Epipe : A Novel Electronic Woodwind Controller

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ABSTRACT
The Epipe is a novel electronic woodwind controller with continuous tonehole coverage sensing, an initial design for which was introduced at NIME ’03. Since then, we have successfully completed two fully operational prototypes. This short paper describes some of the issues encountered during the design and construction of this controller. It also details our own early experiences and impressions of the interface as well as its technical specifications.

Keywords
woodwind controller, variable tonehole control, MIDI, capacitive sensing

1. INTRODUCTION
There is a large pool of work in the area of development of expressive musical controllers, the vast majority of which have had the goal of emulating the responsiveness and feel of traditional musical instruments [2,3,4]. To date, the wind-instrument community has been poorly served, in particular those who perform with open tonehole instruments, such as the baroque flute, the recorder or the pipes. These instruments afford the player fine control over the pitch and timbre of the generated sound, by varying degree to which their fingers cover the toneholes. Controllers thus far developed for wind instrument players have largely been keyed types, with either binary states for each tonehole (i.e. WX5 by Yamaha [7]) or continuous control but not in the traditional way (i.e. Gary Scavone’s Pipe [5]).

The Epipe interface mimics the feel and responsiveness of an open tonehole wind instrument, and provides sensing of the degree of tonehole coverage. Our prototypes have their form factor modeled on the chanter of the Irish Uilleann Pipes, in terms of the number of toneholes and the spacing between them. However, the technology is equally applicable to any open tonehole wind instrument. This work is a continuation of that presented at NIME 2003 [1], at which stage there was no working prototype. Since then, we have implemented the design, as shown in figure 1. We have also developed a MIDI-based protocol for output from the controller, and created a basic application in the PC software synthesizer ‘Reaktor’. This application performs a basic conversion from tonehole coverage information to a pitch parameter, which directly drives a simple tone synthesizer, and also provides a basic visualization of the coverage for the 8-tonehole instrument.

Figure 1: The Epipe showing the front 7 toneholes and the “Energy Input” FSR

2. HARDWARE DESIGN
2.1 Sensing Requirements and Technology
The length of the air column within a wind instrument, which determines the pitch produced, is predominantly governed by the position of the first opening in the bore of the instrument. The design challenge was to create a suitable sensing arrangement that measures the degree of coverage of one such hole cut into a bored pipe and not any other parameters, such as the pressure applied around the holes’ circumference. To define it more accurately, the hole is considered covered if there exists an air seal around its circumference. For the human finger to create such a seal around a smooth surface requires only a tiny amount of pressure. Any increase in pressure above this threshold should not affect the sensed coverage. The tactile feedback provided by the feel of the tonehole edges is an important aid to the player of the traditional instrument, and for this reason a flat plate-style sensor would be unsuitable for our purposes. To circumvent drifting and calibration issues, we decided on a discrete sensing system, rather than a purely analog one. We chose capacitive sensing for this, due mainly to its robustness, low cost and high sensitivity, allowing detection of finger presence with minimal pressure being applied. To minimize the wiring complexity and overall size of our design, we integrated the sensing electrodes onto the gold-plated PCB containing the electronics. We arranged 16 such sense electrodes around the circumference of each tonehole, as shown in fig. 2.

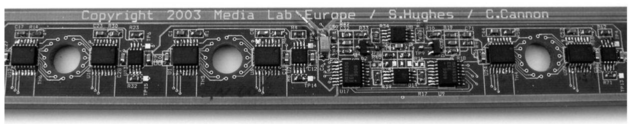

Figure 2: Close-up of a section of the 4-layer PCB which contains all the electronics. The sense pads are located on the rear of this PCB.

2.2 Physical and Electronic Design
Once the sensing technology was chosen, a primary concern was to ensure that the feel of the controller was as close as possible to

that of a real instrument. With this in mind, the dimensions of the eight holes and distances between them were based on measurements taken from an Uilleann pipe chanter pitched in B made by Andreas Rogge and the circuitry arranged to accommodate them.

The circuit works by multiplexing in time the capacitance of all 128 sense pads (16 per tonehole) to two custom designed peak-detect sensing circuits, details of which can be found in section 3 of [1]. A PIC microcontroller monitors the outputs from these circuits, and translates the data into MIDI controller messages. The Epipe also provides an analog input to which an energy input device such as a breath or bag-pressure controller can be connected. In tests conducted to date, we have been using a force sense resistor mounted in a foot widget for this purpose.

2.3 MIDI Protocol

We decided to use a MIDI-based protocol having determined that it provides sufficient bandwidth to handle the maximum data rate possible from the Epipe. We chose to use MIDI continuous controller messages, numbers 20-27, to represent the data of toneholes numbers 1-8 respectively, and numbers 29-30 for the energy input transducer. To minimize the amount of information to be transmitted, a control message is sent for a particular tonehole only if the coverage value differs from the value in the previous time frame, each time frame being 10mS long. The absolute maximum data rate of the controller, if all tonehole coverage states are changing simultaneously, is 76% of the total available MIDI bandwidth. This leaves more than adequate bandwidth to carry the data from the energy input device.

Table 1. Epipe Technical Specifications

Parameter	Min	Nominal	Max
Sense Elements per Tonehole		16	
Controller Update Rate		100Hz	
Output Jitter		<2mS	
Power Consumption		440mW	500mW
Supply Voltage	5.3VDC	5.5VDC	7.5VDC
Analog Input Resolution		10bit	
Capacitive Sensing Threshold	10pF	11pF	12pF

2.4 Epipe Specifications

The main technical parameter specifications of the controller are detailed in Table 1. We obtained the values for the power consumption and capacitive sensing threshold parameters from measurements on two Epipes that we built. The physical dimensions are 400mm X 40mm X 20mm, and it weighs 500g.

2.5 Initial Impressions

The Reaktor patch described above has provided an effective means of evaluating the performance and expressive resolution of this controller. The feel and sensitivity of the interface is uniform, and has thus far proved to be extremely reliable. The response of the controller to the rapid finger ornaments typical of Irish traditional music has proved very satisfactory, and pleasing glissandi can be produced naturally and accurately.

3. LIMITATIONS AND FUTURE WORK

Due to our limited prototyping facilities, the form factor of the Epipe is not cylindrical as a traditional pipe would be. To minimize the wiring of this complex circuit, it was necessary to keep the tonehole sensing pads as close to the electronics as possible, which was achieved by placing them on the opposite side of the same printed circuit board. The only type of PCB that could be curved with a radius as tight as that required are flexible PCBs, but these are unsuitable for this application because of their fragility and high cost [6]. Thus the toneholes are cut into a flat surface. Given greater resources, it would be preferable to have the touch sensors as small gold-plated pin like structures that would protrude through the wall of a cylindrical plastic tube.

The sensitivity of our capacitive sensors is ultimately limited due to the parasitic capacitances of the analog multiplexers, since this capacitance is effectively in parallel with the capacitance being measured. It is essential that direct skin contact be used, as skin conductivity is heavily relied upon so as to achieve a capacitance to ground greater than the switching threshold for minimum finger pressure. At present, if the fingers of the performer are exceptionally dry, extra pressure is required to activate the sensors. Therefore, this controller would not work if for example the performer wore gloves, or had prosthetic fingers. For future revisions of this hardware, we will attempt to address this issue, with the ultimate goal of having non-contact type sensing, where the sensing plates will be buried under the surface of the pipe wall.

4. CONCLUSIONS

We have designed and built what we believe to be the first wind instrument based controller that incorporates open tonehole coverage sensing. Preliminary tests indicate that it provides for very rich and expressive control of physically modeled synthesized sounds. The component cost of this controller comes to less than $100, which is very cost effective, considering the specialized nature of the interface.

5. REFERENCES

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