The Wiikembe- A performer designed lamellophone hyperinstrument for idiomatic musical-DSP interaction

Shawn Trail
Department of Computer
Science
University of Victoria
Victoria, BC
trl77@uvic.ca

George Tzanetakis
Department of Computer
Science
University of Victoria
Victoria, BC
gtzan@cs.uvic.ca

ABSTRACT

The Wiikembe is an augmented Likembe from Zaire, believed to be 100+ years old. A Wiimote affords 3D gesture sensing for musical-HCI. An Arduino interface offers explicit control over DSP functions. Puredata (Pd) scales, converts, and routes control data into Ableton Live. A contact mic is used to acquire a direct audio signal from the Likembe. The audio inputs into a conventional computer audio interface and routed into Live which handles event sequencing, DSP, and audio bussing. The result is a compact and intuitive, robust lamellophone hyperinstrument. The Wiikembe extends the sonic possibilities of the acoustic Likembe without compromising traditional sound production methods or performance techniques. We chose specific sensors and their placement based on constraints regarding the instrument's construction, playing techniques, the author's idiosyncratic compositional approach and sound design requirements. The Wiikembe leverages and combines inherent performance gestures with analogous embedded gestural sensing to achieve unprecedented intimate musical-DSP interaction. Specific gesture recognition techniques and mapping strategies have been standardized using easily sourced and implementable, low-cost components. This work is in efforts to establish an implementable pitched-percussion hyperinstrument framework for experimentation and pedagogy with minimal engineering requirements.

Keywords

Lemellophone, Hyperinstrument, DSP, Gesture Recognition

1. INTRODUCTION

This project merges the author's experience as a percussionist, electronic musician, and studio producer into a singular, real-time performance based practice combining what would have previously only been possible in a static, post-production context. Using sensing techniques allowing for uninterrupted interfacing via traditional playing techniques, our primary contribution is less novel engineering than it is an explicit, formalized approach to developing minimally-invasive hyperinstrument augmentations for idiomatic DSP interaction. Aside from serving the author's artistic mo-
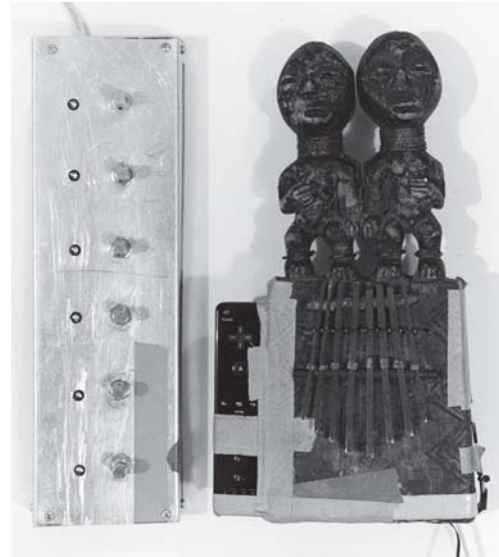
Figure 1: Wiikembe and custom footpedal

tivations, the work is intended to provide an easily replicable reference for other artists to appropriate or abstract in order to develop their own hyperinstruments with minimal technical demands. Typically hyperinstruments require specialized engineering for the development of proprietary prototypes. Because the field of hyperinstruments is so new, standardized systems need to be designed from existing paradigms. Such paradigms are typically singular in nature, solely reflecting the idiosyncrasies of the artist and often difficult to reproduce. This work simplifies this process, offering a basic design prototyping platform.

Lamellophones have a series of tines fixed at one end and free on the other. Musical tones are produced by depressing and releasing the free end with the thumb allowing the tine to freely vibrate [11]. They are excellent instruments for augmentation being handheld, compact and ergonomic. The Wiikembe's (Figure 1) design facilitates uninterrupted traditional playing while the sensors can be engaged with broad or minute arm/hand gestures or explicitly with the free fingers. The unused surface area of the body is ideal for intuitive sensor placement, while direct audio acquisition is simple and robust via piezo transducer. Our augmentations equip the instrument for contemporary settings where audio processing and sound reinforcement are commonplace. Percussionist utilize their feet, so we built a simple arduinio footswitch- it's construction and implementation are trivial.

2. RELATED WORK

Electrified lamellophones are reletively common [21], however lamellophone hyperinstruments are rare. This work is inspired by Konono No.1 from the Democratic Republic of the Congo (formally Zaire). Konono No. 1, a band founded by Mawangu Mingiedi in 1966, combine voice, homemade percussion and handcarved wooden microphones, and 3 electric Likembe. Their music was originally adapted Zongo ritual music played on horns crafted from elephant tusks. Based centrally in the dense urban environment of Kinshasa, their acoustic music became inaudible because of increased noise pollution. Compelled to build amplification systems for their instruments using discarded, obsolete electronics, their motivation was partially of practical concern [4]. To sustain their musical heritage, amplification was essential. As a result, an unprecedented neo-traditional musical movement was born, spawning a range of new instruments and sound design practices. The advent of electronics in their music propelled Konono No.1 onto the world stage, while leaving an indelible mark on their own culture's contemporary music scene[2]. In 2007, they toured as the supporting backing band for Bjork (13 time Grammy Award nominee from Iceland). Konono N1's album *Live At Couleur Cafe* was nominated for a Grammy in 2008. They won a Grammy in 2011, as guests on pianist Herbie Hancock's album *The Imagine Project*.

Instrument manufacturer Hohner experimented with electric lamellophone designs in the past mid-century. The Guitaret[1] has internal tines that are excited when the instruments's unique keys are depressed (Figure 2).
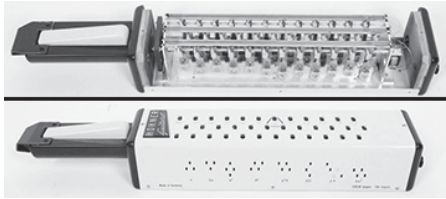

Figure 2: Guitaret

The Pianet[2] is another of their lamellophone inspired instruments from the same period. An electric piano with tines that are, by default, slightly depressed in it's non-played state- a piano-style key press releases the tine causing the tine to vibrate (Figure 3) producing a tone- a type of reverse lamellophone effect. Both have passive electric pickups for audio amplification. Although unique, rare, and antique, they are excellent examples of repurposing ancient music instrument engineering techniques to achieve novel results in contemporary music. This type of repurposing is the focus of our style of engineering for the Wiikembe.
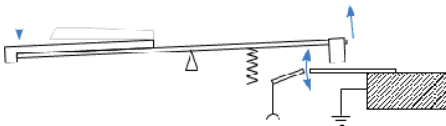

Figure 3: Pianet: top- mechanics of key and tine

Lamellophone style hyperinstruments can be seen in the work of: Adrian Freed's [5] *Kalimba Controller*; Fernando Rocha and Joseph Malloch's *Hyper-Kalimba* [17], Jose A. Olivares' *KALIMBATRONIQUE* [16]; Ian Hattwick's *Mbira*

controller [9]; and Daniel Schlessinger's Kalichord [18]. A patent from 2004 [12] shows an augmented Mbira. A robotically actuated, electrified lamellophone can be seen in Octant's work[3]. There are even virtual software versions: plug-in instruments and multi-touch screen instruments coupled with a lamellophone style GUI graphic for interfacing the synthesis models[4].

3. WIIKEMBE DESCRIPTION

Like Konono No. 1, the Wiikembe uses easily sourced, low-cost components. The design is meant to be easily replicable and modular so that any lamellophone performer could render their own version with little engineering background. The Wiikembe is an augmented Likembe: a Wiimote , 2 rotary potentiometers, 1 slider potentiometer, 1 membrane potentiometer [6] and a piezo transducer[5]. The sensors input into the analog GPIO of an Arduino Nano then bussed to Pd via serial USB and converted into MIDI, then mapped into Ableton Live[6] for control of filter parameters, volume levels, and audio event sequencing. The Likembe audio is acquired via piezo transducer and input into the computer as a discrete mono signal. A flowchart of the configuration can be seen at: (Figure 4).
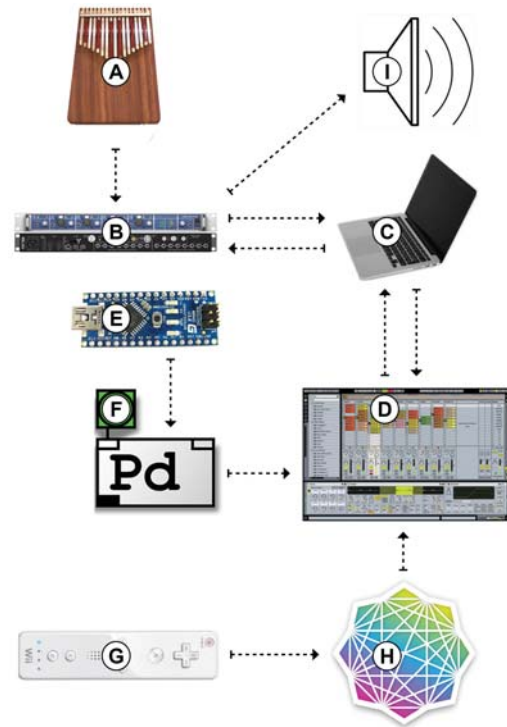

Figure 4: A. Likembe; B. ADC/DAC; C. laptop; D. Ableton Live; E. Arduino interface; F. Puredata; G. Wiimote; H. Osculator; I. speaker

3.1 Likembe

The handcarved, wood Likembe has tines mounted to the body over a bridge with small metal rings added creating a desired sympathetic, sustaining buzz when plucked (Figure 5)- a sound design practice common in West Africa [8].

---

[1] http://en.wikipedia.org/wiki/Guitaret
[2] http://en.wikipedia.org/wiki/Pianet

[3] http://octant.tumblr.com/post/23165788528
[4] http://apploudable.com
[5] http://www.contactmicrophones.com/
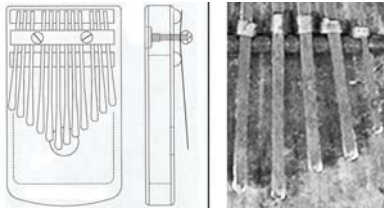[6] https://www.ableton.com/

Figure 5: top, side, and rings on tines

The body is carved out on the inside creating a resonant chamber. The instrument is tuned to a single diatonic scale by adjusting the length of the tine (longer - lower frequency, shorter - higher frequency). Being non-western, it doesn't conform to the tempered chromatic scale. The suggestion of a tonic/intervals or octave is only relative to the notes preceding it and their context within the music- since the instrument is tuned by ear and not by mathematically and uniformly spaced intervals 1.

Table 1: Wiikembe tuning in frequencies

Tine	Frequency (Hz)	Pitch Range
1	213	G#3 = 207.65 Hz
2	247	B3 = 246.94 Hz
3	272	C#4 = 277.18
4	308	D#4 = 311.13 Hz
5	352	F4 = 349.23 Hz
6	383	G4 = 392.00 Hz
7	540	C#5 = 554.37 Hz
8	624	D#5 = 622.25 Hz

Figure 6: tine layout/notes approximate to A=440

3.2 Wiimote

The Wiimote offers versatility in a music controller [22]. Combining wireless 3D position tracking [3] with switches, the Wiimote extends the Likembe, affording the performer a broader set of musical gestures not possible with only potentiometers. The Wiimote's design situates transparently with the ergonomics of the Likembe. The top switches are easily accessible via the thumb, while the switch on the underside is accessible via the forefinger, both with minimal adjustment to conventional playing position. The position tracking allows the performer to interface DSP parameters without interrupting playing in the way having to turn a knob might. This presents an unprecedented level of interaction with software FX, synthesizers, and more that would otherwise require interruption of playing the traditional instrument in order to engage the filter parameters .

3.3 Arduino and Sensors

An Arduino Nano is mounted to the back of the instrument (Figure 8). Four dedicated sensors send CC data into Pd
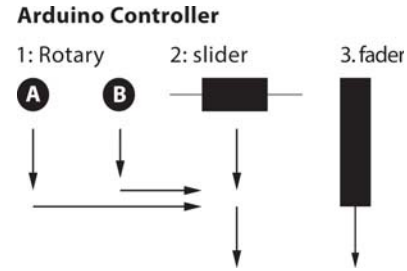

Figure 7: rotary- A (Likembe signal to reverb), B (Likembe signal to delay); slider- master effects (out channel 1); fader- Wiikembe (out channel 2)

via Pduino [19]. Pd is used because it is free and widely supported. This Likembe has a groove carved out of it's back which allows the potentiometers (pots) to sit comfortably recessed in the instrument's body. The pots are mounted to prototyping board alongside a low-profile slider. Situated on the instrument's rear, the sensors are out of the way, yet easily accessible from a natural playing position. They fit comfortably within the space confines as dedicated controllers for specific filter parameters meant for this type of interaction [7]. Lastly, a membrane pot is mounted on the right side of the instrument's body. Nearly as thin as paper, it is minimally-invasive to the Likembe's traditional playing techniques, yet remains easily accessible via the performer's index finger [13]. The sensor data from the Arduino is converted into MIDI in Pd and routed into Ableton Live.
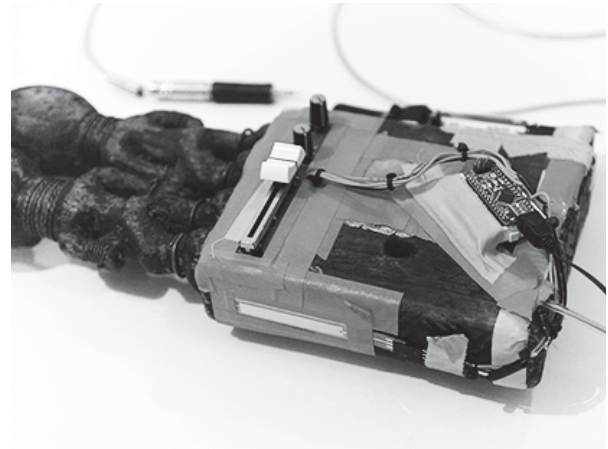

Figure 8: Arduino controller

3.4 Software

Osculator is used to receive and convert the Wiimote data into OSC or MIDI messages to be mapped to the user's software or hardware of choice [7]. Osulator is flexible, inexpensive, robust and intuitive. It streamlines the sensor data acquisition, scaling and mapping stage of working with the Wiimote. In this implementation all data is sent as MIDI data into Ableton Live and mapped to filter parameters and device controls. Live is used as a sequencing, looping, effects processing, and audio mixing environment. Audio from the instrument inputs from the contact mic via the audio interface. The signal has a dedicated channel in Live and passes "in-line" through a frequency shifting delay plug-in (Figure

---

[7] http://www.osculator.net/

9: in this case, the free Valhalla DSP *Frequency Echo*[8]) and the Ableton Looper device respectively. The signal is output mono via Output Channel 2 on the audio interface to it's own speaker. The Wiimotes gesture tracking is mapped to: Table 2; and the Wiimotes switches control: Table 3.
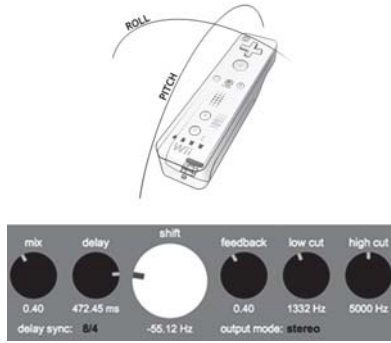

Figure 9: wiimote axes and filter parameters

Table 2: Wiimote axis mappings

Axis	Mapping
Pitch +	freq. shift up
Pitch -	freq. shift down
Yaw +	delay rate
Yaw -	feedback rate
Roll +	filter wet
Roll -	filter dry

The Wiikembe's volume is controlled by the membrane potentiometer. Two rotary knobs are mapped to auxiliary sends A and B sending the Wiikembe signal to: Send A- reverb; and send B- simple delay. Both aux channels are bused to the master channel, whose volume is controlled via the slider potentiometer (Figure 7). The effects chain outputs a mono signal from Output Channel 1 on the interface to its own speaker. These explicit mixing controls are essential to electro-acoustic, computer music performance of any style. The Arduino interface is designed to afford the performer the ability to mix multiple audio signals from the instrument itself with minimal adjustment of technique or interruption of performance.

These specific mappings are mostly arbitrary, except for reflecting the artist's performance idiosyncrasies and personal mapping preferences. Any artist can obviously map the controllers to whatever parameters they like. However, it is worthy to note that the looper device in Live is configured so that one button press activates the loop recording, loop completion, then playback. A double press starts and stops play, respectively. The button chosen for this function is nearly at the location of the thumb in normal playing position and makes for a very intuitive interface for this application versus a conventional looping pedal paradigm or external controller (Figure 10).

The 3D tracking allows the player to interface parameters typically reserved for traditional knob turning which forces the player to disengage from instrumental practice in order to manually interface a separate hardware device. Ben Niell shows an example of mounting knobs to a trumpet embedding the knob interface on the instrument itself, making for a more intuitive interface [14]. The Wiikembe goes beyond this by turning the *whole instrument* into several different
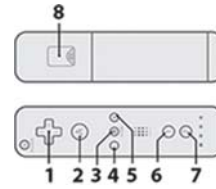
[8]http://www.valhalladsp.com/valhallafreqecho

Figure 10: wiimote switch mappings

Table 3: Wiimote switch mappings

Switch	Key Code/MIDI	Mapping
1- up	key 5	loop double speed
1- down	key 2	loop half speed
1- left	key 3	loop undo
1- right	key 4	clear loop
2- A	keycode 6	view looper device
3- home	MIDI note F2 ch 7	tap tempo
4- minus	key 1	loop reverse
5- plus	MIDI note 5 ch. 12	freq. filter on/off
6- 1	MIDI note 1 ch. 5	Trk. mute
7- 2	MIDI note 5 ch. 5	Trk. arm
8- B	keycode shift	global transport

knobs based on the axis of motion simply by mounting a 3D position tracking sensor to the intrument's body. This isn't meant to present a new instrument, but rather to offer immediate control over parameters that would typically require separate interaction and whose parameters would otherwise simply remain static during performance. The Wiikembe presents the possibility of being able to continually change filter parameters at will while being fully engaged in playing the acoustic aspect of the instrument in a traditional context without interruption. This allows for the possibility of the continual re-contextualization of the relationship of the acoustic signal vs. filter modulation output in real-time. Being able to interface the filters this way greatly diversifies the potential for sonic possibilities, improving the control aspect of interacting with filters in performance. As a result, this also increases the improvisational capacity of digital effects processing, evolving it into a musically dynamic practice, analogous and symbiotic with the traditional techniques of the acoustic instrument.

3.4.1 Ghost Hands

A machine learning tool intended to recognize repetition within the gesture control language and then automate/loop patterns it recognizes as being constant within a detection threshold [20] was developed. This appropriates and abstracts the audio looping paradigm, essentially serving as a *real-time* event parameter automator. While it can be used as an audio looper or event sequencer, it has primarily been explored as an effect's parameter looper. The way an audio engineer/producer might automate effects processing parameters in post-production, Ghost Hands is designed for the stage. When a particular gesture is repeated enough times based on the device threshold settings, the gesture is learned and then repeated. The control data is then mapped to the parameters of choice, in this case the various delay settings on the Valhalla device. When the filter parameter "loop" has been established, the performer can continually re-contextualize how the filter modulates the incoming audio by constantly shifting the relationship between musical phrases and the continually changing filter parameters. In this way, the filters can be explored in a more dynamic capacity rather than being set to sheerly static settings. Be-

413

cause the hands are preoccupied during a lamellophone performance, Ghost Hands, coupled with the gesture tracking, affords the performer freedom of expressivity in an unprecedented, non-invasive, intuitive manner without interrupting the traditional playing techniques of the instrument. Many parameters can be mapped and automated simultaneously. There is no limit to how many parameters are engaged at a given instance. This opens up an entirely new world interaction that would have previously required several other individual's to be at a mixing desk turning knobs during performance in order to approximate the same results.

4. CONCLUSIONS AND FUTURE WORK

This work is meant to establish a rapid prototyping framework for idiomatic, intimate musical-DSP interaction so that artists can design custom instruments and computer music interfaces with minimal engineering overhead. The Wiikembe has been used in concert with Trimpins robotic prepared pianos- (CanonX+4:33=100), at NIME 2012 with the Notomoton[10], and at Sound and Music Computing 2012 with EMMI[9]. In all of these concerts the author used the instrument in it's native capacity, along with the hyperinstrument extensions to control parameters modulating filters used for creative signal processing, as well as control the robotic instruments' parameters: velocity, sequence launching, and signal modulation. The instrument has proved stable, robust and compelling to use in concert: achieving the artist's goals; and easy to reconfigure. The Wiikembe presents new avenues for sound design, sonic interaction, and musical-HCI in an idiomatic context specific to lemellophones, making technology that would have previously required custom engineering available to the conventional percussionist using common, low-cost, easily sourced contemporary components that are simple to work with. Further engineering experiments are intended, including the development of an open source, autonomous, and proprietary framework that eschews the laptop and Wiimote dependencies. This work is in development, results prove promising. Work with MEMS microphones and sensors are being explored to reduce the footprint of the embedded circuitry on the instrument. Non-invasive gesture sensing[15] using novel sensing technologies is also being developed in efforts to achieve position tracking on the tines to use as faders. Lastly, electromagnetic actuation of the tines is underway[1], which produces a sustaining acoustic drone effect. A user study contrasting our idiomatic DSP interface against conventional setups (guitar effects pedals/mixing board) is underway.

5. ACKNOWLEDGMENTS

6. REFERENCES

[1] N. C. Britt and et al. The emvibe: An electromagnetically actuated vibraphone. In *Proc. Int. Conf. New Interfaces for Musical Expression (NIME)*, 2012.

[2] J. Brown. Buzz and rumble: Global pop music and utopian impulse. *Social Text*, 2010.

[3] M. Brynskov, R. Lunding, and L. S. Vestergaard. Dul radio: A light-weight, wireless toolkit for sketching in hardware. In *Tangible and Embedded Interaction Work-in-Progress Workshop Proceedings*, 2011.

[4] D. Font-Navarrete. File under "import": Musical distortion, exoticism, and authenticité in congotronics. *Ethnomusicology Review*, 2011.

[5] A. Freed. Kalimba controller.

[6] A. Freed. Novel and forgotten current-steering techniques for resistive multitouch, duotouch, and polytouch position sensing with pressure. In *Proc. Int. Conf. New Interfaces for Musical Expression (NIME)*, 2009.

[7] S. Gelineck. A quantitative evaluation of the differences between knobs and sliders. In *Proc. Int. Conf. New Interfaces for Musical Expression (NIME)*, 2009.

[8] D. Godlovitch and et al. Physical modeling and hybrid synthesis for the gyil african xylophone. In *Proc. Int. Conf. Sound and Music Computing (SMC)*, 2012.

[9] I. Hattwick. Mbira controller.

[10] A. Kapur. The karmetik notomoton: A new breed of musical robot for teaching and performance. In *Proc. Int. Conf. New Interfaces for Musical Expression (NIME)*, 2011.

[11] G. Kubik. "Lamellophone", in: *The New Grove Dictionary of Music and Musicians*. Macmillan Publishers, 1981.

[12] L. F. Ludwig. Real-time floor controller for control of music signal processing, mixing, video, lighting, and other systems. Patent, 2004.

[13] D. MacConnell and et al. Reconfigurable autonomous novel guitar effects (range). In *Proc. Int. Conf. Sound and Music Computing (SMC)*, 2013.

[14] B. Neill and B. Jones. Posthorn. In *Proceedings of the 28th of the international conference extended abstracts on Human factors in computing systems*, 2010.

[15] G. Odowichuk. Sensor fusion: Towards a fully expressive 3d music control interface. In *IEEE Pacific Rim Conf. on Communications, Computers and Signal Processing (PacRim)*, 2011.

[16] J. A. Olivares. Kalimbatronique.

[17] F. Rocha and J. Malloch. The hyper-kalimba: Developing an augmented instrument from a performer's perspective. In *Proc. Int. Conf. Sound and Music Computing (SMC)*, 2009.

[18] D. Schlessinger and J. O. S. III. The kalichord: A physically modeled electro-acoustic plucked string instrument. In *Proc. Int. Conf. New Interfaces for Musical Expression (NIME)*, 2009.

[19] H.-C. Steiner. Pduino.

[20] S. Trail and et al. Non-invasive sensing and gesture control for pitched percussion hyper-instruments using the kinect. In *Proc. Int. Conf. New Interfaces for Musical Expression (NIME)*, 2012.

[21] Wikipedia. Electric lemellophone.

[22] E. L. Wong and et al. Designing wii controller: a powerful musical instrument in an interactive music performance system. In *Proc. of the 6th Int. Conf. on Advances in Mobile Computing and Multimedia*, 2008.

---

[9]`http://www.expressivemachines.com/`