The FrankenPipe: A Novel Bagpipe Controller

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ABSTRACT
The FrankenPipe project is an attempt to convert a traditional Highland Bagpipe into a controller capable of driving both real-time synthesis on a laptop as well as a radio-controlled (RC) car. Doing so engages musical creativity while enabling novel, often humorous, performance art. The chanter is outfitted with photoresistors (CdS photoconductive cells) underneath each hole, allowing a full range of MIDI values to be produced with each finger and giving the player a natural feel. An air-pressure sensor is also deployed in the bag to provide another element of control while capturing a fundamental element of bagpipe performance. The final product navigates the realm of both musical instrument and toy, allowing the performer to create a novel yet rich performance experience for the audience.

Keywords
FrankenPipe, alternate controller, MIDI, bagpipe, photoresistor, chanter.

1. INTRODUCTION
1.1 The Inspiration
The premise of this project revolves around the first author's personal love of the traditional Highland Bagpipe. It is an ancient instrument that has changed very little over the past millennium and is severely limited in its ability to co-mingle with instruments and performance styles of the modern world. Although this creates part of the mysticism and appeal of the Bagpipe for many, it has been a personal frustration for many years.

The first author started playing bagpipes at the age of nine and since then has competed with a Pipe Band in two World Championships, Two USA West Coast Championships, and many other competitions around the Pacific Northwest. He has also performed in many Parades, Social Gatherings, Weddings, Funerals, and other events and thus knows well the beauty and powerful presence of the acoustic bagpipe. Lately, however, he began performing with rock bands, creating "techno" bagpipe compositions, and attempting to play more with contemporary instruments. Much of the inspiration for this project stems from not only attempting to further these efforts but in fact to take a few small steps toward bringing the tonally limited Great Highland Bagpipe into the performance world of today, much like the transformation of the acoustic guitar into the electric guitar during the last century.

1.2 Current Electronic Bagpipes
About five electronic bagpipes are commercially available [1], all of which use capacitive contacts in place of the holes and provide only a binary on or off value. These include a model made by Version MIDI, the DegerPipe, Master Gaita, Fagerstrom's Technochanter, and the Ross Electronic Bagpipe. Each is very similar in design, but not all provide MIDI capability. The Ross and Fagerstrom models include a synthesizer that sounds like a bagpipe and can be pitch-shifted to play in different keys. The Master Gaita is strictly a MIDI controller, and the Version MIDI and DegerPipe have both MIDI interfaces and synthesizers. The DegerPipe is arguably the best commercially available model, because it is reasonably priced (about US$ 400) and provides MIDI output as well as a dedicated audio output. The DegerPipe can alternate between Highland Bagpipe sound as well as Smallpipe sound and can be pitch-shifted over several octaves.

The bagpipe instrumental metaphor has yielded interesting and successful models in the academic community. These include the EpipE controller [2] and robotic bagpipe-playing systems such as those of [3,4]. A particularly striking automatic player in recent years is found in the McBlare robot [5]. Our work lies closer to that of these instruments rather than their commercial counterparts.

2. PROBLEMS
2.1 Limitations of the Acoustic Bagpipe
As stated before, the Highland Bagpipe is a limited instrument in many ways. It traditionally only plays nine notes: low A-flat, low B-flat, C, D, E-flat, F, G, high A-flat, and high B-flat, comprising the modes of B-flat Mixolydian, C Minor, and E-flat Major. (In contemporary piping, two additional notes—D-flat and G-flat—are played as well.) These notes are played with the fingers on what is called the chanter, and then octaves of the lowest B-flat on the chanter are played by the drones, which fit over the piper's shoulder. The piper generally does not touch the drones while playing. A player can also slur notes if a hole is uncovered in an upward or downward motion.

Another very prominent feature of the bagpipe is its relatively harsh timbre and absence of dynamic range. It is well known that this instrument cannot be played quietly! A final restriction of the Highland Bagpipe is that it produces a continuous sound that is difficult for the player to stop and start suddenly. In conclusion, owing to the restricted range, constant B-flat pedal tone, continuous sound, and the fact that it has one volume level ("loud"), the bagpipe in its traditional form does not interact well musically with other instruments in an ensemble.

2.2 Limitations of the Electronic Bagpipe

Attempts at creating a purely electronic bagpipe thus far have not proven satisfying to most bagpipe players. While they typically employ a fairly acceptable synthetic bagpipe sound or a MIDI output that can control a synthesizer, they are not very bagpipe-like. The fingering is the same of course, but the look and feel fail to emulate traditional bagpipe aesthetics. Perhaps the most noticeable feature missing from them is the bag and drones. Furthermore, electronic bagpipes can cost significantly more than their acoustic counterparts, even though their cost of production might be far less in some cases. In addition, the use of capacitive contacts in these commercial electronic bagpipes is a great limitation. The presence of a small round piece of metal in place of a larger concave hole seems very unnatural to most pipers. Furthermore, commercial instruments do not allow pitch-bending without taking a hand off the chanter to press a button.

3. THE FRANKENPIPE

3.1 Main Concepts

Construction of the FrankenPipe involved conversion of a real acoustic Great Highland Bagpipe into one capable of creating sound electronically. A primary design requirement was to retain the look and feel of a real bagpipe as much as possible without producing actual acoustic output.

First, we began choosing appropriate sensors for the fingers by narrowing the decision to three types: capacitive contacts (like those employed in [2]), some kind of force-sensing resistor above or below each hole, or optical sensing via photoresistors. We chose to use photoresistors in the chanter (Figure 1) for several reasons. They can be mounted underneath the hole on a chanter so that the fingers never come in contact with them, yielding a natural feel imperceptibly different from a traditional acoustic bagpipe. This is also a good choice because light in this sense can mimic the air traveling through the pipe. The photoresistors also have a full range of values allowing for pitch bend if a hole were to be partially uncovered in a slurring motion. This is something of which no other commercially available bagpipe is currently capable.

Next, an air-pressure sensor was mounted in the stalk of the middle drone. At first we attempted to hang the sensor in the bag, but it did not allow for enough pressure to cause a voltage difference at the output of the sensor. To remedy this, a hole was drilled through a bagpipe cork that was then put into the drone stalk. Next, we placed the end of the pressure sensor in the hole in the cork. This allowed for much more pressure to be applied at the sensor. Each of the other drone stalks were plugged as well (but with no sensors) so the bag could be filled entirely without loss of air, therefore allowing the piper to control the pressure in a natural way with the arm. The analog voltage produced by the pressure sensor was sent through an A/D converter and then to a microcontroller for processing. The values are translated into MIDI messages and sent as pitch-change information. Furthermore, when the player squeezes the bag, the bagpipe can modulate to another key, something that a real bagpipe could never do.

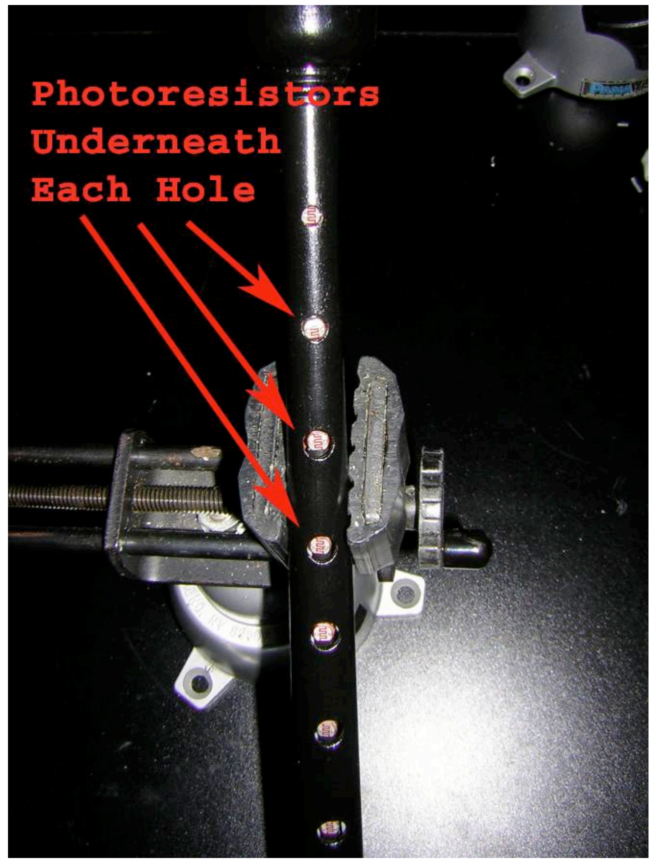
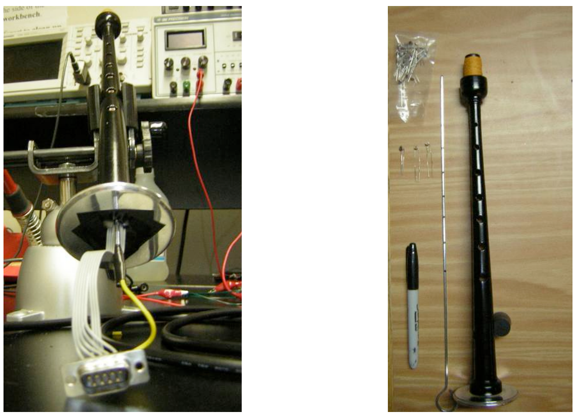


Figure 1. The FrankenPipe chanter.

3.2 The Chanter Design

There are many ways to mount photoresistors in a chanter. The first approach we tried involved making a mold of the inside of the chanter, making a complementary mold of that, and casting replicas of the space inside the chanter. The idea behind this was that pieces of the cast part could then be carved out and the photoresistors put in their place. This proved problematic, however, owing to the mechanical difficulty involved in mounting and securing the required sensors and cables within the small internal space of the chanter. Eventually, we gave up on this idea and became inspired by the idea of using a simple barbecue skewer as a sensor mount.

A barbecue skewer is typically made of stainless steel and is therefore a great conductor. In addition, it is very rigid and narrow, making it a great candidate to attach one leg of each photoresistor to as a common ground while leaving enough room for a very small wire to connect to the other leg. Unfortunately, it is difficult to solder to stainless steel, so tape or tightly wound wirewrap had to be used. (It was later discovered that the straight part of a standard metal clothes hanger could substitute for the skewer while allowing solder contact to be made.) Next, a nine-conductor serial cable was connected to each of the unused photoresistor pins. The chanter is terminated with a standard D-subminiature connector (Figure 2).



(a) (b)

Figure 2. (a) A first prototype with ribbon cable and 9-pin connector; (b) barbecue skewer and photoresistors ready to be mounted inside the FrankenPipe chanter.

The chanter is connected via a serial cable to a small box containing analog circuitry and a microcontroller. Each of the photoresistor outputs is translated into an analog control voltage via a standard voltage divider circuit and then digitized using a MaximMAX1270 eight-channel, 12-bit A/D converter. (For the chanter to produce the largest dynamic range of control values on average, we found that 470-KΩ resistors work well in providing the second leg of the voltage divider.) The MAX1270 then communicates serially with a Basic Stamp 2SX microcontroller. Under typical lighting conditions, the photoresistors have a range of 80 KΩ–5 MΩ.

After the voltages are converted to 12-bit binary values, they are scaled and processed in the Stamp. Raw output values from the A/D range from 1500–2700, and MIDI generally uses values of 0 to 127. Therefore, the Stamp must scale each of the holes separately depending on the lighting conditions in the room. This can cause some problems, because in order for the FrankenPipe to work in different lighting environments, each hole must be tested and calibrated individually. It was found that a calibration routine upon initial powering-on of the FrankenPipe was required to allow operation under different conditions. In this routine, the instrument assumes all holes are uncovered for the first five seconds of power-on, and that they are then closed for the next five. The extrema values can then be stored for use in subsequent processing and normalization.

Once the values have been scaled, the Stamp sends a MIDI Control Change value for each hole. (The controller numbers assigned to holes from bottom to top are Volume, Pan, Portamento, Breath Control, Expression, Foot Pedal, Bank Select, and Effect Control 1, for no particular reason.) In addition to sending MIDI Control Change information, the Stamp also references an eleven-entry lookup table to determine the correct pitch being fingered, and then it sends the corresponding Note On message. Generally, the Highland Bagpipe plays only nine notes as previously mentioned. The extra two notes (D-flat and G-flat) correspond to those that can be created on a bagpipe using false fingering, which is increasingly used in contemporary bagpipe music.

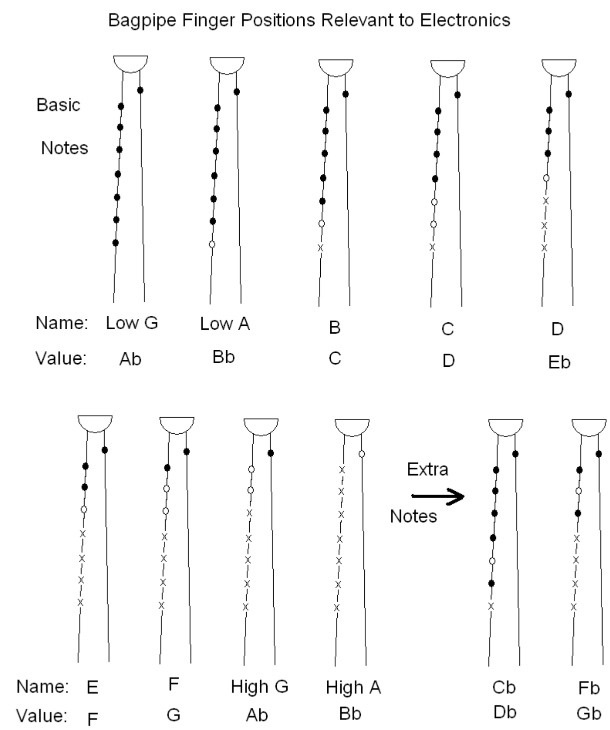


Figure 3. All of the finger positions used in bagpipe music. The "x" on a hole means it is a logical "Don't Care."

4. THE MIDI-CONTROLLED RC CAR

4.1 Main Concepts

The design and testing of the FrankenPipe prototype was relatively straightforward, and it was tested and used to control standard software synthesizers as well as instruments designed in Max/MSP. Next, we attempted to augment the performance capabilities of the instrument by enabling control of an RC car. The broader concept of the MIDI-controlled car was inspired by the fact that a performance can be supplemented by anything that reacts to a musical instrument. (Some drummers employ lights that are triggered when they hit their drums, for example.) Another conceptual art form afforded by this toy-music interface is that of the musical game: music can be generated by the performer during the process of attempting to drive the car through a maze, for example.

4.2 Design

Equipping the FrankenPipe with radio-frequency (RF) control of an RC car was also straightforward. The transmitter of an RC car was disassembled, and it was discovered that only four different contacts needed to be grounded to move the car forward or backward, or to turn the front wheels left or right. Thus, we only needed to connect these four contacts to four pins on the Stamp, using transistors as switches that connect each contact to ground based on which pins of the Stamp are set to high or low. These four circuits create seven possibilities of motion: forward and left, forward only, forward and right, no movement, reverse and left, reverse only, and reverse and right. To incorporate the capabilities of the RC Car into the bagpipe design, each of the original nine notes of the bagpipe move the car in one of the seven basic ways. This simple mapping was undertaken as a first attempt to drive the car, and amusing results were easily produced.

5. INITIAL EXPERIMENTS

Once the entire FrankenPipe prototype had been assembled, it was tested in various ways, both technically and musically. Perhaps the most striking success of the controller lies in its natural feel; it actually feels like playing an acoustic bagpipe owing to the CdS photocell sensors, which are recessed into the finger holes, thereby providing non-contact sensing. The second feature lies in the interaction and engagement provided to the player and audience by controlling the RC car. The result is a marriage of audio and game controller, future mappings of which must continue to be explored..

The chanter exhibited a few problems, particularly in slow reaction time due to the Basic Stamp. Quite simply, it takes the Stamp a little too long to poll for values, store them, scale them, determine which note is being fingered, and output MIDI messages. Some bagpipe music is well known for having extremely fast fingering, and so this issue must be solved.

Ongoing experiments with the FrankenPipe continue to explore a variety of aesthetic approaches to playing the instrument in musical (and other) contexts. The instrument has proven successful for playing in ensemble contexts (unlike the acoustic bagpipe), and a concert featuring the FrankenPipe is scheduled for May 2007 in Miami.

6. FUTURE WORK

The FrankenPipe is an ongoing project and presents opportunities for enhancement in several areas. Fingering latency is somewhat higher than desired, a problem that could easily be solved by using a faster microcontroller and by performing some of the sensor scaling using analog circuitry rather than lines of program code. Another improvement involves the attachment of a three-dimensional accelerometer on the chanter, which would provide even more control capabilities to the performer.

In addition, we are currently investigating compositional and performance activities centered around the instrument. First, we are investigating its use in mixed-ensemble performance environments by controlling a software sampler containing actual sounds recorded from an acoustic bagpipe. Because the FrankenPipe produces no acoustic output, it can easily be used to produce a wider variety of pitches and dynamic range than that of the traditional bagpipe.

Ultimately, it would be nice to be able to nondestructively and quickly retrofit any bagpipe so it is capable of being played both acoustically and electronically, but such a system will take more time to develop. Regarding the incorporation of the car into performance situations, several investigations are currently underway. One use for this sort of control is in the visual examination of an ensemble playing in unison. Two FrankenPipe players playing a piece in perfect unison, for example, should result in two RC cars driving in parallel (provided that any sensing noise from the instruments is smoothed and taken into consideration). Any slight deviation in performance would cause a discrepancy in the path of the cars. Another compositional opportunity exists in the blurring of music and game, whereby cars play "musical tag," chasing each other and thereby generating musical content as a result.

7. ACKNOWLEDGMENTS

We gratefully acknowledge support and resources from the Music Engineering program at the University of Miami's Frost School of Music for this project. This work was also supported by an award from the Audio Engineering Society student design competition.

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