PHYSMISM: A control interface for creative exploration of physical models.

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ABSTRACT

In this paper we describe the design and implementation of the PHYSMISM: an interface for exploring the possibilities for improving the creative use of physical modelling sound synthesis.

The PHYSMISM is implemented in a software and hardware version. Moreover, four different physical modelling techniques are implemented, to explore the implications of using and combining different techniques.

In order to evaluate the creative use of physical models, a test was performed using 11 experienced musicians as test subjects. Results show that the capability of combining the physical models and the use of a physical interface engaged the musicians in creative exploration of physical models.

Keywords

Physical models, hybrid instruments, excitation, resonator.

Figure 1: The final look and feel of the PHYSMISM was among other things inspired by old analogue synthesizers.

1. INTRODUCTION

To synthesize sounds using physical models means to understand the physics of sound production mechanism and simulate it using numerical algorithms. Physical modeling techniques provide the possibility to add new perspectives to the constant search for novel interesting sounds present in the world of electronic music.

Different physical modeling techniques have been researched for decades [8, 13, 4], but they have not been completely accepted in the performance and production of electronic music compared to many other synthesis techniques.

Only a few and not completely successful attempts have been implemented in commercial synthesizers. It appears that physical modeling techniques have been mostly used in the academic milieu.

In this paper, we are interested in investigating the reasons for the lack of use of physical models in commercial synthesizer.

After talking to different musicians experts in electronic music, we realized that physical models have not been utilized to their full potential. This might be due to the lack of musically interesting implementations of the technique.

Most of the physical models we have encountered focus mainly on the interactive aspects of physical modelling or the ability to simulate an existing acoustic instrument as accurately as possible. If one were to only focus on the sonic qualities of a sound itself without being concerned with accurate simulation of physical mechanisms, would it be possible to further explore the musical potentials of physical models?

Many physical models have been created, emulating acoustic instruments and physical phenomena found in nature. A lot of characteristics of the natural instruments have now been captured and a diversity of physical models has been developed. Most of the physical models produce sound like an original acoustic instrument with the possibility to change the physical parameters and characteristics of the instruments. Would using these models to keep the characteristics of the existing instruments, but then merging them with something completely different, help to enhance the creative exploration of physical modelling?

In the early 60s the so-called modular synthesizers were introduced.[1] These synthesizers gave the users the possi-

[1]http://moogmusic.com/history.php

bility to have full control of the sounds they produced and to combine the different parts of the synthesis techniques themselves instead of simply using a preset from the factory. Together with the synthesizers followed a variety of manuals concerning how to combine different oscillators, envelopes, filters and so forth, to reproduce existing sonorities such as bells or bird sounds. Several musicians used such synthesizers to simply reproduce sounds existing in nature, while others tried to create their own experimental sonorities. Some users followed the manuals, while others tried to experiment with the modules as part of a creative process. The output produced consisted of artificial electronic sounds far from the every day sounds or existing instruments.

The initial idea behind this research is that the same creative process could be achieved when exploring physical modelling sound synthesis.

In order to achieve this goal, the possibilities as well as the benefits and drawbacks of physical modelling synthesis have been explored and analyzed.

2. RELATED WORK

2.1 Interfaces for physical models

A lot of different attempts have been made to create controllers for physical models, both within the commercial and the scientific world.

The first commercial synthesizer using physical modelling techniques was the Yamaha VL1 synthesizer, which was first released in 1995. This synthesizer was especially satisfactory for wind instruments. The design of the synthesizer was very similar to a typical keyboard with different buttons and sliders but is also included a quite accurate breath controller. The physical models were based on the digital waveguides technique [13]. It was possible to change the size of different wind instruments as well as to choose between different kinds of excitations (single reed, double reed, jet reed, bow...). Using the breath controller one was able to control parameters like breath pressure, throat formant, tounging, embouchure and scream. The synthesizer was very suitable for expressive performance by skilled wind players.

The Yamaha VL1 synthesizer never became really popular, and the production of it stopped shortly after the introduction.

Another commercial synthesizer using physical modelling was the Korg Prophecy,[2] released in 1996. This synthesizer also simulated acoustic instruments, but not with the same precision as the VL1 synthesizer. One of the interesting issues regarding this synthesizer is that it was one of the first synthesizers to use physical modelling to emulate analogue synthesizers.

An example of a software synthesizer using physical modelling is Reaktor 5.[3] The physical modelling sound synthesis used is based on modal synthesis [1]. The software synthesizer enables the user to control a lot of different parameters mostly related to the resonators of the models.

Another small software program recently developed is Modelonia[4] from Nusofting. The Modelonia software synthesizer is a pure physical modelling synthesizer and it uses a plucked string and a blown bore model respectively as the basic sound source. The Modelonia synthesizer also allows cross-synthesis between the two models.

Non-commercial controllers of physical models often try to simulate real acoustic instruments and in many cases they focus on providing the user with precise excitation devices, which are as close as possible to the way the original instrument is excited.

Perry Cook has developed different interfaces such as flute controllers, wind instrument controllers and many others. An example of one of Perry Cooks interfaces used to control physical models is the Nukelele [7]. The Nukelele is a control device using among other things two linear force sensitive resistors to control the excitation of a physical model of a string.

Another example developed by Cook is the Squeezebox [7]. The Squeezebox is an accordion, which controls a human voice model. Different sensors attached to the accordion as well as the accordion itself, control the breathing, pitch and articulation of vowels and consonants of the human voice model.

In [9] the human voice is used to control a physical model of a plucked bass guitar.

Physical models have also been implemented in virtual reality projects. In [11] a physical model of a drum membrane is controlled and visualized in a virtual reality environment. The physical model is based on the 2D waveguides technique [14].

2.2 Compositions using physical models

Even though physical modeling sound synthesis has been studied for decades, it appears that composers are mainly using other synthesis techniques when producing electronic music. This could be due to the fact that other techniques such as granular synthesis, sampling or frequency modulation often produce richer sounds than physical models have provided so far.

However, some composers have been working with physical modelling. Most commonly used in compositions is the use of physical models to extend possibilities offered by traditional instruments. One of the pioneers of the use of physical models in compositions is David Jaffe. In his piece *Silicon Valley Breakdown*, premiered in Venice during the International Computer Music Conference 1982, a physical model of a plucked string implemented using the Karplus-Strong algorithm [10] is extended to reach unreal dimensions, such as the length of the Golden Gate bridge. Another pioneer in the use of physical models in creative applications is Chris Chafe. In [5], he reviewed the work of himself and other composers regarding this topic.

Paul Lansky also used physical models in his creations. In [5] he describes how he has enjoyed using the physical model of a flute by Perry Cook, using a 20 feet long tube with a diameter of 3 feet as the resonator in some of his pieces.

Other composers are using replica extended models to achieve abnormal excitation. An example is the piece *Pipe Dream* by Gary Scavone, written in 2003. In this piece, Scavone uses a physical model of a saxophone, over-blowing the excitation.

Other examples of creative and alternative use of physical models in compositions include hybrids of physical models, where composers combine different resonators or excitations. As an example, *S-Trance-S* by Matthew Burtner is a piece where a saxophone acts as a controller for a physical model

[2]http://www.korg.com
[3]http://www.native-instruments.com
[4]http://nusofting.liqihsynth.com/Modelonia.htm

of a string [3].

As another example, *Voice of the Dragon* by Juraj Kojs is a composition where physical singing tubes interact with virtual ones, simulated using physical models [12].

3. PHYSMISM

The PHYSMISM, shown in Figure 1, is an interface designed to investigate how physical models can be controlled and used creatively. Based on the review presented in the previous section, a set of goals for what the sound synthesizer should be able to implement, was proposed.

The goal of the sound synthesis engine is to implement many different physical models, in order to make this device a generalized interface. Moreover, we are interested in simulating real instruments, with the possibility to vary their parameters in order to make them extend limitations of the real world. Furthermore, we want to allow the possibility to use the same excitation device to control different models.

Finally, we are interested in combining different physical models in an intuitive way.

3.1 Implementation of physical models

In the PHYSMISM, each model chosen represents a difference in sound, technique, complexity, resonator, and exciter. This is mainly in order to show the diversity of physical models. For the current prototype the following physical models were chosen:

- A **turbulence model**, which implements a one dimensional waveguide [13] with a non-linear excitation [13].
- A **stochastic model**, which implements the PhISM model [6] having a randomized stochastic excitation.
- A **friction model**, based on one dimensional waveguides with a complex non-linear excitation, described in [12].
- An **impact model**, based on two dimensional waveguides [14] with a simple nonlinear excitation.

The models were written in C and compiled as Max/MSP[5] externals in order to control and combine them inside the Max/MSP environment. The users had the possibility to control four parameters related to the resonator.

4. HARDWARE INTERFACE

4.1 Resonator control

Two control stations with four dials each were implemented, shown in Figure 2. The user was then able to assign whichever model he wanted to a control station. Each control station had a model chooser, which assigned the model to the station.

4.2 Excitation devices

[5]www.cycling74.com

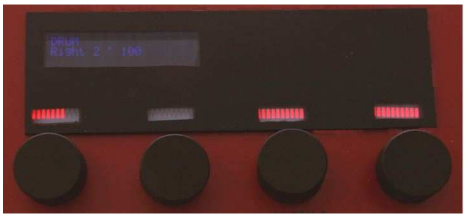

Figure 2: The control stations on the PHYSMISM allows the user to see which parameters and models he is controlling.

Figure 3: The blowing excitation device is created using a fan attached to a dynamo for measuring the amount of wind blown.

4.2.1 Blowing

In order to give the user the capability of creating a blowing excitation, a flute device was implemented, shown in Figure 3. A small fan was attached to a dynamo in order to measure how hard the user was blowing into the device. When the user was blowing at the fan the dynamo turned and created detectable voltage, which was used to control the excitation of the turbulence model. The device itself was borrowed from [2], where it was used to control a physical model together with a graphical virtual reality flute.

4.2.2 Rubbing

In order to control the friction model an excitation device was created using two slider potentiometers and a pressure sensor, as shown in Figure 4. The device was created in order to give the user the same input capabilities as if he was rubbing his hand over a surface. The left-right motion was detected by the first slider, which was placed horizontally on the device. The pressure sensor located on top of the device detected the pressure applied to the surface. Finally, in order to simulate the capability of rubbing on different areas of the surface, the second slider was placed vertically on the device. The three sensors were used to control the velocity, bow position and force inputs of the friction model respectively.

Figure 4: The rubbing excitation device is implemented with a two dimensional slider with a pressure sensitive ball on top.

Figure 5: The crank implemented for exciting the stochastic model is attached to a dynamo.

Figure 6: The hitting exciter is implemented with two drum pads. Inside each drum pad there is a pressure sensor, which picks up the force applied by the user.

4.2.3 Grinding

In order to excite the stochastic model, a crank was chosen, as shown in Figure 5. The user rotated the crank to simulate a grinding motion. The velocity of this motion was mapped to the number of beans in the stochastic model. The crank was attached to a dynamo, which worked exactly like the one used for the blowing excitation device. The crank was implemented because it gave the user the capability of creating a continuous motion with a meaningful gesture.

4.2.4 Hitting

The percussive excitation part consists of two custom-made drum pads, shown in Figure 6. Inside each pad a pressure sensor was placed, which detected the force applied to the pad. In order to detect a hit, the signal was thresholded and peak detected.

4.3 Combining the models

In order to combine the models we decided to take the output sound from one model and use it as an input for another model, thereby creating the possibility of obtaining different hybrid models. In this way the second model is not excited by the energy from the user, but by the sound from the first model. This feature demanded some extra work concerning the implementation of the actual models. All the models needed a sound input. This sound input needed to have a significant impact on the sound produced, in order to avoid the effect of just adding the two models together.

In order to let the user combine the models a patching system very similar to the old analogue modular synthesizers was implemented. The user was capable of patching two models together, one being the output, and one being the input model, using a patching cord to connect the models.

The patching system was implemented on the hardware interface using 8 mini-jack cable inputs, as shown in Figure 7. One patching cord with two mini-plugs, one at each end, was used to establish the connection from one model to another. The mini-jack inputs were used as on/off switches. These on/off signals were processed and mapped inside the Max/MSP environment in order to establish whether a connection was made, and if so between which two models.

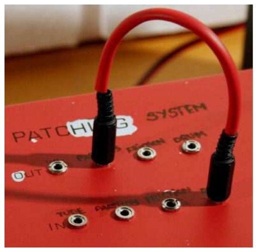

Figure 7: The patching cord system is implemented using 8 mini-jack inputs. They act as on/off switches that establish whether or not they are connected.

4.4 Extra features

It was chosen to add a sequencer to the interface, to enable the test subjects to get a feel of how sounds created using the PHYSMISM could be used in a context.

A decision was made to supply the sequencer with 4 tracks, each with a 10 second sound buffer. The user was able to create a loop for each buffer, using three parameters: loop start, loop length, and loop speed.

4.5 The overall setup

Because of the many tasks carried out by Max/MSP, namely the many ingoing and outgoing data streams (sensors, displays, sequencer, sound) running the whole interface on one laptop was too computational intensive. Dividing the tasks between two laptop computers solved this problem. The computers were connected via a hub, creating a small LAN. The first computer was processing the sound and had all the excitation devices connected, while the other computer took care of the connection between Max/MSP and all the hardware devices of the PHYSMISM.

5. TESTING THE PHYSMISM

The PHYSMISM interface was tested with 11 professional musicians. In order for the musicians to feel comfortable in playing with the interface, the tests were performed in the musicians' own studio or working environment.

After filling in a questionnaire concerning the subjects' level of musical experience, the subjects were asked to get familiar with the interface for approximately 25-30 minutes and try to understand the possibilities of the instrument.

After the short practice session, subjects were asked to improvise with the PHYSMISM for about five minutes. During the whole test period, observations and additional comments from the test persons were annotated.

After having practiced with the instrument, test subjects were asked to fill in a questionnaire.

Additionally, changes in the control values and excitation devices were recorded in Max/MSP as text files and later analyzed in Matlab[6].

5.1 Test results and discussion

One of the goals of the testing procedure was to allow the musicians to be creative with the interface, while being able to gather quantitative data obtained by recording the gestures of the player.

[6]http://www.mathworks.com/

In order to facilitate creativity, we did not ask the test subjects to perform specific tasks with the PHYSMISM, but rather we allowed them to explore its potential while observing their behavior.For this reason, the quantitative data obtained by analyzing the gestures of the performer provided too diverse information among the subjects, to be useful enough for the final analysis.

On the other hand, the final questionnaire was extremely useful in providing insights concerning our original question on the creative possibilities provided by physical models.

When asked what are the basic elements which a physical model should contain, in order to improve its creative use, all subjects agreed on the need of having a large number of parameters to control.

As an example, the impact model, in which only two control parameters could be varied (frequency of the resonator and impact force) was considered rather uninteresting by all subjects.

Another problem observed with the impact model was the high predictability of the sound produced, which contributed to make it uninteresting after a very short amount of time. On the other hand, models which created rather rich, unpredictable and complex sonorities like the friction model were appreciated by most of the test subjects.

The impact model was perceived as interesting only when very low frequencies were generated, since it created a warmer and powerful bass sound.

Concerning the combination of the physical models, it is interesting to notice that many subjects expressed the fact that models with few control parameters became much more interesting when combined with other models. As an example, using the rich sonorities of the friction model as input device for the drum resonator, opened up several interesting novel sonic possibilities. Even the impact model and turbulence model, which were the two lowest rated models, became interesting when combined.

We were also interested in understanding if the users appreciated playing with a physical interface while controlling physical models. We noticed that subjects got easily adjusted to the physical interface, and appreciated especially the natural interactions it provided. Subjects found especially the crank rather interesting, since it provided a very intuitive and effective way of interacting with the particle model.

Table 5.1 summarized the characteristics of physical models in order for this technique to become interesting from a musical perspective, according to the data gathered from our test subjects.

Although some of the observations made by the test subjects were rather expected, it is noneless interesting for us to observe that they are shared by several musicians, regardless of their level of expertise with sound synthesis and physical models.

As a final observation, we were interested in understanding if the musicians would have been interested in using the PHYSMISM in a live situation. Half of the subjects said they would, commenting that they appreciate the possibility of creating different sounds with lots of choices of control.

The subjects who did not feel the desire to use the interface in a live situation, commented on the difficulties in predicting the behavior of some knobs and input devices (which was also due to the limited time used in practicing with the interface), and the fact that they did not like the musical quality of the sound produced. Again, as expected, such final comments were mostly provided by musicians more experienced with classical pop music rather than contemporary electroacoustic music.

Positive	Negative	Application
Many parameters		Friction
	Few parameters	Impact
	Predictability	Impact
Unpredictability		Friction
Low frequencies		Impact
Combined models		Friction+Impact
Bi-manual control		Physical interface
Natural interaction		Physical interface
Clear interaction		Crank

Table 1: Summary of the positive and negative features of the different physical models as expressed by the test subjects.

6. CONCLUSION

The starting point of our research was the exploration of the possibilities for improving the creative use of physical modelling sound synthesis.

The creative use of physical modelling was reviewed, including topics such as compositions using physical models and the existing musical interfaces for the sound synthesis.

Based on the review a set of possible factors for improving the creative use of physical modelling was proposed. In order to test the relevance of the proposed factors a novel interface for controlling physical models, the PHYSMISM, was designed and implemented. Even the impact model and turbulence model, which were the two lowest rated models, became interesting when combined.

The PHYSMISM was implemented with four different excitation devices, which allowed the user to either blow, grind, rub or hit on the interface in order to produce sound.

An additional patching system for combining the different physical models was also implemented. In order to control the different resonator parameters of the models, parameter controls were implemented with the possibility of changing four different parameters on each model.

Four different physical modelling techniques were used in order to explore the implications of using different physical modelling techniques. The implemented models included a turbulence model, an impact model, a friction model and a stochastic model.

Finally, a test was performed with 11 different musicians, in order to evaluate the creative use of physical modelling. The test showed that especially the models with significant possibilities of variation of sonorities were desirable. Some of the models had an element of unpredictability and this seemed to enhance the creative use of the models and the application.

The effect of combining the physical models was also evaluated and it showed that some of the more simple and unpopular models, became much more interesting for the users when they were combined with other models.

It seems possible to use physical modelling much more in modern music production if more creative interfaces and applications to control and combine the models are developed. This sound synthesis technique has a lot of potential for creative use, and the musicians seemed much more positive towards the technique after having tried the PHYSMISM.

In testing the PHYSMISM, we found it difficult to combine its creative use with a formal testing methodology. We also noticed that most of the results provided by the musicians were strongly contextual to the kind of musical backgrounds they had.

7. FUTURE WORK

Alternative solutions for controlling physical modelling as well as the possibilities of combining the models should be considered as an important field of research because they improve an understanding of the musical potentials.

An essential element of physical modeling is the simulation of existing musical instruments. However, if an accurate and complex model is developed and the simulation does not go beyond emulation of the real counterpart, it is most likely that the use of physical modelling will be overlooked, especially within the electronic music community.

We share the opinion that many of the existing applications using complex physical models are interesting from a researchers perspective. Most of the time these models appear less interesting for a creative electronic musician, because the interactive and complex possibilities do not clearly appear in the interface or immediate output.

Physical modelling could have lots of potential, but, in order to achieve a more creative use of this synthesis technique, it is important to establish a stronger communication between scientists and musicians. There is no doubt that introducing more alternative and interesting applications or interfaces for physical modelling would increase their creative use.

Another interesting issue regarding physical modelling is the possibility of natural interaction and a very tight connection between gestures and sound. Physical modelling offers a great potential in this direction, because of the way the sound is produced.

We believe that the PHYSMISM serves as an important inspiration of how to implement physical modelling for musical and creative exploration.

8. ACKNOWLEDGMENTS

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