Tingle: A Digital Music Controller Re-Capturing the Acoustic Instrument Experience

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ABSTRACT
Tingle is a new digital music controller that attempts to recapture the acoustic touch and feel, and also gives new opportunities for expressive play. Tingle resembles a pin-art toy which has been made interactive through a new sensing technology, with added haptic feedback and motion control. It pushes back, vibrates, and warps the sound through the musicians nuanced input. In this article Tingle will be discussed in combination with CataRT.

Author Keywords
Tingle, CataRT, tactile shape control, expression, gesture, haptic feedback, motion control

ACM Classification
H.5.2 [Information Systems] INFORMATION INTERFACES AND PRESENTATION (e.g., HCI) User Interfaces
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1. INTRODUCTION
Tingle resembles a pin-art toy which has been made interactive through a new sensing technology. Tingle essentially combines four different types of interactions which have been discussed within NIME in an attempt to make a commercially viable digital controller that bridges the acoustic and digital worlds. The four interactions are; commercially viable digital music controllers (monome[1], fader boxes), '3D' game controllers which are adapted for use as musical controllers (Wii[2], Kinect[3], Leap Motion[4]), tilt based musical controllers, and haptic feedback.

Tingle was coupled with the CataRT[5] sound-synthesis program because its software interface seamlessly matched with Tingle's physical interface. Tingle has an array of pressable pins which are spread over a 2D space. CataRT can break a sound-file into sound-grains and spread them in a 2D space so that similar grains are placed next to each other. CataRT allows the user to explore a body of sound-grains interactively, triggering and transforming many grains in parallel, thus matching the inherent multi-dimensionality of Tingle's input (see video[6]).

[1] http://monome.org
[2] http://wii.com
[3] https://www.microsoft.com/en-us/kinectforwindows/
[4] http://leapmotion.com
[5] http://ismm.ircam.fr/catart
[6] https://vimeo.com/119138523

The goal of this article is to discuss methods with which a digital music controller can recapture the acoustic touch & feel, by stepping away from available technologies to ones designed to mimic an acoustic experience.

Figure 1: The Tingle digital music controller being played.

2. METHOD
All the insights shared in part 3 of this article have been found through regular demonstrations of Tingle and CataRT in experience events open to the public. Further insights came from the inventors' experience in building these two systems and their experience guiding students in the process of making their own music instrument / technology. This experience spanned a minimum of 2 years and has resulted in a wealth of generated knowledge.

During all of these events, Tingle was treated as a 'Design & Technology Probe', which is used to challenge the values of a design towards creating its envisioned future. This was done by using functioning technological prototypes to generate knowledge of the use and users of the technology in a real-world setting [6]. These technological prototypes often go under the name 'provotyping', being a combination of a provoking and a prototyping component to test the underlying values of new systems, and ensure their usability in a given practice [10]. The results of qualitative research, or "probes", are called "returns" [7] and are often generated through "Reflection-in-action", wherein the practitioner allows himself to experience surprise, puzzlement, or confusion in a situation he finds uncertain or unique [1, 2]."

A lot of knowledge was also generated by reflecting on the successful integration of acoustic values in some recently developed musical instruments. These include the *Roli Seaboard*[7], *Ableton Push*[8], *Morff* by Jasper de Kruiff[9], *Kasmin* by Thomas van Lankveld[10], *GePS*[11], *Sculpton* by Albert

[7] https://www.roli.com/seaboard/
[8] https://www.ableton.com/en/push/
[9] http://jasperdekruiff.com/project3.html
[10] https://www.youtube.com/watch?v=tUPNR4Gy4EY
[11] http://geps.synack.ch

Boem[12], *Dirty Tangible Interfaces (DIRTI)* by UserStudio[13] and *MATRIX* by the MIT Media Lab[14] [8, 12].

The most valuable lessons learned from these instruments was the importance of feedback/feedforward in creating a dialogue between the user and the instrument, and the range of motion attached to the building of sound for 'performability'. See also section 3.

One instrument shows particular similarities with regards to Tingle, being MATRIX (Multipurpose Array of Tactile Rods for Interactive eXpression) by the MIT Media Lab, as shown at NIME 2001. It consists of an array of square plastic rods, where each rod presses down onto spring-assisted sensors, to 'give users a 3-dimensional tactile interface to control sound with their hand(s)'[14]. Tingle works in a very similar way, but has managed to compact the sensor down from a large table mounted instrument to something more compact and handheld. Furthermore, the resolution is increased, (4 vs 20 rods / inch^2) as well as the total number of pins (144 vs. 512), and the springs used in Tingle are much softer. Next to this, Tingle adds motion sensing and can be played both downwards and upwards. Playing upwards gives a different experience as the player is now looking at the results of their actions, and not at the actions themselves. It also adds vibro-tactile feedback to enhance the acoustic feel. Lastly, when coupled with CataRT, Tingle delivers a more expressive and full sound design for a richer experience. All of these differences are important in making Tingle market viable.

The first proof of concept for Tingle was controlled via a webcam that viewed Tingle from above. The webcam was able to discern where people pressed pins through the use of image differencing[15]. However, issues with latency, noise, no vertical resolution, and lack of portability all meant that this version of Tingle was not market viable.

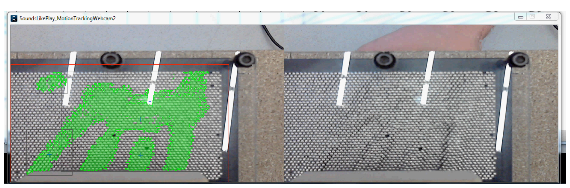

Figure 2: Early tests of Tingle's webcam measurement program (programmed in Processing)

3. REQUIREMENTS & REALISATION

3.1 Technical Setup of Tingle

Tingle has a custom built sensor that was adapted from an article published during NIME 2011 about a 'Robust and Reliable Fabric, Piezoresistive Multitouch Sensing Surfaces for Musical Control–lers' [11]. The sensor in that article was recreated for early testing, and once it proved to work for Tingle, it was adapted to a PCB format. Tingle's technical buildup consists of five parts:

1. A PCB with a grid of sensing points. Each point resembles two semicircles separated by a small gap which is an adaptation of the original design, which had three layers. The semicircles surround a hole in the PCB through which a pin slides. One semicircle supplies a voltage and the other measures the analog voltage (Figure 3 SEQleft).
2. A sheet of piezo-resistive material (such as Eeontex[16]) which is placed on top of the PCB. This creates a circuit between the two semi circles. By applying pressure, the resistance of the piezo-resistive material decreases, allowing more electricity to pass from one side to the other. The receiving semi-circle measures this resistance change and communicates this to a computer via USB (Figure 3 SEQ right)
3. 512 pins with a thickened element halfway down their body, which is used to push a spring against the piezo-resistive material (SEQFigure 3 right).
4. An enclosing body which holds and aligns the pins.
5. Teensy 3.1[17] integrated onto the PCB with extra EM shielding components and a stripped firmware for lower latency. The latency of the current setup is 55ms, and for the demo model at NIME we expect a latency of 5ms.

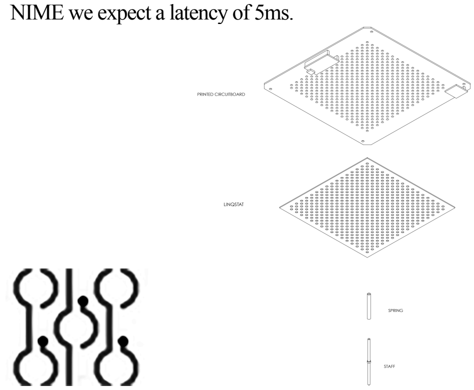

Figure 3 Left: Sample of the PCB grid showing the two semi-circles. Left supplies and right measures voltage. Right: Technical setup for Tingle

3.2 Tactile Feedback and Feedforward

Making sound with an acoustic instrument requires a user to apply a force to a part of the instrument or the air surrounding it to create a vibration. This application of force causes the player to feel a multi-sensory reaction (feedback) from the body of the instrument and the air around it. The way a player applies the force, and the multi-sensory reaction felt, defines the way in which the user experiences the instrument; thus the sensational signature.

The pins in Tingle can be moved (deformed) up and down along the z-axis of the instrument. Because each pin is spring loaded, an applied pressure by the musician will cause the pin to 'push' back on the player's hand in exponential strength related to the pressure applied (force feedback). Next to this it will trigger haptic feedback as part of the multi-sensory reaction (see section 3.3). Also, a player can reproduce a sound sensation if the same pins are pressed in the same way. This is important when mimicking acoustic instruments as the fixed physical form of an acoustic instrument results in a fixed sound experience. We have chosen to develop Tingle towards a standardized platform which will likely be developed as a consensus between players and programmers. This way, Tingle users do not need to completely relearn the instrument between different sound designs.

3.3 Haptic Feedback

Haptic feedback is used to imitate the experience of vibrations felt by a player's body on the surface material of an acoustic instrument when it is being played. For Tingle, it does not matter whether or not the perceived source of the haptic feedback is the actual source, as long as the perceived source is consistent with the expectations of an acoustic instruments. Moreover, the perceived source of the vibrations are the pins that are pressed in, but the actual source is from two vibration motors directly below the hands of the player. Lastly, the vibration motors are strategically attached to the printed

[12] http://www.albertoboem.com/index.php/project/sculpton/
[13] http://www.smallab.org/dirti/
[14] http://alumni.media.mit.edu/~dano/matrix/
[15] Image differencing is comparing a photo from a moment in time earlier with the current video feed to spot differences.
[16] http://www.eeonyx.com/eeontex.php
[17] https://www.pjrc.com/store/ic_mini54_tqfp.html

circuit board, through which the pins slide. In this way, the body of Tingle vibrates (secondary) as well as all of the pins (direct). The sensation therefore is similar to feeling the vibrations in the body of a guitar (secondary) and through the strings (direct).

3.4 Feedforward: Visual-Tactility

With a new instrument, there is no history or examples of ways to play the it. This makes the threshold for starting to play the instrument very high. 'Visual-tactility', in the scope of this article, refers to interfaces that 'beg to be touched'. We deem this important when making a market viable musical controller, as it makes it easier to accept for a potential musician. Seen from a business perspective, this effect can cause people to buy a controller simply because of it's expected playfulness and intriguing interaction.

'Feedback is the information that occurs during or after the user's action. But before the user's action takes place the product already offers information, which is called feedforward' [17]. The handle design, positioning of the cable, height extension of pins, and slight looseness of pins in Tingle all communicate how the instrument is to be used. We believe that this inherent feedforward is what gives Tingle it's visual-tactility.

An instrument can achieve visual-tactility by making use of patterns, materials, or physical shapes that seem to be pleasant to touch. To discern which forms have the most pleasant visual-tactility, we co-reflected [16] with physical prototypes. The exploration models we used did not resemble existing musical instruments, as we were looking for a novel interface. For Tingle, this visual-tactility was first spotted in user tests performed in a classroom in Amsterdam. Three objects were placed there for discussion, but only one got attention from the kids; namely the pin-art toy.

3.5 Motion & Gestures in Play

This section concerns the modification of sound by moving the entire instrument. Tingle is a handheld instrument and therefore affords for this form of interaction. This is a common interaction element in many new musical controllers, and it is usually achieved through accelerometers. At this moment, effects applied to sounds created with Tingle are directly mapped to the tilt values. However, the aim of Tingle's tilt function is to recreate the slight modifications to sound that would happen with physical elements included as in acoustic instruments (see Future Work). A good example of this design strategy can be found in the way mapping is done in the Sponge [9].

As stated in section 3.2, the way a player applies the force, and the multi-sensory reaction felt, defines the way in which the sensational signature of an instrument. This sensational signature is nuanced, and has to do with the expected *gestures* a player can use to create a sound. For example: When your hand is pressed into Tingle and you pull your hand outwards, pins will drop, which removes grains of the full sound, until the whole hand is removed and the sounds disappear entirely.

3.6 Complexity

Tingle has many degrees of freedom. It has 512 pins, each with an effective range of 0-100 (integer) over the range of that pins pressable depth, as well as 3 (*XYZ*) tilt values for the entire instrument. To control each pin separately and consciously would be an impossible endeavor. Yet this impossibility is a defining characteristic of the instrument, and could be called the acoustic feature. Tingle seems to be a complex instrument to play but is in fact quite intuitive.[18][19]

[18] Bushnells Theorem [17], or more commonly known as 'Easy-to-learn, hard-to-master', is important when engaging a starting player, and also to keep an existing player interested. It is rather self-explanatory; the instrument should look like it is easy to start using, and through play you learn that there are more detailed nuances that allow for more depth through skill and practice.

[19] http://www.wolfsheadonline.com/bushnells-theorem-easy-to-learn-difficult-to-master/ - d2cb5

A djembe player does a very comparable action to what happens with Tingle. The player will shape his hand and choose the place to hit according to his expectation of the sound he wants to hear. Tingle affords us the same opportunity in both slow/fast motion and continuously. The chosen mappings are according to this reduced mental schemata (we follow hand shapes rather than individual pins pressed) and is one of the reasons why Tingle and CataRT form such a great combination. Both are concerned with sounds connected to physical space, rather than individual notes.

3.7 Association (Skeumorphism)

Skeumorphism is a design principle in which a designer will take inspiration from the existing physical world. This is a necessary design ethos in fields where the digital alternatives are less universally accepted, as it acts as a 'softer' bridge between the current and the newly introduced reality. The change over to digital music controllers is underway but still moving rather slow, making skeumorphism useful for helping people to cross that threshold.
However, skeumorphism can also lead to less-creative design decisions because the existing examples are not used as inspiration, but rather as the grounding design.

In the case of Tingle, this inspiration came from the pin-art toy. It was not only fun to play with, and completely different from all other existing instruments, but it could be deformed in a way that afforded for musical play.

3.8 Sound Mapping through CataRT

For an immediate and expressive access to the rich sound world offered by concatenative or granular synthesis, the 512 playable grains need to be laid out logically and consistently on the playing surface of Tingle. This is achieved by using the descriptor analysis of corpus-based concatenative synthesis (CBCS), as realised in the CataRT system for Max/MSP. CBCS is also a good match for the high dimensionality of control information from the interface. Typical corpora contain hundreds of grains of sound (small segments out of several larger sound files), that can be played simultaneously by the pins of Tingle.

We can leverage the spatial layout of the interface by mapping it to a space of musically and perceptually meaningful sound characteristics, expressed by automatically extracted audio descriptors. For instance, the brilliance of the sounds, expressed by the mean spectral centroid, would rise from left to right, and their noisiness, expressed by their periodicity index, would decrease from bottom to top.

This way, a large number of grains from different recordings will be spread over the interaction surface enabling expressive and controllable sonic evolutions while retaining the richness and nuances of recorded sound.

The mapping itself is not trivial as the density of the grains in the descriptor space is highly irregular, with dense clusters of grains within large empty regions (see Figure 4 left) Therefore, we apply a first step of uniformisation of the grain density in a chosen 2D projection of the descriptor space via the *Unispring* algorithm [8], the result of which can be seen in Figure 4SEQ right.

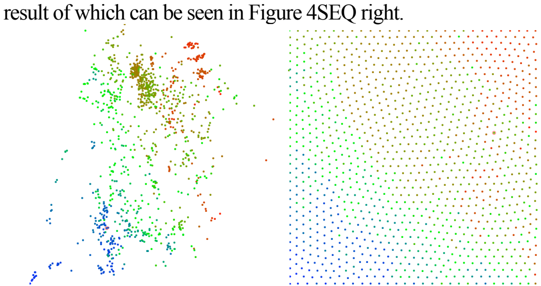

Figure 4 Left: Example of the 2D visualisation of a corpus, plotted by Spectral Centroid (x), Periodicity (y), NoteNumber (colour). Right: Distribution of this corpus.

The *Unispring* algorithm produces an irregular, not quite gridded layout with uniform density that has then to be mapped to the regular grid of pins of Tingle. We proceed by going through all pins, and finding the closest grain for each in a Euclidean geometric sense. This procedure has the advantage of avoiding dead pins, although double assignments can be possible. In the example mapping in Figure 5 we see that the spatial distortion is minimal.

The activation of a pin will then play its assigned grain in a loop given by its length or by a global loop time. The displacement of the pin influences the playback volume within a range of 18 dB. Finally, the tilt angles of Tingle can be mapped to one of the granular playback parameters like transposition, its random variation, envelope, filters, and so on.

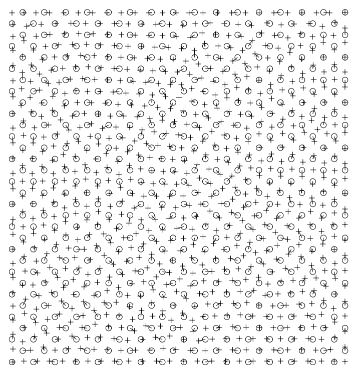

Figure 5: Example mapping from a corpus of fire sounds (crosses) to pin positions (circles).

4. Future Work & Discussions

One significant topic for future work will be the difference of landscape play vs. note play. The physical design of Tingle affords for both, which means a player can both play with their fingertips (notes) or play with their whole hand (landscape). Landscape play could influence the spectrum and timbre more of a soundscape, reverb could be linked to this so that a distinction is made between local and field sounds (note play = low reverb, landscape play = high reverb) [4].

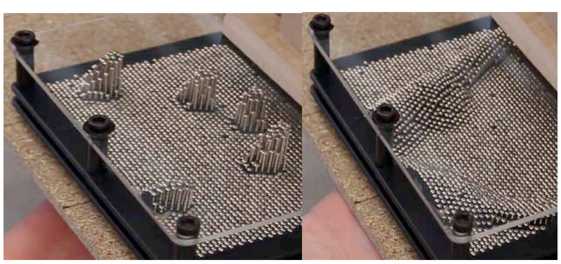

Figure 6 Left: Early explorations in noteplay (in a chord) Right: Early explorations in landscape play.

Next to this, the haptic feedback of Tingle will be improved (see section 3.3). This would be done by using surface inducers instead of vibration motors. In this way Tingle's body will become a soft speaker for the actual sounds being generated. This not only makes the created sound resonate from within the object, but it also benefits from the sinusoidal-vibrations that are directly linked to the generated sound. Both of these are consistent with acoustic instruments. What you hear is what you feel.

The last piece of future work has to do with how Tingle's tilt sensor will recreate the slight modifications to sound that would happen with physical elements included, as you would experience in acoustic instruments. An example of a future version could be that shaking Tingle results in a varying sound envelope and audio effects, that react like a macaracha would. Or because CataRT makes uses of grains of sound, which can often sound windy or sandy, it would be interesting to imitate the effect of tilt on these more natural elements by, for example, adding extra 'wind gusts' in the direction of tilt. The key to this effect would be to make the sound modification appear to follow the logic of physical entities.

Lastly, we are currently debating the musical direction of Tingle. Originally it was intended as an instrument for educational use, but we see more opportunities for use in both experimental and mainstream music contexts. To explore this we have built five high quality, fully functioning prototypes that will be given to 5 users of varying backgrounds. This gives us valuable input from users which we will use to fine-tune Tingle's playing experience before releasing it commercially. This is also valuable for the commercial viability of Tingle as we believe that the adoption of Tingle by a renowned (or soon to be renowned) artist will act as a role model for future Tingle users, thereby lowering the threshold to give it a try.

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