Envelope Detection for the African Kalimba

Michael Dean
CS6242 – Physical Computing
University of Limerick
12056545@studentmail.ul.ie

ABSTRACT
An analogue circuit-based envelope follower was designed and developed, specifically for use with an African lamellophone known as the kalimba. The signal generated from the circuit is converted into the digital domain using the Arduino microcontroller and translated to MIDI protocol control change values. By converting data that is a natural component of instrumental performance, the use of both laptops and MIDI controllers can be avoided in favor of instrumental performance. Instrumental performers can thus take advantage of digital technologies while avoiding the aesthetic performance problems associated with laptop performance. Furthermore, a unique and natural interface for digital control is created which capitalizes on instrumental virtuosity, a prominent problem within the development of digital musical instruments.

Keywords
Non-invasive sensing, performance, kalimba, Arduino.

1. INTRODUCTION
The development of hardware-based, hyper-instruments are motivated by two concepts. First, it is important to preserve the lineage of performance practices developed over several generations of performers. The development of new instruments without a history of training and practice may inhibit the development of virtuosity on an instrument. The temporary nature of digital instruments often means that by the time virtuosity can develop, the digital instrument is outdated or no longer supported by newer, more advanced digital technologies, effectively killing any development of performance practices. Second, the aesthetics of instrumental performances and the perspective of audiences contribute to the sensory perceptions of music performance. Many studies have shown that the presence of a laptop on stage, and the performer's tendency to focus on the technology, contributes to a disconnection between the audience and the performer resulting in various perspectives towards laptop-based performance to develop.

An analogue, circuit-based envelope detector built specifically for the kalimba is presented with these intentions. This apparatus serves as one component of a system containing many more analysis methods, ultimately resulting in a complex system with the capability of producing more intricate mappings than simple one-to-one mappings, as described in [9].

NIME'12, May 21-23, 2012, University of Michigan, Ann Arbor.

1.1 Non-Invasive Sensing
In order to not only preserve performance practice in instruments that have been modified to make use of digital supplements, but also to prevent interference with the sound production and playability of an instrument, non-invasive sensing techniques should be the focus of the hyper-instrument designer. In this context we will define non-invasive sensing as methods of data collection that do not interfere with the normal, natural playability of the instrument, and do not obstruct the sound production of an instrument in an obstructive manner. By doing so, methods of digital control can be designed such that they make use of existing technique and practice of the performer. It should be the focus of the designer to create natural, organic methods of digital control that build upon a lineage of advancements in instrumental performance practice [13].

In the case of the kalimba, a contact microphone is mounted to the underside of the instrument and the signal is fed to an analogue circuit, which performs analyses on the signal. It can be argued that this placement may affect the resonance of the instrument, but through experimentation with and without the mounting of this sensor, such an affect appears to be minimal. Alternative solutions, such as traditional performance microphones pose many problems. The movement of the performer is greatly restricted which may affect the ability of the performer to fully express his or herself, and the potential for external sounds to interfere with any analyses during a performance is greatly increased.

1.2 Laptop Performance
Several studies have shown that there are multiple factors, apart from auditory stimuli, that contribute to the perception of auditory experiences in live music performance. One major factor is the movement and visual cues exhibited by the performer. Research in music psychology and emotions have illustrated that visual cues, the ability for audience members to interpret musical expression through movement, and the spectator's understanding of an instrument contribute to auditory perception in a live music performance [1, 4, 6, 8]. It has been demonstrated that emotion can be communicated to an audience depending on the level of expression exhibited by a performer, that expressive movement provides cues for a musically expressive performance and that "it is more interesting to both see and hear a musician perform" [1], giving value to the presence of a performer.

It is well known that the presence and use of a laptop in musical performance raises many questions among audience members as to what is actually happening in a performance. There is a disconnection created between the sounding music and the visual cues. Cascone examines the use of laptop computers in music performance through an approach grounded in "reception theory". He found through his experience that "audiences experience the laptop's use as a musical instrument as a violation of the codes of musical performance" [2]. The laptop is designed as an office tool, and it is the way in which audiences are familiar with its use. By creating alternative, non-visible ways for instrumentalists to interact with digital technologies, the interruptions or negative effects for spectators with the presence of a laptop in performance may be avoided. One such method is the use of hardware apparatus that does not place the performer behind a bright screen, averting their attention from their instrument to an office tool.

2. DESIGN

Several stages in the current design were necessary to create an optimized envelope following strategy. Voltage changes are collected through the use of a single piezo transducer, placed underneath the instrument. The signal is filtered by a first-order, high-pass filter and fed into a buffer stage. The output of the buffer is then amplified by an inverting amplifier and prepares the signal for the envelope detection component. Finally, another inverting amplifier allows for adjustable output from the circuit by using a variable resistor. The output voltage is then limited by means of a zener diode connected to ground. A schematic representation of the design is shown:

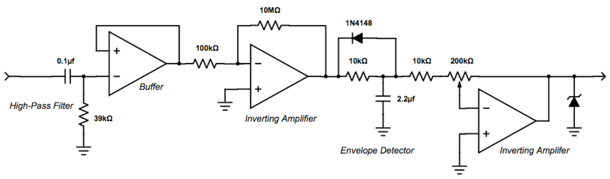

Figure 1. Schematic representation of the circuit design.

2.1 High-Pass Filter

After testing the input signal from the piezo transducer, it became apparent it was necessary to reduce the amount of DC offset present in the incoming signal. This was achieved through the implementation of a first-order, high-pass filter with a -20dB/decade roll off, realized by means of an RC circuit. The cut-off frequency of the filter is calculated:

$$f_c = \frac{1}{2\pi RC} = 40.81Hz$$

The filter is made active through introduction of the buffer stage.

2.2 Buffer

The buffer stage consists of a powered op-amp with negative feedback. Like all op-amps in the circuit, a TL074 chip was used. The addition of the buffer component serves to isolate the preceding stage from the following one. Input is of high input impedance, since the circuit receives line level input from the piezo transducer, and output is of low output impedance. By separating the circuit in this way, we prevent undesirable operation of the circuit in the case that the second circuit may load the first circuit unacceptably. Unity gain is provided by an op-amp with negative feedback.

NIME'12, May 21-23, 2012, University of Michigan, Ann Arbor.

$$G = \frac{V_{out}}{V_{in}} = \frac{R_1 + R_2}{R_2} = \frac{0}{\infty} = 1$$

2.3 Inverting Amplifier

The incoming signal provided by the piezo transducer is of significantly low gain. In order to achieve desired operation from the diode of the envelope detection stage, the signal's gain needed to be boosted preceding the demodulation. A substantial amount of gain was applied:

$$G = -\frac{R_2}{R_1} = -1000$$

2.4 Envelope Follower

The envelope detection component is made up of an RC component and a diode. The diode is used to rectify the voltage. That is, only one half of the input is allowed through. 0.62V are necessary to activate the 1N4148 diode so that current is passed. This was achieved in the preceding amplification stage. The RC component allows the output of the waveform to follow the envelope of the incoming signal. A capacitor effectively reduces the ripples in the output wave since the output voltage from the capacitor does not drop as rapidly. The capacitor is charged and discharged depending on the RC time constant. Essentially, this stage functions as a method of demodulating the amplitude envelope from the incoming signal. The output of this stage is the demodulated envelope, which we desire as a control signal.

2.5 Inverting Amplifier

Another inverting amplifier is used to boost the envelope signal to an acceptable level. This was implemented using a variable resistor, with the desired gain set in conjunction with the BZX55C5V1 zener diode. The zener diode serves to regulate the output voltage so that any signal exceeding its breakdown voltage will remain at this value.

2.6 Arduino and MIDI

Once the instrument has generated an appropriate signal and the envelope has been extracted, the signal is converted to the digital domain using an Arduino microcontroller. This micocontroller was chosen for its ease of use, and already existing MIDI[1] library. Within the microcontroller, the signal is converted to a 10-bit number, and then scaled to a 7-bit number so that it can be used as a MIDI protocol message. A MIDI message is generated and output through a five pin DIN jack, like those commonly used to connect MIDI instruments.

By converting the signal to a protocol that can easily be accessed by decades of existing equipment, the performer can implement the design into a complex set-up of hardware, controlling any desired parameter within his or her set-up. As a result, the presence of a laptop has been avoided, although the performer who still wishes to connect to one still has the full ability to do so through readily available MIDI interfaces. An example of such a set-up is shown. Here, the device has been connected to a hardware sampler and sequencer. This possible set-up allows the performer to record both the control data produced with instrument, and loop the resulting audio.

[1] Musical Instrument Digital Interface. http://www.midi.org/

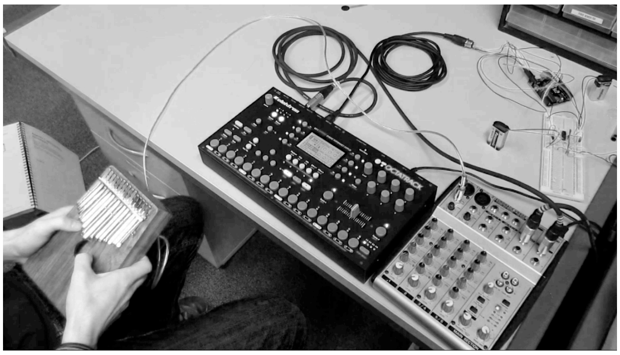

Figure 2. Envelope follower connected to hardware devices.

2.7 Power

The circuit is powered by a simple 18V bi-polar power supply, created using two 9V batteries. A 0V middle point, acting as ground, is created by connecting the positive terminal of one battery to the negative terminal of the other. The two remaining leads are then used for -9V and +9V, supplied to the TL074 op-amps. The Arduino microcontroller is also powered from one of the batteries, thereby eliminating the need for any external connections to the device.

3. DISCUSSION

A number of improvements may greatly increase both the effectiveness of the designed circuit, and the musical possibilities of the implemented system. As discussed earlier, envelope detection should be one part of multi-part analyses, allowing for complex mappings and interactions between an instrumentalist and the digital tools available to them. A number of improvements may also be made to actual design of the circuit to improve the efficiency of envelope following. The addition of more controls features could also be added to allow the device to be utilized by multiple instruments and devices.

The addition of pitch tracking and onset detection could substantially improve the musical possibilities of the system. For example, through a combination of pitch tracking and a modification of the envelope following to detect the onset of notes, each key of the kalimba could be used to trigger different events. Using the pattern recognition developed by the author in [13], rhythmic patterns could also be identified and used to trigger events or sequence musical material. This would cohesively compliment the performance style of the instrument, given the percussive nature of the kalimba.

More specific filtering could be added to the envelope detection design, further eliminating the possibility of an external noise that may affect the generated envelope. The addition of attack and release control would also allow the performer to optimize the system for a variety of controls. A longer release may greatly improve the system, as the decay envelope of the kalimba occurs fairly rapidly.

An immediate improvement that will be added in future work is the control of the MIDI control change number that the system sends over the MIDI jack. Currently, the device is hardwired, but the performer may need to adjust this value for a variety of devices, or even live in a performance to effect different parameters.

Finally, a powerful adjustment would be to adjust the system to accept a variety of gain levels. Such an addition would allow the system to be connected to a hardware mixer's post-fader send output. In this way, the volume of any part of a mix that was routed to the send of the mixer could control MIDI devices. Effectively, a DJ or sound engineer could simultaneously control a number of effects that react to a mix. Any hardware mixer would be able to also serve as a MIDI control device.

4. REFERENCES

[1] Broughton, M. and Stevens, C. Music, Movement, and Marimba: An Investigation of the Role of Movement and Gesture in Communicating Musical Expression to an Audience. *Psychology of Music*, 37 (2). London, UK: SAGE Publications, 2009, 137-153.

[2] Cascone, K. Grain, Sequence, System: Three Levels of Reception in the Performance of Laptop Music. *Contemporary Music Review*. 22 (4). London: Routledge, 2003, 101-104.

[3] Collins, N. Generative Music and Laptop Performance. *Contemporary Music Review*. 22 (4). London: Routledge, 2010, 67-79.

[4] Davidson, J. W. Visual Perception of Performance Manner in the Movements of Solo Musicians. *Psychology of Music*. 21 (2), 1993, 103-113.

[5] Dobrian, C. and Koppelman, D. The 'E' in NIME: Musical Expression with New Computer Interfaces. In *Proceedings of New Interfaces for Musical Expression*. IRCAM, Centre Pompidou Paris, France, 2006, 277-282.

[6] Fyans, A. C., Gurevich M., and Stapleton, P. Examining the Spectator Experience. In *Proceedings of New Interfaces for Musical Expression*. Sydney, Australia, 2010.

[7] Fyans, A. C., Gurevich, M. Digital musical interactions: Performer-system relationships and their perception by spectators. *Organised Sound*. 16 (2), 2011.

[8] Gabrielsson, A. and Juslin, P. N. Emotional Expression in Music Performance: Between the Performer's Intention and the Listener's Experience. *Psychology of Music*. 24 (68). London, UK: SAGE Publications, 1996, 68-91.

[9] Hunt, A., Wanderley, M. M., Paradis, M. The importance of parameter mapping in electronic instrument design. In *Proceedings of New Interfaces for Musical Expression.* Dublin, Ireland, 2002.

[10] Kimura, M. Performance Practice in Computer Music. *Computer Music Journal*. 19 (1). Cambridge, MA: The MIT Press, 1995, 64-75.

[11] Schloss, W. A. Using Contemporary Technology in Live Performance: The Dilemma of the Performer. *Journal of New Music Research*. 31 (1). New York: Routledge, 2003, 239-242.

[12] Stuart, C. The Object of Performance: Aural Performativity in Contemporary Laptop Music. *Contemporary Music Review*. 22 (4). London: Routledge, 2003, 59-65.

[13] Trail, S. Dean, M., Tavares, T. F., Odowichuk, G., Driessen, P., Schloss, W. A., & Tzanetakis, G. Non-invasive sensing and gesture control for pitched percussion hyper-instruments using the Kinect. In *Proceedings of New Interfaces for Musical Expression*. Ann Arbor, MI, 2012.