The STRIMIDILATOR: a String Controlled MIDI-Instrument

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ABSTRACT
The STRIMIDILATOR is an instrument that uses the deviation and the vibration of strings as MIDI-controllers. This method of control gives the user direct tactile force feedback and allows for subtle control. The development of the instrument and its different functions are described.

Keywords
MIDI controllers, tactile force feedback, strings.

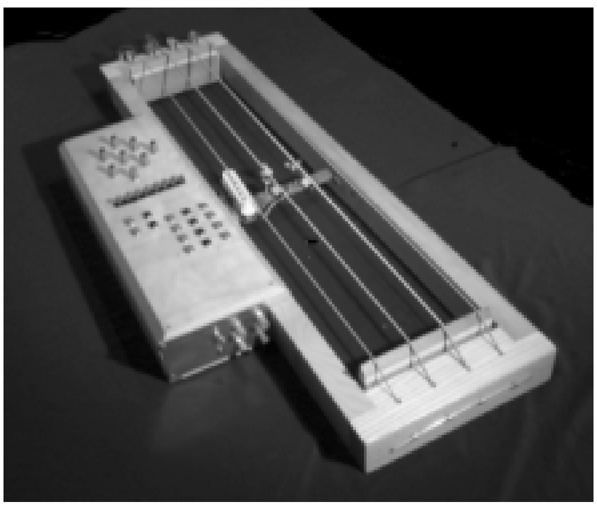

Figure 1. The STRIMIDILATOR

1. INTRODUCTION
In acoustical instruments there is a direct connection between the interface, i.e. that which the musician manipulates, and the creation of the sound; for example in a string instrument the musician lets the string vibrate and the vibration of the string is amplified by a resonating body. In electronic instruments this connection between interface and the resulting sound is not direct. Here there needs to be a conversion from mechanical movement to an electronic signal, which goes through an electronic circuit and finally is converted back into a mechanical movement of a loudspeaker to produce the desired sound.

The objective for the development of the STRIMIDILATOR (see figure 1) was to create an interface between the mechanical and electronic world, which has an intuitive feel to it, which allows the musician to use subtle hand movements for control and gives the musician tactile force feedback of the instrument (in addition to the auditory feedback that he gets).

The objective was also to create an interface that could be used for various (existing) electronic instruments, therefore it was decided to choose for a conversion to MIDI control signals as the main output of the interface.

The development was carried out as a project during my attendance of the Sonology Course at the Royal Conservatory of The Hague in The Netherlands, from March to September 2002. Further development is still ongoing.

2. CONCEPT
The vibration of strings is an ancient way in which musical instruments make sound. As such a large amount of know-ledge has been built up of the mechanical construction and of the practical use of string instruments over the last millennia.

The string in itself provides a good interface for a user. It is easy to manipulate, the effect of the manipulation can easily be seen and felt. A string under tension can either be brought into vibration or be held and given a deviation. Both the vibration and the deviation of the string can be used as controllers.

In the past, various other attempts have been made to use string instruments as the basis for controllers for electronic music. Cutler [1] gives an overview of commercially available MIDI string instruments. All implement pitch-to-MIDI conversion in one way or another; some also implement MIDI controllers depending on pick-position, string vibration envelopes and pitch bend. The vibration of the string is in all cases simplified to a pure MIDI-note, not taking into account the more complex characteristics of the vibration.

The VideoHarp (Rubine & McAvinney [2]) is an example which uses the interface of a harp by using the positioning of the fingers for parameters. Though the writers stress the importance of tactile feedback, this feature is only marginally implemented, through a dependency on how hard a finger is pressed against a plate. The VideoHarp does not use actual strings in its design; as an advantage this has that pitch control can be more continuous; a disadvantage is that the tactile feedback from the strings is missing.

The Web of Michel Waisvisz (see Krefeld [3] or Bongers [7]) uses the tactile force feedback of strings. In this it is quite similar to the STRIMIDILATOR; the difference is that The Web is designed with the aim to change many parameters at once, by creating a large interdependency between all used strings. In the STRIMIDILATOR one parameter is changed at a time and the musician can choose to control more than one parameter with one hand.

2.1 Vibration of strings
A vibrating string can of course be used directly to create sound, but this was not the objective of development. Instead, the vibration of the string can be used as a complicated kind of oscillating control parameter. A string that is brought into vibration produces a series of harmonic frequencies, based on its length, thickness and tension. Additionally, due to the mechanical construction (or faults therein) the vibration is never completely harmonic and has some irregularities. Taking all this into account, the vibra-

tion of a string makes a good source for a complex oscillating control parameter, which has a very intuitive interface.

A second way of using the vibration of the string is by following its envelope. In this way the frequency spectrum of the vibration is not used, but the decay of the vibration is used. Depending on the speed of the envelope follower irregularities in the decay are detected or not. This type of control allows for a slowly changing parameter, that can be easily (re)triggered by the musician, giving it the desired start amplitude.

2.2 Deviation of strings

By pulling or pushing the string and holding it, the string is given a deviation. This deviation can be used as a parameter for the sound to be created. As an interface this pulling and pushing of a string works quite well. The tension of the string makes that it wants to go back to its rest state; the harder you pull or push the string, the stronger it pulls or pushes back. By pulling or pushing at a different location on the string, the force feedback is different; it is easier to pull a string in the middle, than that it is near its ends, where it is fixed to the body of the instrument. This gives the user the choice where to manipulate the string. If he wants to make grand movements, he can choose to push on the string in the middle, where the force needed is minimal. If he wants to make small changes he can push near the ends, where more force is needed to get a more subtle control.

3. DESIGN

The design of the instrument can be divided roughly into three aspects: the mechanical, the electro-mechanical and the electronic design. Of course, each aspect has influence on the other two.

3.1 Mechanical design

For the mechanical design there were a couple of demands that needed to be fulfilled:

- The structure should be able to bear the tension of the strings
- The construction should contain the electronic circuits at some place
- The instrument should be comfortable in use and should be durable
- The instrument should look good

For the frame to bear the strings, a wooden construction was chosen. Ash wood was chosen as it is strong, durable and looks good.

The frame was constructed as shown in Figure 2. This way of construction is very robust. The wooden parts, once glued together, cannot glide away.

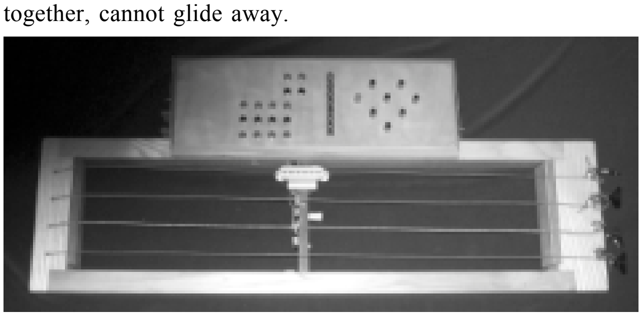

Figure 2. Frame structure of the instrument.

Connected to the frame a little box was created, which contains the electronic circuits of the instrument. As we used the MicroLab technology (see below), it was possible to add more controllers on the instrument and we had to create space for these additional functions as well. Therefore, we created space on the box for extra knobs, switches and buttons. On the sides of the box room was made for the connection of various cables, some tuning knobs for the electronics, a MIDI channel switch and the on/off switch.

The box's frame and the top were made of wood, for constructional and esthetic reasons. The bottom and the sides of the box were made of aluminium, in order to reduce electromagnetic interference of the outside world with the electronics inside.

In order to connect the electronic sensors used for the strings to the electronics inside the box a little hole was made into one of the sides of the frame to pass cables through.

3.2 Electro-mechanical design

The main problem in designing such an instrument is finding the best way to transfer the mechanical movement into an electronic signal.

3.2.1 Deviation

For detecting the deviation a choice was made for a linear transducer. This is a variable resistor that has a little pin that can move up and down, thus determining the resistance value. Using a little bus and a small elastic band the pin can be connected to the string, as shown in Figure 3.

The box of the resistor was fixed to the frame at the small wooden bar in the middle (fig. 2) in such a way that it could rotate at the connection point, so that the user would have as much freedom in moving the string as possible.

Connecting the linear transducer however influences the behavior of the string. Initially the linear transducers also contained a spring inside, which caused the transducer to pull at the string. As this was an undesired effect, I removed this spring from the transducer. Even with the spring removed, the transducer still influences the string in such a way that the string can no longer vibrate freely. The transducer provides so much damping to the system, that the string, when it is released, goes back to its rest state, without vibration.

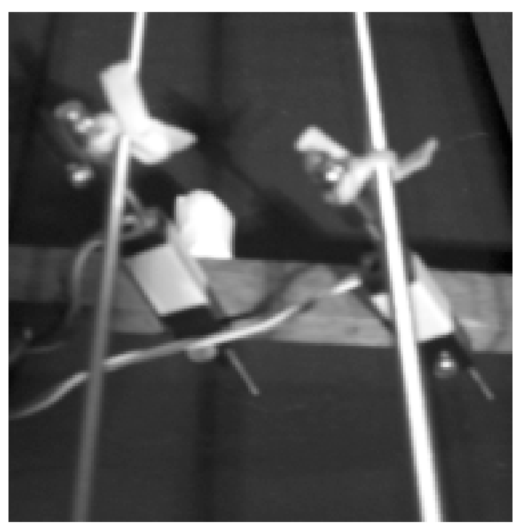

Figure 3. The linear transducer and the attachment to the string with a little bus and an elastic band.

3.2.2 Vibration

For detecting the vibration of the string, another solution had to be found. I chose for a conventional way of translating vibrations into an electronic signal: a coil that one can find on any electric guitar.

As a common guitar coil only gives one signal for all of the six strings together, the choice was made to use a coil for each string. They were placed on metal crossbars that were placed parallel to the strings across two small wooden bars in the middle of the frame (figure 2 shows only one of the wooden bars, the second one and the metal crossbars were added after the photograph had been taken); as the coils are magnetic they stay fixed, but can still be easily moved to allow the user to choose on which place it should pick up the string's movement.

The mechanical construction was made to attach four strings, so a choice had to be made for how to use each string. In the end, to two strings linear transducers were attached and for the other two strings two coils were used.

To avoid influence of one coil on the other, we placed the coils on the two outer strings and attached the linear transducers to the two inner strings. Having the two linear transducers in the middle also has the advantage that one can manipulate both strings with one hand and even using the same hand to trigger the vibrating strings.

3.3 Electronic design

The main demand for the electronic design was that the instrument should output signals that could be used directly, without needing further processing by a computer.

As the Royal Conservatory, aided by STEIM, had already developed a general device, the MicroLab [5], for the translation of sensor data into MIDI-data, it was decided to use a modified version of this device for the STRIMIDILATOR. The MicroLab is a cheaper, one-time-only programmable version of the SensorLab of STEIM [6].

The SensorLab was used to prototype the programming of the software in order to discover the best way of translating the MIDI-data. This had as a drawback that the program-code made in Spider (SensorLab's programming language) had to be translated manually into assembly code for the MicroLab (a PIC16F873 chip), which may not have been the most optimal way of programming. As some additional electronic circuits were made, based on the power supply of the SensorLab, for the eventual version of the instrument a power conversion circuit had to be made also.

Eventually the software used the direct sensor data of the linear transducers (with only a condensator placed in parallel in order to limit the influence of noise) and the output of the coils after an electronic envelope follower. The envelope follower can be tuned in its speed and in its amplification of the signal.

In addition to the MIDI-output, the direct output of the coils was given as a (low-frequency!) audio output via a stereo-jack-connection. After amplification these signals could directly be used as control input, provided that the output is sent to a device that can use an analog input as such.

3.4 Extra functions

As the choice for the MicroLab technology gave room for additional functions, this opportunity was seized by choosing to add buttons for MIDI-note messages, knobs for additional controller messages, analogue inputs for input of other sensor data and a set of switches for switching between functions of components. The hardware components for these were integrated in the design of the box, where esthetic and ergonomic considerations determined the placing of the knobs, switches and buttons. The buttons are laid out in a pattern which allows the user to be able to reach all of the buttons without moving the hand too much, thus being able to cover 16 semi-tones (see Figure 4).

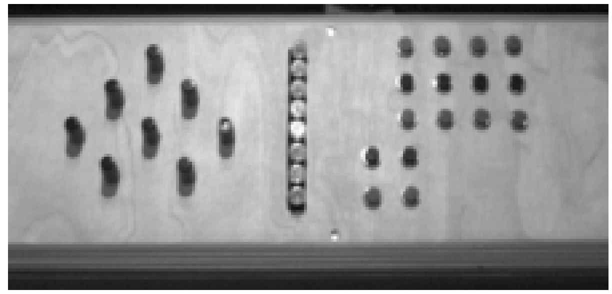

Figure 4. Button and knob layout on the box of the STRIMIDILATOR. On the left are the knobs, the lowest two are for the note-on and note-off velocity. In the middle are the switch buttons for the various modes. On the right are the note-on/off buttons.

3.5 Software design

The software determines in which way the sensor data was translated into MIDI-data. The design question here was: what are the most interesting ways to translate the sensor data? The design was carried out with the notion that the eventual function of the controller output could be determined in the receiving MIDI-instrument, that is: no care was taken to consider the standardized MIDI-controller number functions. There was taken into account that one may want to receive MIDI on different channels: a switch was assigned to change between sending all data on one channel, or about half of the data on one and the other half on another channel.

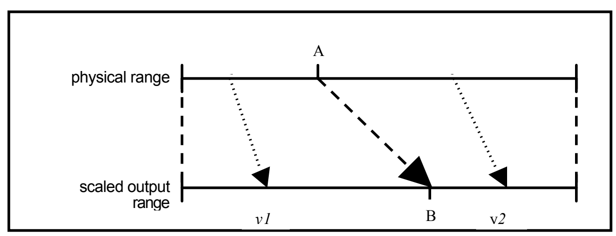

Figure 5. Dynamical mapping. When switching from one mode to another the last value (B) of the controller is put into memory and the next time the mode is entered, the controller value takes this value as a starting point; the physical value A is mapped to B. While the instrument is in this mode, all other values are mapped accordingly. For example, value *x1* is mapped to *y1* and *x2* is mapped to *y2*.

For the linear transducers we found three ways to translate the sensor data to MIDI:

1. Directly, that is a direct linear mapping between the resistance value and the MIDI controller value.
2. Through a software-implemented envelope. This function slowly follows the changes of the controller, or allows the user to suddenly "jump" to another value. A timer ensures that eventually the value goes back to zero.

3. Dynamical mapping. This means that when switching from one mode to another the last value of the controller is put into memory and the next time the mode is entered, the controller value takes this value as a starting point. The remaining physical range is then mapped between 0 and 127 according to the new mid-point. This is clarified in Figure 5.[1]

For the coils we used the first two functions mentioned above, both using the signal from the coil, after it passed through the envelope follower implemented as an electronic circuit. This allowed for a choice between a fast and slow envelope of the vibration to be used.

Eight switches determine the mode in which each sensor input is translated. The first two determine as a two bit-number the function (where no switch pressed means that the sensor is not used and no controller data is sent out) for the first linear transducer, the second two do in a similar way for the second transducer. The next two determine which function for each of the two coils is used. The last two determine whether a coil is on or off. Each mode sends out a different MIDI control number.

The resistances of the potentiometers of the knobs were directly and linearly translated into MIDI control data. Two of the knobs were used to determine respectively the note-on and note-off velocity of the buttons, which were mapped to send out MIDI note-messages: a note-on message when the button was pressed and a note-off message when the button was released.

Finally the sensor data coming in from the eight sensor inputs is translated directly, linear to MIDI controller data.

An overview of all the functions is given in Table 1. A photograph of the resulting instrument is shown in Figure 1.

4. PRACTICAL EXPERIENCES

The STRIMIDILATOR has been used in two performances so far.

The first performance was in Theater Kikker in Utrecht, the Netherlands, where the author used the instrument in the second half of a 20-minute improvisation.

The STRIMIDILATOR was connected to a Clavia Micromodular [7], both through MIDI and (via a mixer for amplification) through the audio-input.

The audio-input (providing the coil output) was used as a kind of LFO to control the navigation through vowels of a vocal filter. The envelope of the signal was tracked simultaneously to use as the envelope of the resulting sound. This allowed for a direct control by the user of the volume of the sound, as well as of its character.

The direct MIDI-translation of one of the linear transducers was used to determine the frequency of a noisy wind like breathing sound, while the same mode of the other linear transducer was used to navigate through vowels of the vocal navigator through which this sound was coming. For the first (the frequency control), this proved to be very intuitive and handy: it was possible to move slowly from low frequencies to higher ones by slowly moving the pressure on the string from the middle to the edge (and vice-versa for the opposite effect). By using one hand to pull the two strings up and together or let them release, there was a good control over the two parameters of the sound at the same time, also allowing for quick deviations made by quick movement of the fingers in pulling and releasing the strings.

In mode 2 (the envelope follower), the transducers were used respectively to change the density of a ticking sound and the frequency of the vocal filter that was controlled by the audio input. Two of the knobs were used to control the frequency and the timbre of the ticking sound. The note-values were only used to transpose a melody up and down. Other functions were not used during the performance.

Table 1. Overview of functions of the STRIMIDILATOR built.

Controller	#	Mapping	Output
Bass string – linear transducer	2	Direct, envelope, dynamic	MIDI ctr. 0-5
Bass string – coil	2	Direct, Envelope (with or without software envelope)	Analogue MIDI ctr. 6 – 9
Switches	8	Function mapping of strings	-
Switch	1	MIDI channel switch	Ch. 1-2
Buttons	1 6	Push: Note on Release: Note Off	MIDI note nr. 60-75
Knobs	6	Direct	MIDI ctr. 10-15
Knobs	2	Note on/off velocity	-
Inputs	8	Direct	MIDI ctr. 17-23

The second performance was on the festival *"Ver uit de Maat"* in WORM in Rotterdam, the Netherlands, during a 25-minute improvisation.

The direct MIDI-translation of the linear transducers was used to control the frequency of an engine-like sound, panned to the left for one string and to the right for the other. By pulling and pushing both strings with one hand, one could easily create a changing soundscape between the left and right signals.

For one string the envelope follower of the linear transducers was used to control the frequency of an FM-signal, which was modulated by the vibrating string; the amplitude of the vibration determined the amplitude of the resulting sound. In this way it was possible to control the frequency of this signal with one hand, while creating the sound with the other.

The envelope follower of the other linear transducer was used to control the density of clicks, enabling the user to jump between different densities.

During the performance it was also noted that the instrument either should be heavier or should be fixed to the table it is lying on, as while pulling on the strings, the instrument was lifted a little.

On both occasions the deviation of the strings proved to be very intuitive for the control of sound parameters. The dynamical mapping could not yet be tested, but experience with the direct mapping made clear that dynamical mapping, once implemented, should prove to be very useful. The switch between modes sometimes had as a result that the sound suddenly changed when returning to a mode, which was not always desired.

[1] At the moment of writing (10th of April 2003) this function does not yet work in the eventual implementation. Corresponding assembly code remains to be written.

As can be noted, the envelope follower of the string vibration was not yet used in a performance, due to the fact that the function did not work properly yet. This has now been fixed.

It was noted during the testing of the instrument that the vibration of the string caused the other controllers to become less stable. By rewiring the ground and decreasing the length of the wires, this problem was solved.

5. CONCLUSIONS

The STRIMIDILATOR provides a good interface for controlling parameters for electronic music. The use of the deviation of strings ensures that good tactile force feedback is given to the artist using the instrument and the strings allow for a subtle and versatile way of control. The implementation for the use of the envelopes of the vibrating strings still needs to be tested.

Further application and experience with the instrument will show on which other points the instrument can be improved.

6. ACKNOWLEDGMENTS

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[2] See http://www.paulbeekhuizen.nl

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