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The microtonal legacy of the Pocket Gamelan

Greg Schiemer
University of Wollongong, schiemer@uow.edu.au

Mark Havryliv mh675@uow.edu.au
University of Wollongong

Greg Schiemer
Sonic Arts Research Network
Faculty of Creative Arts
Wollongong, 2522
Australia
schiemer@uow.edu.au

Mark Havryliv
Sonic Arts Research Network
Faculty of Creative Arts
Wollongong, 2522
Australia
mhavryliv@hotmail.com

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Abstract

This paper examines the origins and motivation for the Pocket Gamelan, a performance interface for mobile phones where musical interaction between players is facilitated via bluetooth. The performance scenario for mobile phones has its origins in two works composed more than 25 years earlier. Mandala 1, composed in 1980 and Mandala 2, in 1981, were the first in a series of works in which an ensemble of players swing mobile sound sources while Mandala 3 and Mandala 4 were composed to be performed using bluetooth-enabled mobile phones. The Mandala series all have a common feature related to microtonal tuning. While the later works Mandala 3 and Mandala 4 have specific just intonation tuning characteristics that represent a particular system, the earlier works Mandala 1 and Mandala 2 are based on two different arbitrary approaches to tuning. Mandala 1 is based on the interaction between pitches in found objects and microtonally tuned sound sources while Mandala 2 is based on just intervals selected gratuitously by each player. The original sound source consisted of a twin-T oscillator, battery-powered amplifier and loudspeaker. These were mounted in plastic kitchenware which is attached to a cord and physically swung to produce audio chorusing. Like the Pocket Gamelan, the original instruments were designed for performance by large ensembles of non-expert players. The paper summarises common features of works created for both Tupperware Gamelan and Pocket Gamelan through a window onto what is perhaps an unprecedented period of change that has taken place in musical instrument technology over a quarter f a century.

Introduction

In the past decade there has been a paradigm shift from desktop to ubiquitous computing. Mobile phones represent a major part of this shift. The Pocket Gamelan project which began in 2003, was intended to focus on development of applications that allow microtonal composition to be performed using mobile phone technology. The project has resulted in the development of new tools that allow tuning and composition software programs designed for desktop environment to be exported to java phones.

Tupperware Gamelan - UFOs

New performance scenarios explored so far using mobile phone handsets have their origins in works entitled *Mandala 1* and *Mandala 2*. I first created these works in 1980 and 1981 for purpose-built set of electronic instruments known as the Tupperware Gamelan (Jenkins, 1988, Atherton, 1991, Schiemer, 1999) which were intended for ensemble performance.

Unlike the first instruments of the Tupperware Gamelan which were played as percussion instruments, the largest contingent of instruments in the Tupperware Gamelan was a group of sixteen individually- tuneable oscillators - called UFOs - each housed in a plastic container and attached to a cord approximately 2 metres in length. In performance each of these instruments, is a swung by a cord to produce audible artefacts such as Doppler shift and chorusing which are produced as a by-product of movement.

UFO is an acronym for Ubiquitous Fontana Oscillator, in acknowledgement of sound sculptor Bill Fontana who first used flying speakers during experimental workshops which he conducted at the Sydney Opera House in 1976.

The sound level of the UFO is quite low being battery powered. A single oscillator was driven by a half-watt class A transistor amplifier. Though the output sound level of the sound source is relatively low, moving the source has the effect of making the sound more noticeable than simply increasing the output level.

The mobile performance gesture that was first developed for the UFOs has been applied to mobile phones even though sound levels that can be achieved in today's mobile phones frequently have higher output levels.

A musical feature common to all four *Mandala* pieces is the chorusing produced from the beating of microtonal intervals which are produced as by-products of movement. As a sound source moves, Doppler shift produced by the moving sound source results in microtonal pitch shifts which are heard simultaneously with the original unshifted pitch. This results in chorusing or the periodic fluctuation in level that characterises each moving sound source as it travels in a circular trajectory.

The rate of chorusing is a function of the radius of the circular trajectory. It is also possible to control the rate of chorusing to a certain extent by varying the length of cord used to swing the instrument. However, there is an optimum radius for the most desirable chorusing effect. If one were to increase the radius of the circular trajectory, the sound source would travel faster because it has to cover a greater distance in a given time. This in turn would increase the degree of Doppler shift thereby producing a rate of beating where the effect is less like a periodic fluctuation in level and more like a sensation of roughness. However, for all four *Mandala* pieces I have chosen a cord between 1 and 2 metres in length. At the same time I have also tended to encourage players to use the longest length of the cord available in performances, space permitting, swinging the sound source as slowly and as effortlessly as possible as this produces the most pleasing effect.

Chorusing produced in this fashion demonstrates that microtonal intervals are as much about timbre and rhythm or rate of beating as they are about harmony.

Mandala 1 (1980)

The UFOs were first used in 1980 as part of an accompaniment to a dance work entitled Between Silence and Light created as part of an environmental trilogy by choreographer Yen Lu Wong for the One Extra Company. The music was performed by an ensemble drawn from experimental community arts groups brought together by the director of One Extra, Kai Tai Chan. The music, entitled *Mandala 1*, was performed on the Northern Broadwalk of the Sydney Opera House on 18th November 1980. Though the work's dramatic quality was intended to complement the dance narrative it was also intended as a stand alone concert work.

Mandala 1 was scored for 12 bamboo poles, twelve handbells and four UFOs and lasted about fifteen minutes. The work opens in canon as each player in turn slowly raises and drops a 3-metre bamboo pole vertically onto the stage floor in unison with the other players.

Sustained tones were gradually introduced with each percussive event. Four UFOs provided a backdrop of sustained pitches punctuated by the sound of handbells. Each UFO was tuned approximately to the pitch of one of the handbells. Percussive handbells produced fluctuations in the level of sound produced by the UFOs. In addition the UFOs were swung as the players gradually faded the sustained sounds by moving slowly away from the audience. The character of the percussive gestures that open the work owe much to the canon in *The Great Learning Paragraph 4* by Cornelius Cardew.

In the context of an outdoor performance where the sound environment is not contained by a ceiling and four walls, Doppler shifted pitches produced by the movement of the UFO took on the musical character of the bull-roarer, a ceremonial instrument used by the Australian Aborigines. This is quite distinct from the chorusing effect produced by the microtonal interplay of fixed and shifted pitches that occurs when surfaces of a performance enclosure reflect sound.

A high degree of maintenance was required to keep the first UFOs in working order as the purpose-built analogue circuitry was mounted on vero-board where a large percentage of the circuit interconnections required manual insertion of wires. Any future performance would require a more robust hardware design with circuitry mounted on printed circuit board.

Mandala 2 (1981)

Sixteen UFOs were built for *Mandala 2* a work created for the Leichardt Festival in 1981. The performance was staged by sixteen performers brought together from a variety of performance backgrounds especially for the occasion. Performers included middle-aged people who had lived in an institution for many years along with members of their community support group and complemented by several performers working in theatre and music who served as leaders in various sections of the work.

Figure 1. One of 16 UFOs from the Tupperware Gamelan built for Mandala 2 in 1981.

Figure 1 shows one of the UFOs developed for *Mandala 2.*

The consort of 16 UFOs was divided into four colour-coded sub-groups, each spanning a compass of an octave and a major sixth. In total, all instruments covered a pitch range of five and half octaves. Subgroups were colour-coded in a way that matched the range of each subgroup: yellow (soprano) orange (alto) blue (tenor) and green (bass). Each instrument produced a single tone that could be turned on and turned off. Once on, each instrument could be tuned or swung. There was no other means of control; volume and timbre remained constant throughout the performance.

The score contained simple verbal instructions designed to be performed by any member of the group irrespective of musical training. At various times prescribed in the score, one of the leaders in each sub-group [a] turned on a UFO [b] selected a preferred interval and [c] began swinging the UFO for a duration predetermined in the score. Each of the other performers in that subgroup followed suit entering in canon.

Preferred intervals

Preferred intervals were selected by adjusting the tuning knob on the held UFO using as a reference the pitch of any other oscillator that happened to be audible at the time. If no other oscillator was audible, a player had the option of choosing any pitch. The process of selecting preferred intervals had much in common with the process by which vocalists selected pitch in *The Great Learning Paragraph 7* by Cornelius Cardew.

One performer in each colour-coded group provided timing cues for other members of the subgroup. Except for one section in the piece at which all oscillators sounded simultaneously, the work consisted of chordal blocks made up entirely of UFO sub-groups of the same colour. At specified points in the piece the work featured transitions from a chordal block played by one subgroup to a chordal block played by another. Each block was made from simultaneous layers of up to four oscillators from the same subgroup. The pitch of each oscillator was arbitrarily chosen.

The term preferred interval is one used by Benade (1976) to describe intervals identified by performers as consonant. According to Benade these tended to be simple just intonation intervals. A just interval expressed as a fraction, is the separation between two points in the harmonic series where the numerator is the higher pitch and the denominator is the lower pitch. Consonant intervals described by Benade tended to involve small integers that appear lower in the harmonic series.

Intervals used in *Mandala 2* - and indeed *The Great Learning Paragraph 7* - are no different to those described by Benade. They are derived by the same perceptual processes implied in the score rather than any systematic approach to harmony that applies in most other microtonal composition where precise pitches are prescribed.

Porcelain Dialogue (1983)

Neither *Mandala 1* or *Mandala 2* was recorded before the UFO hardware was eventually modified in 1983 to make way for a new work entitled *Porcelain Dialogue* created for the One Extra Company. All sixteen UFOs were modified so they could be sequenced by a single player. The modified UFOs each had pre-set tunings that could be sequenced in real-time using streams of clock pulses. Each UFO was wired to a central console that allowed its audio signal to be tuned on and off remotely or the sequences of pitches to be clocked. In effect, the instruments became fixtures in a theatrical set and no longer performed their original function namely that of playing with chorusing.

The UFOs were suspended from the ceiling so that sixteen sound sources configured in a large 4 x 4 matrix were placed above both the performance space and the area where the audience was seated. Each UFO was released as the performance began swinging like a pendulum for the duration of the performance and gradually coming to rest by the end of the piece. Dancers used long dowel rods to release the UFOs at the start of the piece.

A purpose-built pseudo-random sequencer was added to the Tupperware Gamelan for the production of *Porcelain Dialogue*. The sequencer was designed to produce streams of synchronised pulses that were sub-divisions of a common clock frequency. A single player operating banks of switches could route melodic sequences based on a fixed set of pitches. By operating binary switches the player produced hocket-like melodic configurations involving antiphonal interplay between groups of instruments in the same register.

Provision was made in the design of the sequencer to modulate the pulse streams with square wave signals running at audio rates. This allowed the system to produce variations of timbre resembling a very crude form of frequency modulation. Line impedance of the cables connecting each UFO to the control unit also influenced the timbre as oscillators were rapidly turned on and off by control signals running at audio rates. In particular, line impedance helped to filter out some of the transients produced when oscillators are rapidly switched in this fashion.

It is ironic that One Extra Company had set aside a budget to record the modified UFOs while these were set up for the performance of *Porcelain Dialogue* in the Recording Hall of the Sydney Opera House. However the instruments became the centre of an industrial dispute that prevented them from being tuned before the recording session.

The dispute centred on differences between the stage-hands union who saw Tupperware instruments as stage props and the electrical trades union who saw things differently because the UFOs had electrical cables – albeit cables that carried signals between devices powered by 9-volt batteries. As a result, the recording that was made featured instruments that were not tuned according to the scheme of tuning required for the piece.

After its Sydney season One Extra toured with *Porcelain Dialogue* to Melbourne and Canberra. By this time many of the modified UFOs had become dysfunctional, and many of these were no longer working by 1985 when the only commercially released recording of these instruments was made. A recording was made as the instruments were being checked to find how many were still functional after One Extra's performance season. What was recorded was an improvisation with Australian trombonist, Simon de Haan, an enthusiastic supporter of my instrument-building activities whose trombone playing reacted to sounds made by the semi-dysfunctional Tupperware instruments.

The ultimate irony however is that this recording was released by mistake as part of the Anthology of Australian Music on CD. The pseudo-random sequencer used to drive the modified UFOs, along with other remnants of the Tupperware Gamelan now sits in a public display shelf at the Sydney Conservatorium of Music.

Four UFOs were eventually returned to their original state. The hardware of the pseudo-random sequencer was reincarnated in software algorithms that ran first on the DATUM microcomputer. *Monophonic Variations* and *Polyphonic Variations* the two interactive MIDI works developed on the DATUM using this algorithm eventually led to the design of another purpose built hardware system known as the MIDI Tool Box (Schiemer 1998).

The MIDI Tool Box was an interactive composition system I developed between 1989 and 1994 to create compositions that can be implemented as algorithms that run in firmware on a HC11 microcontroller. Its design philosophy was very much about a musical paradigm shift that has taken place over the past few decades, viz. the shift from music scores prescribed on paper to musical processes defined in silicon. It also reflects a shift that taking place with the technology itself; composer's work spaces have become less like an office desk and more like a mobile electronic workplace.

The MIDI Tool Box was used to create an algorithmic composition in 1991 called *Spectral Dance*. This work once again featured moving sound sources using of the four UFOs restored after modifications done to the original UFOs for *Porcelain Dialogue* in 1985.

Pocket Gamelan

The Pocket Gamelan project was developed to address the challenge of composing music for mobile computing environments. The project seeks to develop an interactive musical performance interface that allows non-expert performers to perform microtonal music using mobile phones (Schiemer, Sabir and Havryliv, 2004, Schiemer et al, 2003).

A set of software tools has been designed to allow musical applications for mobile devices to be created using public domain composition software.

Pd2j2me is used to export musical applications created in the Pure Data composition language in order to create live musical applications that run in hardware that supports the java 2 micro edition (Sun Microsystems, 1999). Pd2j2me is described elsewhere (Schiemer, and Havryliv, 2005(a)).

Another tool developed for the Pocket Gamelan project was a script developed using Scala tuning software. The command file, called scale-player.cmd, allowed tuning data and documentation to support file formats used in Pd. Scale-player.cmd was released in Scala version 2.2o.

Both tools were designed to address two of computer music's most persistent technological legacies. One is its dependence on performance interfaces designed around 12 equal divisions of the octave. The second is the desktop computing environment where musical resources are concentrated in the hands of a single user. Both legacies are an inevitable consequence of the score-orchestra metaphor on which computer music composition languages like Music4 are based. As technological development shifts away from this towards mobile computing, a new computer performance paradigm begins to emerge.

Java phones

The Pocket Gamelan project seeks to explore an alternative performance metaphor to the one that has dominated computer music since its origins. The alternative metaphor is based on mobile java technology. Mobile phone handsets have been adapted for performing music in non-standard tunings. This has allowed exploration of tuning systems inspired particularly by composer and theorist Harry Partch (1949) along with a host of other composers who built instruments to realise music in tunings systems outside twelve-divisions of the octave.

The ubiquitous nature of java phone technology provides a ready made platform for the development of a robust set of instruments that are easy to play, quick to learn and able to be used by large numbers of people.

The flexibility and extensibility of this technology offers the promise of a development pathway for a new musical genre of work that may be created and realised without building new hardware. Such technology is appropriate for the musical realisation of new theoretical systems proposed by contemporary tuning theorists such as Erv Wilson (1961, 1967, 1975(a), 1975(b), 1986) and John Chalmers (1993).

Microtonal music for mobile phones

Two new microtonal works for mobile phones have been created and performed. The works are entitled *Mandala 3* and *Mandala 4*.

In performing both the works, players swing mobile phones on the end of a cord in a circular trajectory, as shown in Figure 2. Each mobile phone is mounted in a pouch made of semi-transparent fabric attached to a cord.

Figure 2. Mobile phones are used as flying sound sources in *Mandala 3* and *Mandala 4*.

Bluetooth communication allows audio algorithms used in *Mandala 3* and *Mandala 4* to be altered during performance as shown in Figure 3. During hand-held operation a phone keypad may be operated easily through the fabric as shown in Figure 4.

Figure 3. Flying phones are controlled by hand-held phones

Bluetooth commands sent from a phone keypad perform a variety of functions. In some cases, these commands allow a new tempo or octave transposition to be selected. In other case, commands select new tuning modes.

In just intonation, a new tuning mode is formed when one interval in the scale is used to transpose all notes in the scale. Unlike transposition in equal tempered systems where the intervals are equally spaced, in just intonation transposition may result in the formation of new pitches that did not occur in the original (i.e. untransposed) scale. The harmonic variety produced by the use of transposition is part of the musical attraction of working with just intonation tuning systems.

Figure 4. Pressing a button sends a bluetooth message

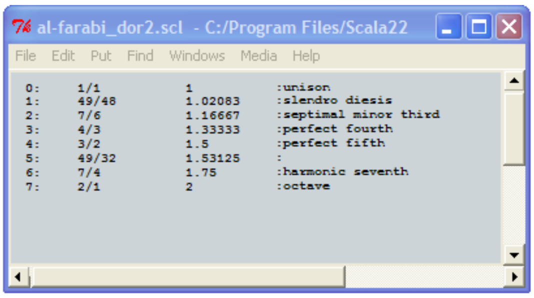
Mandala 3 (2005)

In *Mandala 3*, three mobile phones (Nokia 6230) interact with one another via a fourth mobile phone (Nokia 7610) which acts as a dedicated server, as shown in Figure 5.

Each 6230 is used both as a sound source and bluetooth controller while the 7610 is used to relay control messages to the other phones. This configuration allows all three sound sources to be affected by the action of any player.

Figure 5. A mobile 'server' configuration allows any player in the ensemble to affect sound on other phones

Mandala 3 uses a microtonal scale ascribed to 8th century theorist Al-Farabi (Op de Coul, 1992) as shown in figure 6.



al-farabi_dor2.scl - C:/Program Files/Scala22

File Edit Put Find Windows Media Help

0:	1/1	1	:unison
1:	49/48	1.02083	:slendro diesis
2:	7/6	1.16667	:septimal minor third
3:	4/3	1.33333	:perfect fourth
4:	3/2	1.5	:perfect fifth
5:	49/32	1.53125	:
6:	7/4	1.75	:harmonic seventh
7:	2/1	2	:octave

Figure 6. Al-Farabi's Dorian scale used in *Mandala 3*

Mandala 3 was first performed at the 13th Australasian Computer Music Conference 2005, Queensland University of Technology, The Loft, Creative Industries Precinct, Kelvin Grove, Brisbane, July 12th 2005. Subsequent performances have been presented at Sonic Connections 2006 and NIME06.

The work is an improvisation structured round a three-part hocket. Performance involves interaction between three players who use buttons on the phone handset to control the combinations of voices that can either play melodically, hold a tone or be silent. Any player has the option of selecting these combinations using the clock or voice function keys followed by a single data key. The voice function determines which one of eight combinations of the three voices are audible at a given moment while the clock function determines which combination of voices is melodic. A non-melodic voice may play a held note or remains silent depending on the voice combination selected.

Each player also has the option of selecting the tessitura of each voice in two ways; octave function key followed by one of four data keys (0-3) selects the octave, while mode function key followed by one of seven data keys (0-6) selects the starting note of the scale. Players also have the option of selecting the tempo whenever keys 4 5 or 6 are pressed regardless of the other functions selected.

Mandala 4 (2005-6)

In the second of these works , *Mandala 4*, mobile phones communicate with one another on an ad hoc basis. Four Nokia 6230 phones are used both as sound sources and bluetooth controllers; each player in turn operates the phone as a bluetooth controller in order to affect sound on one of the other flying phones. The configuration is shown in Figure 7.

Figure 7. An ad hoc connection system makes connections only when required

Each phone is colour-coded as indicated by the colour of its LCD screen. When a single coloured button appears on the screen of a hand-held 6230, a player may choose to respond by sending a control message that affects a flying sound source on another phone. The colour of the on-screen button indicates which phone is affected.

The composition specifies a sequence of cues communicated by players during the performance. These cues ensure that each player is ready with phone in hand before the button appears on the screen. As soon as it appears, a player may respond by pressing any key on the 6230. This selects new tuning modes as described in section 4.

Mandala 4 uses one of Wilson's combination product set scales called the Euler-Fokker Genus (Op de Coul, 1992) as shown in Figure 8.

Mandala 4 was first performed in the Wild Dog Concert as part of UK Microfest, Riverhouse Barn, Walton-on-Thames, October 15th 2005.

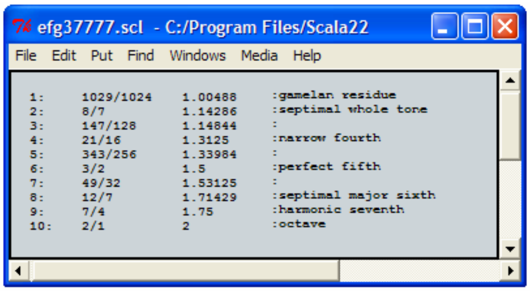


Figure 8. Erv Wilson's Euler-Fokker Genus scale based on harmonics 3 and 7 used in *Mandala 4*

Conclusion

Mandala 3 and *Mandala 4* were recently performed in the University Recreation and Aquatic Centre at the University of Wollongong, on May 8th 9th and 10th as part of Sonic Connections 2006. It was also presented as part of NIME06 at Ars Longa, Paris, on June 8th 2006.

Because space inside the gallery was severely restricted, the second of these performances had to be presented outdoors. This was also most a return to the situation in *Mandala 1* except that the outdoor space where the performance took place was a narrow street lined by the walls of apartment blocks and these provided reflections needed to create chorusing effects described in this paper.

Phone technology developed for the Pocket Gamelan used for these performances can also provide a suitable alternative means to realise the original works *Mandala 1* and *Mandala 2*. so that these can at last be recorded.

Inspiration for the Pocket Gamelan has been as much a legacy of my work building instruments as it is an exploration of interactive possibilities inherent in java phone technology. The former has involved on-going musical and creative reflection throughout a period of technological change. The latter is part of a desire to see global technology used to serve many musical cultures rather than impose a single system of tuning by stealth.

Work done so far demonstrates the potential of new musical applications using mobile phones. All development has been done using open source software. The tuning resources of Scala, already accessible in many desktop applications like Csound, Artwonk and Metasynth, can now be exported to Pd where pd2j2me is currently used to export applications to java phones. In time, these musical resources can also be extended to other music composition environments.

Currently, phones require wired connection for downloading musical applications. In the future, we envisage scenarios in which servers allow tunable applications to be downloaded by multiple clients via a wireless connection. These scenarios provide a broader musical framework in which musicians in future will work with sensor networks based on ultrawideband (UWB) communications (Nekoogar 2005). Such networks will dramatically extend the capabilities of bluetooth beyond those explored in *Mandala 3* and *Mandala 4* and address shortcomings of bluetooth implementation in the current generation of phones. One hopes that ultra-wideband devices have the capability to multicast in an ad hoc network without the necessity to use an echo server. Moreover, for live musical performance, connection initiated at the discretion of the player is preferable to connection initiated by an automated process as is the case in *Mandala 4*. Ongoing development of work already begun also calls for a new generation of phone that is fully compliant with MIDI, can synthesise streaming audio files and recognise human performance gestures other than the pressing of buttons [20]. This will allow phones to be widely used by performing musicians.

The frequency hopping algorithm on which mobile phone technology is built has its origins in *Ballet Mecanique*, one of the earliest forays by a twentieth century composer into musical instrument design. Future development of this technology can still be driven by communities of musicians just as such communities drove the development of MIDI more than two decades ago. We see new sensing networks based on UWB potentially as interactive musical instruments that are as diverse as the tuning systems used by musicians over many centuries and in many civilizations.

Acknowledgements

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