Eolos: a wireless MIDI wind controller

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ABSTRACT
This paper presents a description of the design and usage of Eolos, a wireless MIDI wind controller. The main goal of Eolos is to provide an interface that facilitates the production of music for any individual, regardless of their playing skills or previous musical knowledge. Its features are: open design, lower cost than commercial alternatives, wireless MIDI operation, rechargeable battery power, graphical user interface, tactile keys, sensitivity to air pressure, left-right reversible design and two FSR sensors. There is also a mention about its participation in the 1st Collaborative Concert over the Internet between Argentina and Cuba "Tradición y Nuevas Sonoridades".

Author Keywords
NIME, Eolos, Wind, Wireless, MIDI Controller, Digital Musical Instrument

CCS Concepts
• **Applied computing→Sound and music computing**;
• **Human-centered computing**→User interface design;
• **Hardware**→Sensors and actuators;

1. INTRODUCTION
The purpose of this paper is to present central aspects of Eolos (shown in Figure 1), an open design wireless MIDI wind controller. The criteria that guided its design were: to present an interface that facilitates the production of music to any person, regardless of their playing skills or previous musical knowledge; to offer a wireless operation, for the convenience of the player; and to maintain a low building cost. Through its expressive response, sound possibilities and independence of the use of cables, it was sought to allow its integration in diverse music ensembles [7].

Figure 1. Eolos and its wireless MIDI receiver.

There are some commercial wind digital musical instruments such as the Akai EWI, the Yamaha WX series, the Roland Aerophone Go, or the Aodyo Sylphyo. The latter two offer wireless operation, but retail at $830[1] and $1130[2] (USD) respectively. Eolos' estimated total cost is less than $200 (USD), although it's difficult to establish a precise value due to component availability, or even the fact that some parts were hand crafted.

There are also many well documented non-commercial, open or DIY related electronic wind instruments. An early initiative which predates the MIDI era is the Electronic Valve Instrument (EVI) [3], created by Nyle Steiner in the 1970's, who later helped to design the Akai EWI.

Other more recent products include the Epipe [4] (which features continuous tonehole coverage capacitive sensing), MiniWI[3] (based on the EWI), or the CyberWhistle [2]. Eolos, in addition to common characteristics such as breath and finger sensing, features an open design that focuses on the ease of use (both for novices and experienced wind players), a low building cost, and offers a wireless MIDI communication.

2. THE INSTRUMENT
Eolos is based on an Atmega328P (Arduino Nano board) microcontroller, whose power supply is provided by batteries with an embedded recharging system. It uses the MIDI protocol to communicate with audio synthesizer devices, expanding the timbral and artistic possibilities of the instrument.

Its usage is similar to that of an acoustic wind instrument: the user must blow through its embouchure and use the fingers to produce the different combinations of notes available. The instrument then generates the corresponding MIDI messages, which are transmitted wirelessly to a specifically designed receiver. By processing the various sensors and embedded systems, Eolos is capable of producing notes and expressive MIDI control parameters such as Expression, Breath, Pitch Bend, Modulation and others.

The instrument considers elements designed to facilitate its use by novice users, such as a "no effort" embouchure that only requires blowing, rotatable tactile keys, chromatic transposition and others. However, it provides the conditions for a greater use by more accomplished wind players. The following section describes some of the main features and technical aspects of Eolos' design.

3. DESIGN
3.1 Air sensing
A system was designed to measure the degree of pressure increase in a pipe when the user blows through it (scheme on Figure 2). This task is performed by a piezoresistive pressure sensor MPX5010 placed in a branch of the main air conduit. The pressure value recorded by this sensor is digitized and used to generate the fundamental MIDI expression messages [1].

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[1] Model AE-10, price at Roland certified dealers.
[2] Sylphyo + Wireless Link, at https://store.aodyo.com
[3] More information on www.hackaday.io/project/11843-miniwi-woodwind-midi-controller

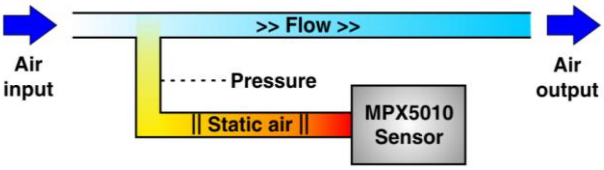

Figure 2. Simplified scheme of the air pressure sensing.

This system also allows the evacuation of the flow through a separate route from that of the sensor, which provides the user the sensation of blowing and also expels the content of the breath moisture out of the instrument. The evacuation conduit is arranged so that it has its outlet in the lower part of the instrument and, under normal conditions, the condensed water falls to the ground.

The mouthpiece of the instrument was modeled (as shown in Figure 3) and 3D printed, in order to optimize its assembly and improve material, ergonomic and aesthetic features. It also provides housing for a lip pressure FSR sensor (see next section), the air bifurcation mentioned above, and the corresponding connections for the air pipes.

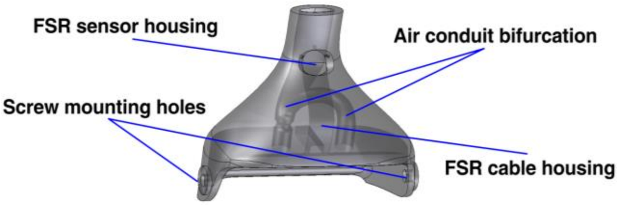

Figure 3. Mouthpiece detail (internal view).

3.2 FSR Expression Sensors

In addition to the dynamic expression controlled by the air flow, there are two additional analog sensors for the control of expressive parameters by the user. Both consist of Force Sensitive Resistors (FSR400 and 402).

The FSR402 (called "A") has been placed in the thumb rest, to be activated by the thumb of the lower (or instrument holding) hand[4]. In this way, the user can press it to produce different intensities of variation to MIDI parameters for expressive control.

The FSR400 (called "B") has been placed in the mouthpiece, in the contact area of the user's lower lip, so it can be controlled by the mechanical pressure exerted by the mouth and jaw muscles. This sensor was intended to provide a means of expression somewhat reminiscent to that existing in reed woodwinds, in which changes in pitch and other effects can be produced depending on how the mouthpiece and the reed are used, specially the pressure exerted on them.

3.3 Fingering

In order to provide an interface that requires little to no initial skill or finger strength, a fingering system based on capacitive touch sensors was designed. To this end, an MPR121 module developed by Freescale has been used. It provides an integrated solution for the use of up to 12 touch keys (thus, they are technically electrodes).

The actual keys were handmade in mirror polished aluminum, to optimize the contact with the user's skin. These were screwed and arranged symmetrically along the instrument (no difference between left and right), which gives the user the option of using their hands in either way. Mere physical contact with a key is sufficient to indicate its activation to the instrument. This design also makes it possible to rotate the keys at different angles to favor the reach of the fingers.

Regarding the production of notes, and in order to facilitate the playing by novice users, it was decided to use a design inspired by the recorder: 8 base notes, arranged in a diatonic scale. For this, 7 keys were used (the absence of touch in all of them is considered an 8th position), and predefined fingerings produce the remaining chromatic notes of the octave. There are about 30 available fingerings within each octave, some inspired by woodwinds like the oboe, flute or saxophone.

There is also an 8th key called "#/b", which can be set to raise or lower any fingered note by a semitone. Finally, two additional octave keys have been placed near the area where the upper hand's thumb rests, allowing Eolos to produce in real time[5] up to 4 octaves with identical fingering in all of them.

3.4 Graphical User Interface

Since it is necessary for the user to visualize and customize the status of some parameters, a monochrome LCD screen (see Figure 4) has been incorporated into the instrument. This screen has a resolution of 84x48 pixels and LED backlighting that can be deactivated when not required.

Figure 4. Detail of the LCD screen (with backlight on).

Next to the screen are 4 buttons to control the software of the instrument. Their functions are: decrease the value of the parameter (-), increase the value of the parameter (+), shift chosen parameter (shifts in a cyclical manner), Panic Button (turns all sounds off and resets the MIDI-CC parameters).

In general terms, control and visualization of the following elements is provided to the user: General Midi program (instrument) number, MIDI-CC dynamic expression parameter (Volume, Breath, Expression or none), MIDI parameter controlled by sensors A and B (Pitch Bend +, Pitch Bend -, Modulation, Portamento or none), breath sensitivity, chromatic transposition (-24 to +24 semitones), sharp or flat setting for the #/b key, status of the wireless module and battery charge level.

3.5 MIDI Messages Generation

The instrument has been conceived in a monophonic manner, that is, it is limited to a single note in the same time interval. The generation of notes responds to the following dynamics: when the pressure measured by the MPX5010 sensor exceeds a given threshold, the attack intensity is estimated, thus assigning a Velocity value for the -next to be produced- note.

After that, the status of the 7 keys is read and a reference note number is set. Then a semitone is added or subtracted if key #/b is being touched. Next, multiples of 12 semitones (one octave) are added according to the state of the octave keys. Finally, the addition or subtraction corresponding to the transposition value chosen by the user is applied. After these operations, a MIDI note number and a Velocity value are available, and a Note-On message is produced.

From here a series of new conditions apply. At regular intervals, the value of the MPX5010 sensor is read and a MIDI expression message (CC) is sent, in order to control the

[4] The layout of Eolos' keys is symmetrical, allowing for the indistinct use of both hands in either position.

[5] The instrument's full range is much larger if base note transposition is taken into account.

dynamics of the note being played. In the same way, the sensors A and B are read and the corresponding messages are sent.

If there is a change in the status of the 10 keys (meaning the fingering has been changed in any way), the system then produces a new Note-On message, and turns off the previous note with the corresponding Note-Off message.

The last instance processed by the system is, as may be expected, the fall of the pressure value below the mentioned threshold (cessation of blowing). This event produces a Note-Off message. This way, all the possibilities of production and interruption of sounds are contemplated. Table 1 shows the MIDI implementation table of the instrument.

Table 1. Eolos' MIDI implementation table.

Message	Transmitted	Comments
Note ON	**YES**	Actual note range depends on transposition and octave keys
Velocity (Note On)	**YES**	Values: 1 - 127
Velocity (Note Off)	**YES**	Always 0
Pitch Bend	**YES**	Divided into upper and lower
Control Change	**YES**	Modulation, Breath, Portamento, Volume, Expression
Program Change	**YES**	Values: 0 - 127
Other CC	**YES**	Panic (All Sound Off + Reset Controllers + All Notes Off)

4. THE WIRELESS SYSTEM

To provide a wireless MIDI transmission system, and taking advantage of the fact that it is a serial data protocol, two Xbee modules (based on the ZigBee specification) have been used in Transparent Mode [6]. In this mode, they function as a virtual “serial cable replacement”, replicating the data (in this case, the MIDI digital signal) provided from one module to the other without any changes.

The modules were set as sender and receiver. Both were configured to work at the MIDI data rate of 31,250 bps. Then a receiving device was made to relay the MIDI signal to the various synthesizers over a standard DIN connector. The receiver uses a rechargeable battery, and has a status display system comprised of 7 LEDs.

The wireless range was tested to work well at least 10 m indoors, which meets the needs of the instrument. The added latency was (preliminarily) measured to be about 9 ms. This measurement (Figure 5) was done using an audio interface, recording simultaneously the MIDI electric signals from both the receiver (left channel) and Eolos' embedded DIN output (right channel). Then, the time difference between the signal edges was calculated to obtain the total latency.

Figure 5. Receiver's latency measurement. A 9 ms difference is observed between both signals.

Since the housing of the instrument is made of non-conductive material (PVC), it does not offer a significant barrier to the RF signal. Thus, the Xbee module could be mounted inside the instrument without compromising its operation.

5. HOUSING

In order to provide an ergonomic housing for the instrument, a 5 cm diameter and 30 cm long PVC pipe has been used, due to its low cost and wide availability. Then, it was heat collapsed so that its section acquired the approximate shape of an oval rectangle of 6 x 3 cm, with two parallel flat faces. This provides a smooth feeling to the touch, without any edges that could interfere with the grip or comfort of the hands. Figure 6 shows the housing with the internal elements in place.

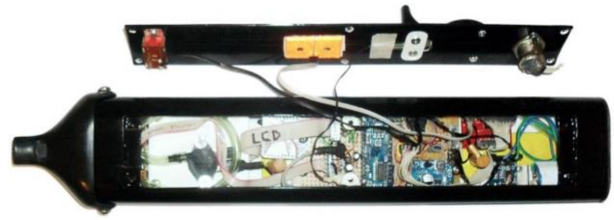

Figure 6. Opened instrument housing and internal elements.

6. USE IN CONCERT

To the date, Eolos has been played live on a few occasions. One of the most significant was the 1st Collaborative Concert Over the Internet "Tradición y Nuevas Sonoridades" between Argentina (National University of Quilmes) and Cuba (ISA - Superior Institute of Arts). This concert was held on March 29, 2018. In it, Eolos participated with the ElectropUNQ Ensemble from Argentina (in the Nicolás Casullo Auditorium of the National University of Quilmes), and an ensemble gathered for the occasion by ISA students in Cuba.

The event was conceived as a first step towards a new stage of collaborative music and digital transmission in Latin America, being the first of its kind, not only between the institutions, but also between the countries. Figure 7 shows the ElectropUNQ Ensemble with Eolos (first from the right).

Figure 7. ElectropUNQ Ensemble during the concert. Eolos being played on the rightmost.

The artistic initiative was to make a series of small pieces (or “situations”) with pre-established forms on a larger scale, but whose contents were entirely of an improvisatory nature, according to the paradigm of composition in real time. This allowed Eolos to be used exploiting extensively its timbric and expressive possibilities: from the use of the wide range of pitches to instrument[6] (MIDI program) changes within the same piece, according to the various “moods” or expressive needs of the group's performance. The concert lasted approximately 30 minutes and, in addition to having a public present in both

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6 A Midiplus Miniengine synthesizer was used for the performance, which is also battery powered.

countries, it was broadcast live on the Youtube platform (available on Links section).

7. DISCUSSION

Since its inception, Eolos has been used in numerous concerts and exhibitions. It was tested by a large number of people, from children and adults without musical experience, to wind instrument players. These experiences proved very helpful, but also provided quite diverse feedback on the ease of use and difficulties of the instrument.

One of the most remarkable observations by wind players was the fatigue that induces after hours of use, which is supposedly caused by the characteristics of the internal air ducts. According to some reports, it requires more volume and air pressure than usual (i.e. compared to woodwinds) to produce long notes and phrases. It is expected to solve this with future revisions of the air system, mainly through the use of larger diameter pipes.

Although the 9 ms latency added by the wireless system was an initial concern -particularly with short attack time sounds-, none of the players who tested the instrument have noticed any delays or odd sensations in this regard.

Another situation highlighted by some users was the seemingly slow reaction for certain types of techniques. This was determined to be caused by the insufficient speed of the Atmega328P processor, which, due to the large number of operations carried out by its software, is currently at the limit of its capabilities. This problem was partially solved by optimizing some functions that demanded a lot of process time, such as avoiding the update of the LCD screen when not needed. Future revisions will consider the addition of a second microcontroller, or even to completely replace the Atmega328P with a faster alternative. Both solutions could also provide the ground to add support for higher resolution protocols such as OSC, which would largely improve the instrument's capabilities.

8. CONCLUSIONS

After the main research and development stage was concluded, a musical instrument that (mostly) satisfied the initial objectives was produced, although the ease of use aspect requires further research. The building cost was kept significantly lower than the commercially available alternatives.

Compared to woodwinds or brass instruments, it's relatively easier to start using and to produce simple melodies on it. Successful tests of more advanced musical interpretation have been made, including a participation in the "Tradición y Nuevas Sonoridades" concert mentioned above. The wireless system, although it has some range limitations, proved to offer a very useful freedom of movement.

The following modifications and improvements will be sought in the future: measurement and documentation of technical specifications (particularly the electrical parameters); creation of a user manual; introduction of more fingering combinations; incorporation of a strap support system; and implementation of USB-MIDI and OSC support.

It should be noted that despite its relative ease of use, it is quite common for similar projects to invest more effort and time in the design and improvement of the produced device, than to perform on it or improve the playing skills [5]. For this reason, I am currently seeking to prioritize instances of musical performance over technical work on the device.

9. ACKNOWLEDGMENTS

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11. Links

Eolos' brief demonstration:
https://www.youtube.com/watch?v=e8JTanBMWI4

“Tradición y Nuevas Sonoridades” concert:
https://www.youtube.com/watch?v=phutHG2vgOg

More information, data, pictures and demonstration videos:
http://www.jaoramos.com.ar/eolos-english/