AlphaSphere - from Prototype to Product

Adam Place
nu desine limited, United Kingdom
PMStudio, Watershed,
1 Canon's Road, Harbourside
Bristol, BS1 5TX,
adam@nu-desine.com

Liam Lacey
nu desine limited, United Kingdom
PMStudio, Watershed,
1 Canon's Road, Harbourside
Bristol, BS1 5TX, UK
liam@nu-desine.com

Tom Mitchell
University of the West of England
Dept. of Computer Science &
Creative Technology
Bristol, BS16 1QY, UK
tom.mitchell@uwe.ac.uk

ABSTRACT

This paper explores the design process of the AlphaSphere, an experimental new musical instrument that has transitioned into scale production and international distribution. Initially, the design intentions and engineering processes are covered.

The paper continues by briefly evaluating the user testing process and outlining the ergonomics, communication prototcol and software of the device. The paper closes by questioning what it takes to evaluate success as a musical instrument.

Keywords

AlphaSphere, OSC, MIDI, HCI, open source, C++, JUCE, GUI

1. EXECUTIVE SUMMARY

The AlphaSphere is beginning to be adopted as a musical instrument, but how can its success as an instrument be evaluated? The advent of computer music has seen a democratisation of the music making process, however music software itself is increasingly moving away from the mouse and keyboard, towards new and original modes of interaction. In this paper we will chart the process that led to this concept becoming a commercially available musical instrument.

2. DESIGN PROCESS

The design and development of the AlphaSphere was a collaborative process which was led by the principal developer. The design was refined through input from multiple collaborators which included instrumentalists, composers, electronic musicians, record producers, audio engineers, music therapists and academics of both music and design disciplines.

2.1 Conception

The AlphaSphere was originally conceived as an interface to explore and catalogue electronic sound. It was designed as a tactile tool, which offered an alternative to writing sonic ideas down and therefore prioritised the exploration of the sounds themselves rather than the symbols or written notation which represents them[1]. The intention was that by creating an object with flexible programmable elements, musical/sonic syntax i.e. notes, could be explored, arranged and quickly discarded if necessary. As the concept was refined it became apparent the AlphaSphere had potential beyond a research tool for ideas on sonic and musical structure, and had potential as an expressive musical instrument.

Figure 1. Early AlphaSphere prototype showcased at NUA.

2.1.1 Shape

The original idea for the shape of the device was a dome, however a spherical shape was eventually determined as it was surmised that the form would lend itself to pitch exploration, with lower tones mapped to the underside of the sphere, middle tones to the middle and higher tones to the top of the sphere. Initial ideas for the shape drew on inspirations from acoustic instruments such as the PANart Hang and the tuning system which it uses[3], and also that the tuning system for an instrument such as the Steel Pan[4] could be represented in a convex form.

2.1.2 Pad interaction design

Initially the pads were intended to act as standard event triggers, however as the concept evolved it was decided that these should have a tactile malleable feel. The first prototypes of the pads were produced by layering up putty stretched over espresso cups until a durable tactile surface was created.

2.2 Concept prototype

The first prototype was built using the main PCB of a MIDI keyboard and an array of paper espresso cups glued together to create a modular sphere (see Figure 1). Each of the espresso cups had latex stretched over them, with a magnet and a reed switch on the underside that allowed the user to trigger single notes. There were a number of problems with this prototype, namely the spherical form contained gaps that prevented seamless play around the sphere. The spherical design itself was inspired by a design found on the website - Instructables[2].

NIME'14, June 30-July 03, 2014, Goldsmiths, London, UK.

2.3 Engineering

Moving to an engineered prototype saw the design of a CAD model (see Figure 2), the initial intention was to close the gaps that existed in the original form. By giving the pads alternate sized shapes the gaps could be reduced and also provide tactile feedback to help users navigate around the sphere. Eight pads per row would allow for an entire octave and therefore allow a circle of fifths to be mapped around each row[5].

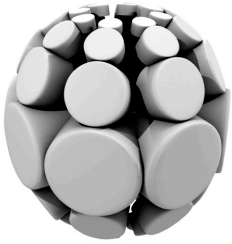

Figure 2. Early AlphaSphere CAD render.

As this CAD model was adapted for production a number of design iterations were produced, and it became apparent that if the pads were arranged diagonally this would ensure that the form was distributed evenly, this also had the result that the spherical form comprised a hexagonal lattice (see Figure 3), which would allow the mapping of notational arrangements such as the harmonic table or the Wicki-Hayden arrangement[6].

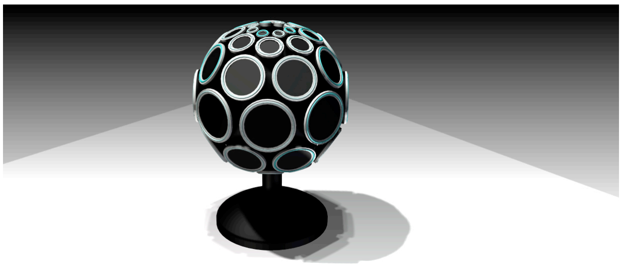

Figure 3. AlphaSphere CAD render exhibiting diagonal columns which form a hexagonal lattice.

2.3.1 AlphaSphere 0.1

In this prototype the pads were mounted on a spherical frame, and used a form of carbonised rubber sheeting as a sensor input. A current flowed across the pad sheet and as pressure was applied the resistance increased, this resistive change could be measured to trigger sound. Individual pad lighting was trialled, with LEDs illuminating each pad. There were a number of issues with this design, especially with the carbonised rubber pads which did not emit a clean signal. It provided useful insights into the direction of the design and illuminated pictures of the prototype generated initial user interest (see Figure 4).

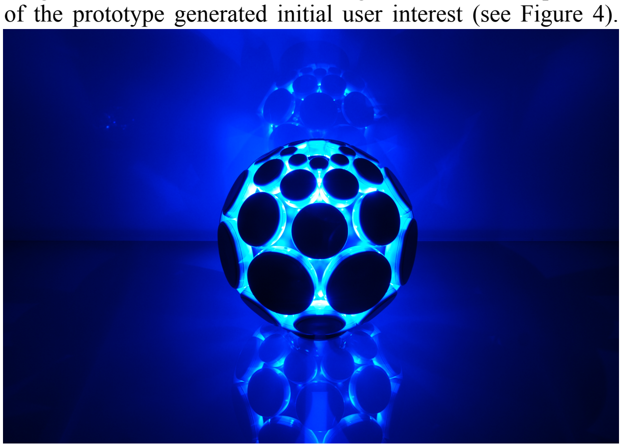

Figure 4. AlphaSphere 0.1 illuminated with internal LEDs.

2.3.2 AlphaSphere 0.2

Figure 5. AlphaSphere 0.2 structure with parts annotated.

After further research, sensors which quantified the displacement of the pad mechanically were selected, these converted pad manipulations into data. In 0.2 the structure was reproduced using only 3 parts, (i) top three rows, (ii) middle row and (iii) bottom two rows (see Figure 5), and did not require an internal frame as 0.1 did. The carbon-loaded rubber was replaced with latex rubber, which was much more elastic and easier to play, but suffered visible wear after medium usage. The pad depths were increased as the sensor mechanism allowed for the possibility of controlling a greater range. The lighting was moved inside the sphere to a single RGB LED unit that changed colour as pads were pressed. 0.2 could be used to play music, but the depth of the pads meant that they were not as responsive as they could have been with a shallower depth.

2.3.3 AlphaSphere 0.3

The intention of AlphaSphere 0.3 was to move towards an ergonomic, manufacturable design which utilsed the new sensor mechanism and user feedback (see Section 3 - User Testing). The main challenge of this prototype was to create a structure that was self-supporting, robust and could be adapted for injection moulding. The modular design was influenced by the structure of the geodesic dome[7]. By using the rotational symmetry of the design, a frame was created out of 48 individual parts that were bolted together - pads were then mounted onto this frame. The pad depth was reduced to utilise the optimum sensitivity of the sensors and the latex rubber was replaced with more robust silicon rubber. The PCB was contained within the base of the device, rather than a box on the side as in 0.1 and 0.2. On the strength of the function and aesthetic of this prototype - orders for over 100 units were attracted which supported the transition into manufacture.

2.4 Production

It was determined that it became viable to produce injection moulding tools once orders for over 15 units were received, at this point the design was refined for batch manufacture.

2.4.1 AlphaSphere 0.4 and beyond

The next iteration, AlphaSphere 0.4, was created to fine tune the design for manufacture. The bolts for the frame were replaced with a clip mechanism as the form was fully designed for the injection moulding process. The pad-caps were threaded so that they could be screwed on and off, and the middle two pad sizes were modified so the sizes changed with a constant ratio. A wider base was created for stability, which also allowed for a larger printed circuit board. The PCB itself was adapted a number of times in readiness for Electro Magnetic Compatibility (EMC) testing as a Professional MIDI unit, reference EN55103-1:2009 for environments E1 - E4[8].

3. USER TESTING

Throughout the design process input was invited from users, ranging from specifically targeted musicians, to musicians who approached the development team, to children and members of the general public.

3.1 Alpha testing

3.1.1 Methodology

Undertaken with 0.2, Alpha testing took place with a series of structured interviews and questionnaires. Largely conducted at the site of development, with the development team present, feedback was collected directly from the participants.

3.1.2 Conclusions

Process led to reduction in size of the device, so sphere could comfortably fit between the hands. It also led to the standard pad arrangements shifting so diatonic notational arrangements could be played fluidly from row to row, rather than notes repeating when progressing between rows (see Figures 6 & 7).

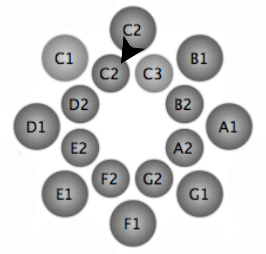

Figure 6. Two rows of C-major scale in 0.2

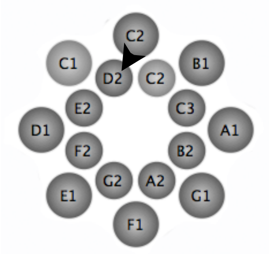

Figure 7. Two rows of C-major scale in 0.3

3.2 Beta testing

3.2.1 Methodology

The Beta testing process saw the device used live on tour by two electronic music producers. This real-world testing process allowed the development team to assess different users understanding of the AlphaSphere through the questions which were asked by the performing musicians. One of the Beta testers was aged under 20 years old and successfully set-up and used the AlphaSphere on tour, however the other Beta tester, aged over 40 had difficulty setting-up the AlphaSphere with the software and was not able to use the AlphaSphere at all.

3.2.2 Conclusions

The beta testing process was not extensive enough to draw significant conclusions, other than that the prototype devices were sufficiently robust to use in a live environment, and that the ease of set-up could be improved.

4. ERGONOMICS

4.1 Form

As part of the design process, the ergonomics of the device were refined. A number of ergonomic principles which were not immediately apparent at the conception of the device, became core to what the instrument now provides.

4.1.1 Pad Size

Table 1. Human hand and fingertip average size compared to rubberised part of largest and smallest AlphaSphere pad.

	Pad		Male	Female
Largest	85mm	Hand Breadth	87mm	76mm
Smallest	22mm	Index Finger Breadth	21mm	18mm

The pad sizes of the AlphaSphere are directly related to the anthropometry of the human hand[9] (see Table 1) The largest pads are designed to be similar to the breadth of the average human hand and the smallest pads are designed to be similar to the average size of the tips of the index finger (see Figure 8).

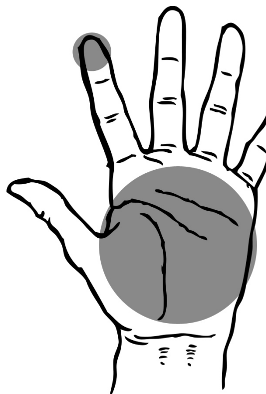

Figure 8. Human hand with render of largest and smallest AlphaSphere pad size on palm and index fingertip.

4.2 Pad interaction design

4.2.1 Tactility

The pads of the AlphaSphere are designed to offer the instrumentalist feedback through the feel and depth of the pads. As outlined in Sections 2.3.2 & 2.3.3 - AlphaSphere 0.2 & 0.3 attention was paid to the depth of the pads, with the optimum depth being found for the current sensor mechanism. The material and padding of the pads are designed to feel malleable in order to improve the experience of the musician.

4.2.2 Control

Each pad sends two messages when pressed - a pressure value and a velocity value. Pressure is sent as a value between 0 and 511 depending on how much physical pressure is applied to the pad. Velocity is sent as a value between 0 and 127 depending on how much force is applied to a pad when struck.

4.2.3 Future development

Touch sensitivity could be improved, specifically to aid fast percussive actions, the amount of force required should be reduced. Also, the endpoint of the virtual pressure value is at approximately two thirds the depth of the physical pad, meaning there is space at the bottom of the pad, so increasing pressure won't continue to change the value.

5. COMMUNICATION PROTOCOL

5.1 OSC

AlphaSphere 0.1 and 0.2 used the Open Sound Control (OSC) protocol for communicating with the computer. OSC was implemented as it is a protocol with high data resolution capabilities and an open-ended naming scheme, ideally suited for communicating between music software and hardware.

5.2 Serial

In 0.3 the device's connection type was changed from Ethernet to USB to allow it to be bus-powered, and adopted the Serial protocol. The AlphaLive software would create a virtual MIDI device or a MIDI output port, at this point OSC conversion support was implemented so OSC could still be used.

5.3 MIDI & HID

A problem which emerged in Beta testing phase is that virtual MIDI devices are only supported on Mac OS X, and third-party MIDI routing software is required to connect the device to MIDI software on Windows. The solution to this was to make the device a composite USB device; a device with a MIDI interface for communicating with external MIDI software but with a second interface for communicating with AlphaLive to program the MIDI messages. The HID protocol was selected rather than the Serial protocol, as HID is class compliant and it would also allow the device to be used as a computer input device/gaming controller. HID & MIDI is the current protocol.

5.4 Future

The main problem with the current communication protocol is that the MIDI messages are being generated within AlphaLive, rather than from the device itself. This can be rectified by moving MIDI message generation onto the device's firmware.

6. ALPHALIVE SOFTWARE

6.1 Concept

AlphaLive is intended to be an application that allows the device to be programmable in an easy and intuitive way. The two main factors in the design and development process were – create an application that would allow the device to control sound in as many ways as possible, and to create a user-interface that reflected the design of the hardware.

AlphaLive was originally developed using Max/MSP (see Figure 9) as it would allow AlphaSphere users to customise the software to fit to their specific needs. However as features increased it was decided that C++ and the JUCE library[10] should be used. Developing the software in a lower-level language allowed more control over the design of the GUI, and the JUCE library was used due to its strong audio and MIDI support. Using JUCE also meant the software could remain open-source, so the software could be customised by the user.

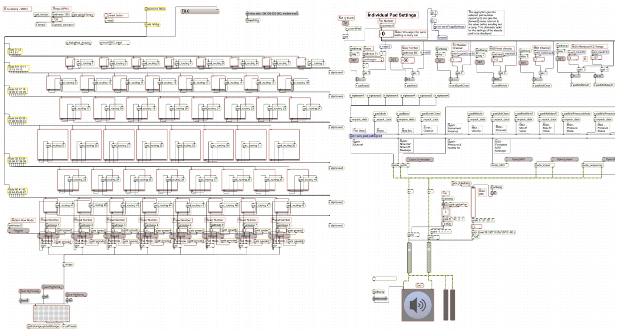

Figure 9. The first version of AlphaLive, made in Max/MSP.

6.1.1 Back-end design

The concept behind programming the AlphaSphere is the idea of independent pads – a pad is selected and given functionality that is independent from other pads. This is the main component behind the design of the back-end of AlphaLive.

6.1.2 GUI design

The arrangement of the pads in the GUI changed throughout the software development process. Initially it was a polygon structure with the rows arranged in straight lines (see top image of Figure 10), however distinguishing the mapping relationship between the pad arrangements on the hardware with this interface layout was difficult. Therefore the layout was changed to a circular structure (see bottom images of Figure 10) to increase the ease of comparing the hardware and software. Various layouts were experimented with in order to develop the best mapping relationship (see bottom right of Figure 10).

6.2 Future

There are many ways that AlphaLive could be further developed. The Sampler and Sequencer modes could be improved so that the application could act as a standalone music production suite that would prevent the need for any external MIDI or OSC software. This would also be useful for exploiting the devices key features for controlling sound in ways that is impossible via MIDI/OSC. AlphaLive could also be improved as a MIDI/OSC mapping editor to allow closer integration with applications that come with extensive mapping/scripting capabilities for third-party controllers.

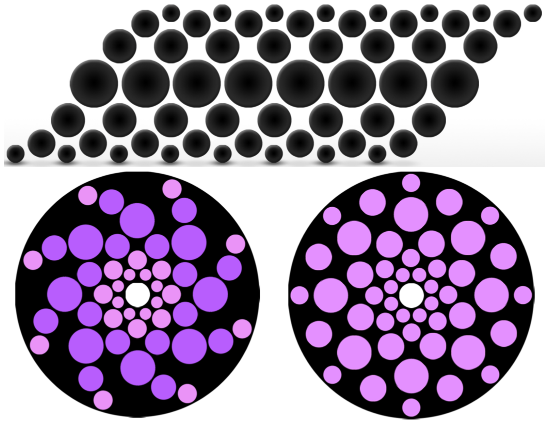

Figure 10. Development of AlphaLive's Pad Layout section.

7. CONCLUSION

How *can* the success of the AlphaSphere as a musical instrument be evaluated? AlphaSphere concerts are becoming more frequent occurrences, and some initial playing styles have emerged. However, the instrument has yet to be mastered and performed virtuosically. As we generally understand that virtuosity constitutes success with an instrument, to evaluate the success of the AlphaSphere as a musical instrument, surely a virtuoso must emerge.

8. ACKNOWLEDGMENTS

Our thanks to the members of the **nu desine** team, the Watershed, Dr. Chris Nash and the JUCE Library community.

9. REFERENCES

[1] Nattiez, J., Music and Discourse: Toward a Semiology of Music. *Princeton University Press* (1990).

[2] Buckminster F_cker, R., Dixie Cup Spherical Dodecahedron. *instructables.com/id/Dixie-Cup-Spherical-Dodecahedron/* (2013).

[3] Rohner, F., and Schärer, S., History, Development and Tuning of the Hang. *International Conference on Noise and Vibration Engineering* (2007).

[4] Kronman, U., Steel Pan Tuning: A Handbook for Steel Pan Making and Tuning. *Musikmuseet* (1991)

[5] Place, A., Lacey, L., and Mitchell, T., AlphaSphere. *New Interfaces for Musical Expression* (2013).

[6] musicnotation.org/wiki/instruments/wicki-hayden-note-layout/

[7] Davis, T., Geodesic Dome. *geometer.org/mathcircles* (2004).

[8] Electromagnetic compatibility. Product family standard for audio, video, audio-visual and entertainment lighting control apparatus for professional use. *British Standards Institution* (2013).

[9] Pheasant, S., and Haslegrave, C.M., Bodyspace: Anthropometry, Ergonomics and the Design of Work. *CRC Press* (2006), 144.

[10] http://rawmaterialsoftware.com/juce.php

10. ONLINE CONTENT

http://www.alphasphere.com