Orphion: A Gestural Multi-Touch Instrument for the iPad

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ABSTRACT
This paper describes the concept and design of Orphion, a new digital musical instrument based on the Apple iPad. We begin by outlining primary challenges associated with DMI design, focussing on the specific problems Orphion seeks to address such as requirements for haptic feedback from the device. Orphion achieves this by incorporating an interaction model based on tonally tuned virtual "pads" in user-configurable layouts, where the pitch and timbre associated with each pad depends on the initial point of touch, touch point size and size variation, and position after the initial touch. These parameters control a physical model for sound generation with visual feedback provided via the iPad display. We present findings from the research and development process including design revisions made in response to user testing. Finally, conclusions are made about the effectiveness of the instrument based on large-scale user feedback.

KEYWORDS
multi-touch instrument, gesture, Orphion, iPad, physical modelling

1. INTRODUCTION
Malloch et al define a musical instrument as "a sound-producing device that can be controlled by a variety of physical gestures and is reactive to user actions" [8]. It could therefore be extrapolated that a digital musical instrument (DMI) falls into the subset of musical instruments that make use of digital technology. However, to understand and design new DMIs, an more nuanced view is required. Miranda and Wanderley propose a model for DMIs whereby the instrument contains a "control surface" and a "sound generation unit" conceived as independent modules related to each other by mapping strategies [11]. This model is shown in figure 1.

Drummond adds qualifiers to this model, proposing that the primary challenge facing the designers of interactive (digital) instruments is to create "convincing mapping metaphors, balancing responsiveness, control and repeatability with variability, complexity and the serendipitous" [5]. We note at this point that whilst there is an axiomatic understanding (at least in Western culture) of what "convincing" and "serendipitous" mean in this context, definitions are by no means clear cut or easily measurable.

Additionally, Blaine and Fels propose that "over time and with practice, a player can continue to refine their range of musical expression and become an expert." [2]. This implies the notion that (digital) instruments can offer the capacity for progression in discovery and mastery of playing techniques over an extended period.
A number of sophisticated commercially-available DMIs exist that have addressed some or all of the criteria described above. Examples include Eigenharp[1], Seaboard[2] and Reactable[3], and Kaossilator[4]. All of these exploit the decoupling possible in DMI design, allowing for multiple timbral identities, or in some cases radically different sound production techniques within a single instrument. Some existing DMIs, for example Reactable also allow for flexible mapping of input gesture to sound production parameters.

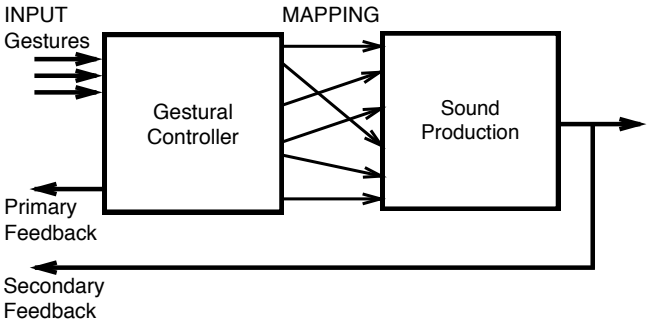

Figure 1: A possible approach to DMI representation [11]

2. DESIGN PRINCIPLES

2.1.Requirements for practical interfaces

The aim of Orphion was to research and develop a self-contained, affordable and widely-available DMI with "long-term" potential for virtuosity as described by Wessel and Wright [14]. and virtu. Additionally, a primary goal was to develop a DMI that had a distinctive, coherent and readily identifiable set of timbral qualities and a fixed mapping between input gestures and sound production. The aim was also to embrace a natural user interface (NUI) paradigm in creating an instrument that feels "natural" to someone familiar with the behaviour of existing acoustic instruments like drums and string instruments [15][9].

The history of instrument making shows that the development of musical instruments had two major objectives: first, the expansion of the tonal possibilities (dynamics, timbre) and secondly to improve the playability of an instrument [4]. Unlike acoustic instruments, where these two factors are inherently coupled, electronic instruments have independent sound generation and control that can interact in a variety of ways depending on the design of the instrument. We define the requirements for musical instrument design *in general* as follows:

- Allow virtuosity and expression
- Ergonomic design
- Traceability (to the public)
- Predictability (for the player)
- Visual (primary) and audible (secondary) feedback

These factors are inherent in the design of acoustic instruments. With a 'cello, for example, the movements of the bow give traceability for the listener. Also, feedback for the player is created by the sounding body the of instrument itself as well as by the position of the bow on the string and the hand on the fingerboard. In contrast, due to the

[1] http://www.eigenlabs.com

[2] https://www.roli.com/seaboard/

[3] http://www.reactable.com

[4] http://www.korg.com/uk/products/dj/kaossilator_pro_plus

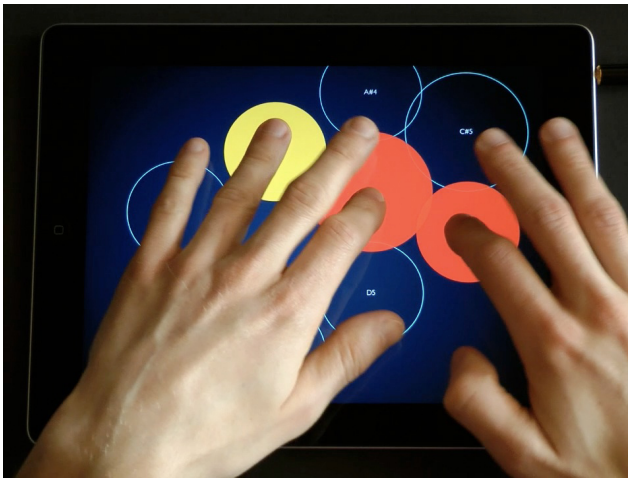

Figure 2: Orphion interface with virtual pads indicating touch point size by colour

decoupled nature of controller and sound generator in the DMI model, a standard MIDI keyboard used as an interface for an electronic instrument that runs as software on a laptop provides no perceptual cues about the sounds the visitor of a concert can expect to hear. It is equally difficult to provide feedback to the player who, for example, wants to play a long-lasting crescendo, but receives no feedback, whether the sound has already started or not. In this case the concrete task determines decisively the requirements of the interface.

2.2. Musical instrument or controller

Since its mechanical structure and the materials used for building the enclosure of electronic instruments normally do not contribute to their sound, which is especially true for software based instruments, these instruments need a strong logical link between the action of the player and the generated audio. This strong link between a very specific interface and the sound generation is what defines that structure as an instrument [7].

Conversely, a hardware or software *interface* in isolation is an open structure whereby arbitrary mappings can be made between human input and resultant sound, and as such can be considered as a *controller* rather than as an instrument [6]. Such an interface can work very well for a variety of situations, however the properties of an instrument we define above are hard or impossible to achieve with this setup. Additional layers of complexity arise if the interface does not control the sound generation directly but drives a time-varying process such as starting a sequencer. Such a "sequencing instrument" points in a new direction but also marks the strongest possible departure from a traditional musical instrument design. For our purposes Orphion therefore focusses on the idea of a strong coupling between interface and sound generation.

3. ORPHION

In order to address our primary goal of creating an "affordable and widely-available DMI", it was decided that the design scope would be limited to existing consumer devices that could be "transformed" into a musical instrument through the addition of custom software. The aim of Orphion has therefore been to find a way to achieve virtuosity and expressiveness within the constraints of a standard multi-touch input device. Most commercial applications involving touch-based interaction use the finger or stylus as a replacement for the mouse to control knobs and buttons. Since multi-touch has been established, new gestures were created, for example pinching two fingers to resize objects. In order to express musical ideas however, more specific gestures and input models have to be developed [6].

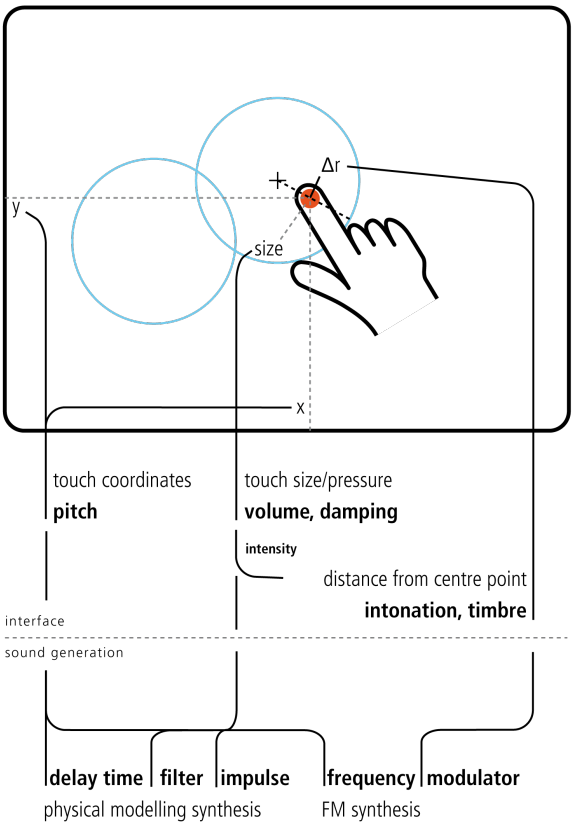

Figure 3: Simplified diagram of interface and sound generation

3.1. Concept and design

Finding a logical interaction model and thus a suggested way of playing is a key component in the development of a new instrument. One of the design goals for Orphion was to allow polyphonic playing of defined pitches with different articulations (staccato, legato) and timbres for each individual voice. The following factors were therefore taken into account:

- *haptic properties* of touchscreens (size and tactile or kinaesthetic ways of interaction)
- *musical playability* (recognition of initial touch point and matching of pitches), musical expression (dynamics, intonation, vibrato, timbre)
- *intuitive and natural feel*
- *technical possibilities* (precision of control data, processing power)

As guiding models for the behaviour and gestures of Orphion these two types of instruments seemed to be most suitable: drums and string instruments.

- *drums*: round playing area with different timbres, release time and damping depend on the velocity and duration of touch.
- *string instruments*: multiple individually tuned strings plus ability to play the tuning via tapping the strings, control of tone and articulation during sustain-phase (intonation/vibrato, damping)

3.2. User interaction

The interface of Orphion therefore consists of virtual pads which are capable of sounding either plucked like a guitar string or produce timbres closer to a slap on a conga drum depending on the size of the touch point. The timbre changes when hit closer to the "rim" like on a real drum, and the sounding pitch is a function of distance from the centre hit point, in order to model something that comes close to "bending" a string (the range varies by the size of the touch point).

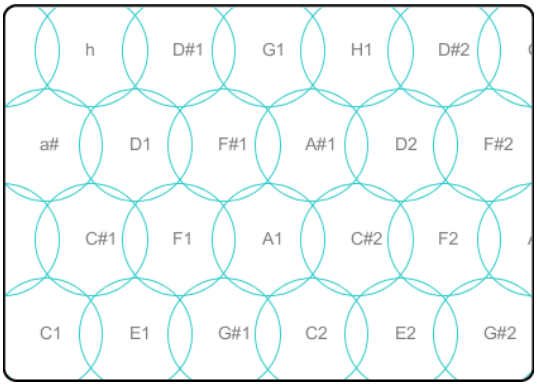

Figure 4: Symmetrical major 3rds horizontally, minor 3rds and semitones vertically, 4ths and 5ths diagonally

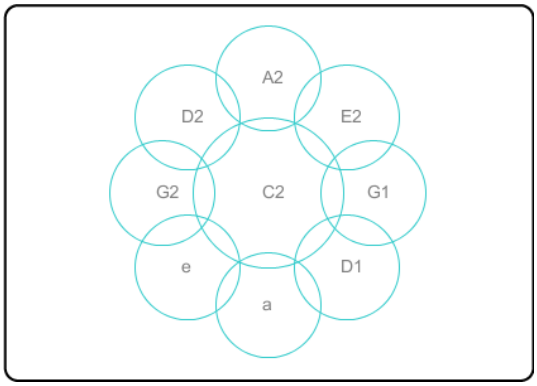

Figure 5: Circle arrangement of a pentatonic scale in layered 4ths

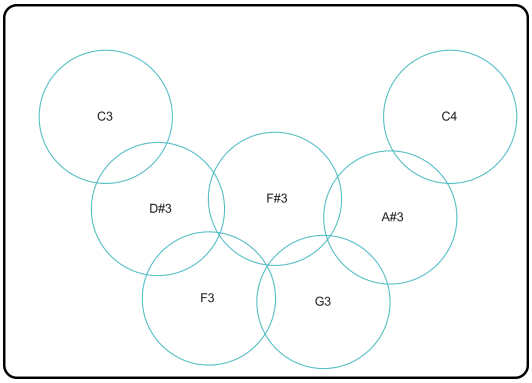

Figure 6: Blues-scale layout

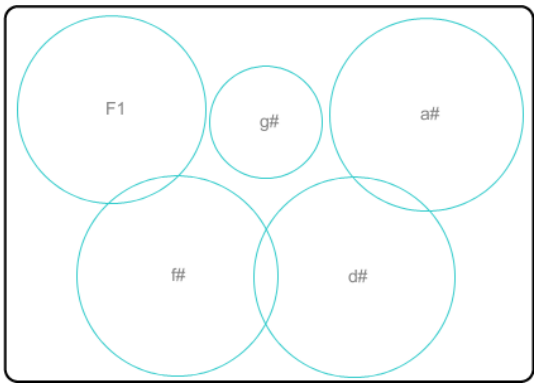

Figure 7: Five-finger layout, e.g. as tuned bass drums

[1] http://www.anyma.ch/2009/research/multitouch-external-for-maxmsp/

[2] https://github.com/jusu/Fantastick

Each parameter-per-voice is controlled by an individual finger. The iPad currently supports up to eleven touch points, but polyphony is currently limited to 8 voices by the processing power of the device (Cf. figure 3 for the connection between the interface and the sound generation by different parameters).

The visual representation is straightforward and functional: a pad is defined as an outlined blue circle with its note name written in the centre. When touching a circle, it is filled with colour, ranging from red to yellow depending on touch size, thus indicating the amount of damping (cf. fig. 2). A pad layout is defined as a set of pads with variable size and position.

The different sets of pads allow the instrument to be adapted to multiple musical situations and genres, and to provide possibilities for virtuosity by the player. The arrangement structure with symmetrical intervals (e.g. fig. 4) in each axis can be used to find new harmonic structures by advanced musicians. Pad layouts with only pentatonic tone material (e.g. fig. 5) or other simplified musical concepts (e.g. fig. 6) make it potentially interesting for musical beginners. Layouts with fewer pads can give the feel of a percussion instrument played with a fixed assignment between finger and pad (e.g. fig. 7).

3.3. Research method

A practice-based research methodology was adopted where the author's own artistic practice was used as a means for continuous evaluation of a working prototype. The first concept study for Orphion used a trackpad interface to control physical modeling synthesis. It was realised as a Max/MSP patch using the *fingerpinger* external[1] to gain raw trackpad data. In order to evaluate the prototype, six test players were asked to experiment with the system and provide free-form feedback on its operation and potential for improvement.

One of the main shortcomings identified during testing was the absence of direct visual feedback relating the haptic stimulus to the resulting sound [1]. Various options were considered in order to address this including the use of stickers or laser engraving on the trackpad. Eventually it was decided that basing the instrument on a tablet device would provide the most appropriate form factor for the instrument, allowing for the sound to be generated by the same physical device receiving haptic input, and for the same device to provide visual feedback in response to input.

Therefore a new prototype was developed, using the iPad as a controller and visual display. Touch data from the iPad as well as Open GL drawing commands were obtained / set on the iPad via a modified version of the *Fantastick* application by Juha Vehviläinen[2]. The device communicated with the sound generating computer via wireless network. At this stage, the predefined layouts of pads (fig. 4-7) were refined to achieve best ergonomic and expressive possibilities, taking the size of the iPad display into account. For a concert performance with this working working prototype a specific layout was designed to exactly meet the composer's needs. The capabilities of the instrument were also extended by adding a new gesture for playing with very soft attack and allow ing continuous glissando between the pads.

Furthermore, constructing the instrument using a tablet, plus an "app" makes instrument production highly scalable—moving away from bespoke and ad-hoc device concepts, and providing the possibility of ensemble performance using multiple instruments. Thus the final implementation of Orphion is a standalone application on Apple iPad. The device was chosen for its multi-touch capabilities, availability and integrated audio. Its sound generation is realized using *libpd* [3], which provides a Pd audio graph controlled via messages from iOS functions.

The sound synthesis is based on a physical model that simulates an oscillating string (*Karplus-Strong*-like algorithm, [13]). It uses a combination of a pulse of filtered noise and a sustained excitation

sound created by a two-operator FM synthesis structure. The low-pass filtering of the feedback path is controlled in real-time for lively articulation of the sound after the initial touch. The complex excitation model allows a variety of different sounds from gently plucked strings to xylophone-like hits or damped attack of muted drums. As long as a finger is touching the surface of a pad the distance from the pad's centre controls slight detuning (intonation) and variation of timbre towards the "rim". Synthesis parameters were determined and refined empirically through process of iterative development and testing.

3.4. Evaluation

The distribution of a musical instrument through an app store offers the opportunity to easily reach a large number of potential users and collect feedback through the integrated review mechanism. Thus a "deploy-use-refine" model as described by Miluzzo et al [10] was applied in order to iteratively improve the instrument's capabilities. Furthermore this data can serve as a source for evaluation the overall user experience. Our data shows that this was perceived to be overwhelmingly positive with an average of star rating of 4.5 from 822 reviews. Figure 8 shows the 30 most frequently used words in review texts following lemmatisation and removal of stop words. Whilst we cannot make precise conclusions about the quality of Orphion from this data, the prominence of semantically positive words such as "fun", "love", "great", "cool" and "good" and the absence of negative ones, correlates with the high average star rating suggesting that overall reviewers wished to express a positive user experience. The prominence of "sound", "play", "music" and "instrument" also correlate with the design goal of creating a "musical instrument".

Figure 8: word cloud of app store reviews

3.5. Further development

After the first release of Orphion, many users provided very positive feedback about its performance capabilities and asked for a new feature to internally record and export audio files, which became possible in the first update. To accommodate the constant question for using its versatile interface as a controller for other synthesizers, a MIDI implementation was added after a few months, although this stands against the initial goal of a strong connection between gestural interface and sound generation To allow customization for any musical context, an editor for individual pad layouts with microtonal adjustment capabilities was also integrated. These custom layouts can also be shared through the internet.

Meanwhile Orphion's interaction model has also been ported to the iPhone as a new instrument called Orphinio. To ensure playability with less screen space, adequate pad layouts had to be developed. Furthermore a "shaker mode" was integrated to make use of the smaller form-factor and allow new playing techniques. Its timbral quality has been slightly modified to accommodate the smaller device yet still keeping the relation to Orphion recognizable. In future it would be interesting to explore the possibility of vibro-tactile feedback for haptically sensing pad edges as a way of enhancing playability without constant visual feedback.

4. CONCLUSION

Orphion accomplishes its goal to create an expressive multi-touch musical instrument by providing a direct link between its interface and the sound synthesis with an easily understandable interface. It is now used by thousands of players around the world. By the availability of custom pad layouts this instrument is suitable for many different styles of music and musicians. Sufficient practice can allow musicians to become virtuosic and expressive, although it is a big challenge to play existing written music on it [12].

As with every instrument it is more interesting to compose or improvise music, which makes full use of the unique possibilities in terms of expression, harmonics and voice leading. App store feedback shows that many musicians and composers already find the sound and interface of Orphion interesting and will hopefully progress in including it into their repertoire.

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