Physical Modeling Modular Boxes: PHOXES

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ABSTRACT
This paper presents the development of a set of musical instruments, which are based on known physical modeling sound synthesis techniques. The instruments are modular, meaning that they can be combined in various ways. This makes it possible to experiment with physical interaction and sonic exploration, thereby possibly extending the potential of the physical models.

Author Keywords
Physical Modeling, Physical Interfaces, Musical Instruments, Exploration, Creativity, Electronic Music.

ACM Classification Keywords
H5.5. Sound and Music Computing: Modeling. H.5.2 User Interfaces: Input devices and strategies. H.1.2 User/Machine Systems: Human Factors.

INTRODUCTION
The PHOXES modular instruments have been developed in order to investigate what happens when physical modeling sound synthesis algorithms are controlled in an environment, which encourages creativity and exploration. The physical control of the models plays a large part in how the sonic potential of the models is perceived – on both a lower level (e.g. which physical gesture must the user perform to excite a certain model?) and on a higher level (e.g. how do different control structures let users explore the sonic potential of the models?).

In order to investigate the impact of the higher level control structures a set of modular electronic instruments have been developed. The goal has been to extend the creative use of physical modeling sound synthesis by focusing on exploration. The HCI research area that deals with *creativity support tools* suggests that in order to support the kind of exploration that is crucial for creative work, one must design for *low threshold, high ceiling, and wide walls* [1]. In other words there must be a balance between how intuitive the system is *(low threshold),* how powerful it is *(high ceiling)* and how well it encourages exploration, letting users keep finding new ways of combining /controlling elements or movements *(wide walls)*.

The proposed system tries to balance the intuitive causality inherent in the physical modeling technique with a flexible exploratory system that provides freedom within the boundaries of the individual elements (each PHOX acts as an instrument on its own and is naturally constrained, but because they can be combined in a modular fashion, they also provide the sense of freedom).

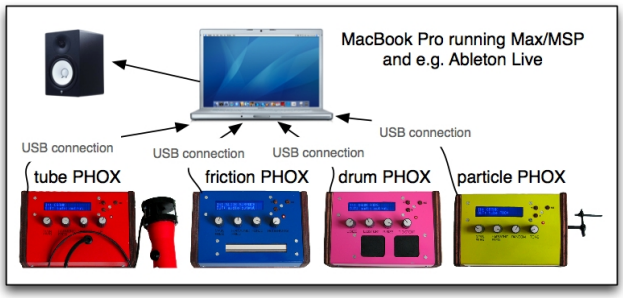

Figure 1. The PHOXES send control data through USB to Max/MSP, which is rewired to the DAW of your choice – e.g.Ableton Live.

PHOXES MODULAR SYSTEM
At present time four PHOXES have been developed: tube PHOX, particle PHOX, friction PHOX, and drum PHOX. Each PHOX implements a different physical model and consists of a unique excitation controller, intended to naturally relate to that model. For instance, the tube PHOX implements a physical model of a tube and a flute-like excitation controller. Each PHOX also consists of four knobs for adjusting model parameters, three buttons for controlling the mapping involved in combining the PHOXES and an LCD screen for displaying mapping settings. We felt that it was important that all input/output functionality was built into the PHOXES themselves so focus could remain solely on the instruments while exploring them (as apposed to also focussing on controlling some parts using a laptop).

The physical models are written as Max/MSP[1] externals and the system is developed in the Max/MSP environment. The idea is that the PHOXES are powered through Max/MSP but the sound is rewired to for instance Ableton Live or Logic so eventual test subjects can explore the PHOXES' potential in a familiar environment. Inputs and outputs from the PHOXES are handled by a PhidgetTextLCD with PhidgetInterfaceKit 8/8/8[2] embedded in each of the

[1] a graphical programming language (http://cycling74.com/)

[2] from http://phidgets.com

PHOXES - See Figure 1 for an overview of the system.

Physical Models

The physical models which have been implemented present a variety in complexity, sonic fidelity, and physicality (the type of excitation gesture they naturally propose). The physical models used are:

- **tube PHOX** – turbulence model based on [2].
- **particle PHOX** – particle model based on Physically Informed Sonic Modeling (PhISM) [3].
- **friction PHOX** – friction model based on the elasto-plastic friction model [4].
- **drum PHOX** – drum model based on 2D waveguides [5].

Excitation Controllers

Each PHOX implements a physical controller, used to exert energy into the model. The controllers have been chosen to naturally extend the physical models they by default are connected to. The modularity of the PHOXES system then lets the user play around with exciting any of the physical models using any of the excitation controllers from the different PHOXES.

The excitation controllers used are listed below, together with the excitation gestures that they afford. They are all used to measure velocity, which is mapped to the amount of energy injected into the system.

- **tube PHOX** – flute controller implementing an amplified low pressure sensor (1INCH-D-4V from All Sensors). The user blows into a small tube attached to the sensor, which senses how hard the user blows, giving the user the feeling of blowing into something similar to a recorder.
- **particle PHOX** – crank attached to a multi-turn rotational potentiometer (Model 357 from Vishay). The user turns the crank to produce energy. The rotational speed is measured and used as excitation. The crank gives the user the capability of experimenting with both continuous and instantaneous excitation gestures.
- **friction PHOX** – friction slider implementing a ribbon sensor (SoftPot from Spectra Symbol). The sensor lets the user slide a finger back and forth on a horizontal flat surface. The velocity of the back and forth sliding gesture is measured and used as excitation.
- **drum PHOX** – two drum triggers implementing piezo transducers (PSG100 from Kingstate). The drum triggers detect the occurrence of a hit (finger tapping gesture) and the velocity of that hit.

Modularity

Two or more PHOXES can be combined by choosing how energy is put into any given PHOX. Energy can either come from an excitation controller (it is possible to use any of the available excitation controllers embedded in the PHOXES to control any of the physical models), or it can come from the sound produced by a different PHOX – similar to [6], where sound is used to drive the excitation mechanism of the physical models. This means that there are a couple of challenges when developing the physical models. Each of the models must 1) be able to respond to energy from different types of excitation gestures (continuous or instantaneous [7]) and 2) have a way of mapping sound to input energy.

When each PHOX is played on its own using its own excitation controller there is a natural mapping metaphor, which makes the relationship between gesture and sound intuitive and natural (for instance making squeaky friction sounds by sliding your finger back and forth, or making flute sounds by blowing into a tube). But the naturalness of the metaphors change when an excitation controller from one PHOX is used to excite a physical model from a different PHOX (when for instance using a crank to make flute sounds or when blowing a drum). Although unnatural, it seems that the mapping is still perceived as being intuitive. Because of the nature of physical modeling there is a natural causality relationship between the amount of energy you put in and the sound you get out. If the amount of energy does not change (only the gesture one uses to produce that energy changes), we believe that the mapping is intuitive. By presenting the user with a variety of physical gestures for controlling the same physical model, we open up for a physical, more embodied exploration of the sonic potential of the models.

Goto `http://media.aau.dk/~stg/phoxes/` for details about mapping, videos, pictures and additional development information.

CURRENT STATE AND FUTURE DEVELOPMENT

An early pre-test was conducted where an experienced electronic musician borrowed the PHOXES for a duration of 10 days – see Figure 2. The goals were 1) to get a first impression of how well the system encouraged exploration and whether the system was creatively inspiring and motivating, 2) to explore the evaluation methods involved in testing such a complex set of instruments in as natural an environment as possible, and 3) to see if the build and functionality of the PHOXES would withhold such a long test period without our interference. Further details about the test can be found in [8].

The early impressions have shown that in order for future test subjects to be able to use the PHOXES in their natural working environment (where they integrate them in their normal setup with mixers, effect-racks, other controllers,

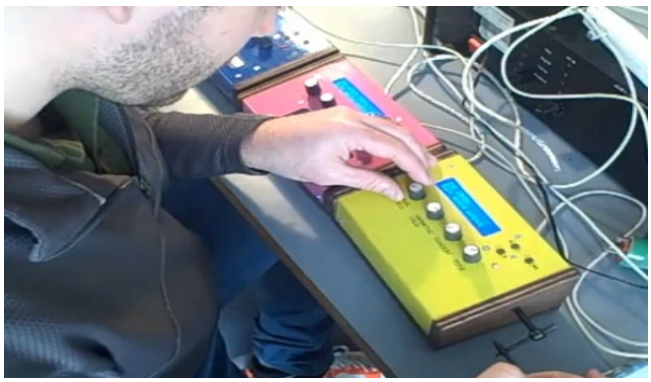

Figure 2. User playing the PHOXES. Here he is playing the particle PHOX on its own. Energy is exerted into the model by rotating the crank.

computer running their favored DAW, etc.) improvements should be made to the efficiency of the code. Some of the synthesis models are quite computationally expensive and are currently run on the test subject's own computer. This means that it is not possible to run large DSP-heavy projects at the same time as playing the PHOXES. This puts an undesirable limit to the potential use of the PHOXES. We want the test subjects to be able to work on projects exactly the way they are used to, in order to see how the PHOXES integrate in a natural environment.

Another issue was that the test subject did not get to explore parts of the modular system. This might have had to do with the mapping functionality being presented in an overly complicated way or because the test period was not long enough, and the test subject simply did not get to some parts.

The pre-test also showed that the test subject was highly motivated and stimulated by the PHOXES. He especially noted the balance between the familiar form factor of the instruments (familiar to an electronic musician, that is) and the naturalness of the physical interaction. It made him feel like he was playing an acoustical instrument, but in an electronic music setting. He found the PHOXES very durable and easy to set up. He found the physicality of the controls very inspiring and lastly he said that the sounds they made were amazing.

Before conducting a larger scale longitudinal evaluation with more test subjects, improvements will be made to the PHOXES regarding computation and in the way that the combination mapping is controlled. Hopefully the large scale evaluation can tell us if the success of the pre-test was a matter of novelty alone, or if developing for this kind of physical exploration does in fact improve the creative use of physical modeling sound synthesis.

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