DSP offers an internal signal process and a compatibility with MAC/PC/Linux.

Used as a controller, Persephone II parameters can be affected to any controllers in different format Control Change 7 bits, Control Change 12 bits (where the 5 LSB bits are mapped on CC + 64), note on trigger, program change, pitch bend 12 bits real, pitch bend14 bits mapped, monophonic aftertouch (channel pressure). Presets, transmission channels, parameter setting can be saved in the internal memory. Each controller has an optimized processing with analogue and digital zooming, offset, inverse, low-pass filter, noise gate to transmit the better signal to the host. In the Persephone II, these processes are fixed for controller presets, but editable in an opened mode. 4 CV outputs, MIDI in & out and USB turn the Persephone II into a versatile controller.

6. Remaking The Ribbon Cello: Ribbons like strings

Working on the Persephone II duophonic ribbons is at the basis of another project involving ribbons: the remake of a 4 strings Ribbon Cello.

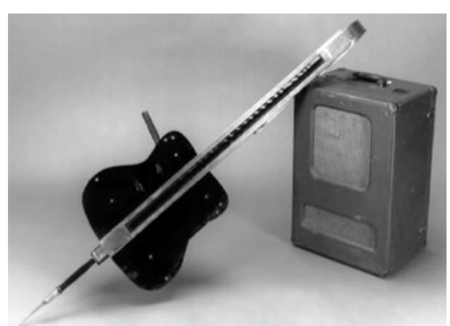

fig. 4. Theremin's Ribbon Cello [5]

fig.5. Eowave multi ribbon surface, 4 strings Ribbon Cello prototype, 2009.

The Ribbon Cello developed by Lev Termen is also known as the Fingerboard Theremin [6]. Instead of strings, it has a flexible plastic film fingerboard which, when touched, produces a tone. As long as the finger remains depressed, a tone is sustained. The technology employed for the ribbon at that time made impossible the making of 4 parallel ribbons. The volume is controlled by a lever on the player's right and the tone color is controlled by knobs, and the sound is amplified by an external amplifier.

6.1 Logarithmic multi-ribbons

The ribbons created for the Ribbon Cello project use the same technical specifications than the linear potentiometers used for the Persephone2. In a way to have the same surface than a bass neck with 4 ribbons, we needed ribbons thinner than the one that can be found on the market. We designed a 65mm x 520mm surface with 4 resistive strips of 10mm large each. Contrarily to the Persephone2, ribbons are not linear but logarithmic to imitate strings ratio.

6.2 Sound Generation and tuning

Sound is generated by 4 oscillators – one per each ribbon. The ribbon strings can be tuned with 4 pegs. 4 Infrared sensors placed in a row on the right side of the instrument table control the 4 VCAs. A 24dB low-pass filter is controlled via a pressure sensor on the back of the cello neck.

6.3 The bow hand

In the original version, the volume was controlled by a lever on the player's right. The multi-ribbon is not pressure sensitive and therefore, does not control the amplitude. If it had, the pressure sensitivity of the ribbons and the fingers contact with the ribbons, would have not been able to reproduce the particular attack or decay of the bow action on the strings…

If some existing systems can track such moves with accelerometers (guitar ring…)[7], we wanted to free the player of any accessories. A row of four infrared sensors placed on the table measure the right arm moves to reproduce the bow movements. This feature needs to be on/off. The inclination of the row of IR sensors also needs to be defined so it corresponds to the bow musical gesture.

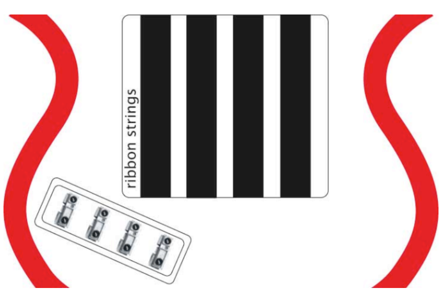

fig. 6. Infrared sensor row to control the bow hand

6.4 Compatibility with the computer music environment

Eowave Ribbon Cello is based on ESS DSP and has the same I/O environment that has been implemented in the Persephone II with high-speed USB, 100% MIDI compatible and freely assignable parameters per controllers available.

6.5 Work in progress…

Many aspects of the 4 strings ribbon cello still need to be defined. Among them, the location of the electronics: this should not be integrated inside the instrument body, but in a box apart. This will also enable to make a wireless version of the instrument.

7. Final Words

Today, sensor technology is reinventing controllers. If some interfaces for musical expression integrate these new technologies, the technical breakthroughs are lead by the game & communication industries. What will be the influence of the rapid rise of new controllers on musical interfaces in the future? Remaking instruments from the past with these new technologies is a way to resurrect forgotten instruments and make reality the dream of their first designer. This confrontation of ideas from different times reveals new issues for today, in particular the definition of the hierarchy of controls vs. acquired musical gestures.

References

[1] The first prototype has been presented in January 2004 at the Winter NAMM Show in Los Angeles and in April 2004 at the Frankfurt Musik Messe. Two years later, the final version has been released with improvements and new functionalities, like MIDI in & out, full tone and half tone modes.

[2] Mp3 are available on www.monstersynths.com

[3] The Persephone markII prototype has been presented at the Francfurt Musik Messe 2009. See www.eowave.com

[4] ESS DSP (Eobody2 Sensor Systems Digital Signal Processing) is an integrated solution for sensor to digital protocols standard needs, compatible with USB, OSC, MIDI, DMX, high speed USB, 7 to 14 bit, internal analogue & digital DSP processing with 32 bit filtering, amplifying. ESS DSP was presented at Ircam Resonances in 2008. www.eowave.com

[5] Images courtesy of National Music Museum, The University of South Dakota, Vermillion, SD.

[6] Albert Glinsky : *Theremin: Ether Music & Espionage*, University of Illinois Press, 2005, 480 p.

[7] www.sourceaudio.net or www.xpresence.com