Creativity, Complexity and Reflective Practice

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Introduction

This chapter describes a research methodology applied to practice-based research in the area of creativity and complex systems. My creative origins are in experimental music and the scientific foundations are in complex systems. Creativity and complexity was the main theme of my PhD research (Burraston 2006). That research forms the basis of this chapter which also extends the work beyond the PhD. The approach is derived from Donald Schön's reflective practice (Schön, 1983, 2003). Methods of research within a practical context place priority on change, making tacit knowledge explicit, and the logic of affirmation and exploration. These aspects of reflective practice will be introduced and discussed. An overview of experimental music and complex systems research developed from this methodology is then presented. The experimental music tradition has loosely evolved from the musical ideas of various composers and artists throughout the twentieth century and continues to the present day. Michael Nyman has described in detail the concepts and methodology of experimental music (Nyman 1999). Complex systems is an emerging multidisciplinary science developing new ways of researching large, highly intricate, dynamical systems in diverse areas such as biology, computer science, physics, social networks, socio-technological systems, socio-ecological systems, economics and the environment (Bossomaier and Green 1999, Norberg and Cumming 2008).

Reflective Practice

Donald Schön's concept of 'reflection-in-action' is a method of researching within a practical context, linking the "art of practice in uncertainty and uniqueness to the scientist's art of research." (Schön 2003)

Professional practitioners depend on tacit knowledge in their day-to-day practice. Professional use research based theories and techniques consciously, but dependence relies on tacit judgements, recognitions and performance. Schön describes tacit knowing (Polanyi 1983) as knowing-in-action, and defines this type of knowing as having the following properties:

- judgements carried out spontaneously
- often unaware of learning to do them
- sometimes once aware, subsequently internalised
- usually unable to describe the knowing

Reflection-in-action is the recognition that sometimes, when using tacit knowledge, professionals think about what they are doing and the experience of surprise has importance. Unintentional creations are often reflected on more than the intended outcome of a process. For example, I sometimes make use of accidents and errors within my own experimental music compositions. Schön gives detailed accounts and examples, such as reflecting on "winning habits" in baseball, jazz music and architectural design. Such processes tend to focus on action outcome, the action, and intuitive knowing implicit in the action. Schön borrows from John Dewey's theory of inquiry regarding the notion of practice situations as "problematic situations characterized by uncertainty, disorder, and indeterminacy"(Schön 2003).

Practitioners must make sense of the complexity and somehow reduce the uncertainty to a manageable level. This may be approached through 'problem setting' rather than 'problem solving'. Schön defines problem setting as "a process in which, interactively, we *name* things to which we will attend and *frame* the context in which we will attend to them" (Schön 2003).

To solve a problem requires that it be mapped to features of the practice situation. Problem setting decides what is treated as the 'things' of the situation and the boundaries of attention. This allows for deciding right and wrong and potential directions for change. Three main aspects of reflective practice are:

1. Frames

2. Repertoire of exemplars / facts

3. Research on fundamental methods of inquiry and overarching theories.

Frames set the bounds of practice and provide a reference for the practitioner. A problematic situation is addressed by a new way of setting or framing the problem. The practitioner enters into a process making the situation adapt to the frame. Bounding the process within a frame enables a practitioner to utilise, build or add to a repertoire of descriptions, exemplars and facts. A repertoire includes a practitioner's past experiences of understanding and action. Making sense of a unique situation entails seeing it as something from an existing repertoire. Seeing it as both similar and different to the unique situation, as a precedent or metaphor. This can result in a new way of seeing and the possibility of a new action for the situation. Fundamental methods of inquiry and overarching theories are connected to the two previous methods by assumption that a practitioner's fundamental principles closely connect to frames and repertoire of exemplars. These methods and theories are the springboards for making sense of new situations, enabling the restructure of practice. The key element, according to Schön, is the creation of themes, "from which, in these sorts of situations, practitioners may construct theories and methods of their own" (Schön, 2003).

A practical context places priority on the interest in change, and the logic of affirmation and exploration. The boundaries of experimental rigour in reflective practice are set by this logic of affirmation. The structure of reflection-in-action according to Schön suggests two kinds of experimenting:

1. exploratory experiment - action undertaken to see what follows, without accompanying predictions or expectations
2. move-testing experiment - action to produce intended change

Exploratory evaluation of problem framing takes into account the value of unintended effects, especially in relation to the production of a coherent artefact. A further concern in such evaluation is to value keeping an inquiry moving. Schön described an exploratory experiment as succeeding when "it leads to the discovery of something there" (Schön 2003).

An example of positive unintended change given by Schön, is a move-testing situation in chess where you accidentally checkmate your opponent. This is clearly a good move and you don't negate it because the result was unintended. He suggests the opposite of this is, for example, giving a child money to stop them crying, but the unintended effect is the child learns to cry for money, clearly a negative effect. Approaching a problem by reflective practice allows the enquirer to remain open to the discovery of new phenomena, not necessarily associated with the initial problem setting.

Experimental Music

The use of experimental music as a theme has been a major element in the reflective practice aspect of my research. The evolving concepts and methodology of this music have been discussed in (Nyman 1999). Composers such as John Cage and Edgard Varèse were unimpressed with the pitch and harmony language structure of traditional music. In the early twentieth century, the use of tonality for organisation diminished as other methods were defined. Cage saw that serialism was restrictive by imposing avoidance on certain combinations of tones. He stated:

> "The opposite and necessary coexistent of sound is silence." (Cage, 1973)

The four basic components of sound are pitch, timbre, intensity and duration, and duration is seen as the commonality between sound and silence. Based on this assumption Cage took the position as follows:

> "Therefore a structure based on durations (rhythmic: phrase, time lengths) is correct (corresponds with the nature of the material), whereas harmonic structure is incorrect (derived from pitch, which has no being in silence)." (Cage, 1973)

In terms of reflective practice the outcome of acts that are unknown could be viewed as a form of exploratory experiment. Cage however is interested in action and indeterminacy, and does not judge the outcome:

> "... here the word 'experimental' is apt, providing it is understood not as descriptive of an act to be later judged in terms of success or failure, but simply as of an act the outcome of which is unknown. What has been determined?" (Cage, 1973)

Brian Eno created the record label, Ambient, with the aim of using perceptions and understandings from experimental music (Nyman, 1999). In answer to the question "What was the experiment?" Eno suggested that it might be the continual re-asking of the question "what also could music be?" The conclusions of experimental music for Eno was that music "... didn't have to have rhythms, melodies, harmonies, structures, even notes..."(Nyman, 1999).

According to Eno, the experimental musician is more concerned with how processes are employed in composition, than the final composition. Experimental music has often been termed a music of process rather than product. Eno concludes:

> "If there is a lasting message from experimental music, it's this: music is something your mind does." (Nyman, 1999)

Nyman's work on approaching a definition of experimental music composition suggests that:

> "Experimental composers are by and large not concerned with prescribing a defined time-object whose materials, structuring and relationships are calculated and arranged in advance, but are more excited by the prospect of outlining a situation in which sounds may occur, a process of generating action (sounding or otherwise), a field delineated by certain compositional 'rules'." (Nyman, 1999).

This focus on process is summed up by Nyman as a being a relationship between chance (arbitration) and choice (organisation). Nyman suggested five processes in an attempt to partially classify experimental music, with the understanding that it can only be partial in this nebulous area. An overview of these processes is shown in Table 1.

Chance	Random numbers, telephone directories, I Ching
People	Performers moving through given or suggested material
Contextual	Actions dependent on unpredictable conditions and on variables arising from the music
Repetition	Extended repetition as means of generating movement
Electronic	Electronics as means of generating music

Table 1. Nyman's Categories for Experimental Music Processes (Nyman 1999)

Chance determination processes, popularised by Cage, are often used to keep the composer removed from the material and allowing this to be determined by some specified system. People processes, where performers move through given or suggested material, can be seen in the work of Morton Feldman. In Feldman's 1957 *Piece for Four Pianos,* the players start together at an agreed tempo but are free to choose note durations. Contextual processes are based on actions dependent on unpredictable conditions and the variables arising from within the music. Repetition processes are used as sole means for generating movement, as in the gradual process music of Steve Reich[i]. Electronic processes are used to generate music by some form of electrical technology.

Creativity and Complexity

A complimentary aspect to experimental music is the use of complex systems as a platform for practice-based research. In this context, the frame of the work now allows for both scientific and artistic outcomes. Complex Systems is an emerging multidisciplinary science and it has much to offer the developments in experimental, and in particular generative, music. The goal of the creativity and complexity research that I pursue is to establish:

1. fundamental links between creative practice and complex systems
2. unifying research in creativity and complexity through combined musical and scientific instruments

This research is undertaken in two main areas:

1. Generative Music and Cellular Automata
2. WIRED Lab

The Generative Music and Cellular Automata research was developed in my PhD thesis, in which a practice-based study of generative music found new ways of making music and enabled a new approach to a significant research problem in complex systems science (Burraston 2006, Burraston 2007). A brief introduction to this work is presented in the following section, although a detailed exposition is beyond the scope of this chapter. To hear samples of the music that these processes have been used to generate, download sound files from my web site (Burraston, 2011).

At the WIRED Lab, I work with a team of artists and scientists interested in consolidating and expanding the work of Australian 'wire music' composer Alan Lamb (WIRED Lab 2011). A brief overview of the newest WIRED Lab project (*Rainwire*) will be given later in the chapter and further details can be found in (Burraston 2010, Burraston 2012). The *Rainwire* project aims to be at the forefront of environmental sonification by demonstrating fundamentally different and novel approaches for research on land-based rainfall through an interdisciplinary art/science project.

Generative Music and Cellular Automata

The use of algorithms in music underwent a paradigm shift over the last two decades of the twentieth century with the advent of complex systems research. Complex systems such as cellular automata produce global behaviour from rule-based interactions of simple cells. Cellular Automata[ii] (CA) have a distinguished and esoteric history in Computer Science, from its foundation to the present day influence in complex systems, artificial life and numerous other important disciplines. They are fascinating objects that produce more patterns than a single human is capable of observing within their own lifetime and, in that sense, quite fascinating. The different classes of behaviour they produce, whether ordered, complex or chaotic, make them interesting to artists and scientists alike. This wide variety of behaviour represents an important generative tool for the artist. However, chaotic behaviour dominates rule space, which has serious implications for application and investigation. Obtaining a variety of 'pattern for free' is, thus, a challenge to the artist and scientist alike. CA are discrete dynamical systems in terms of space, time and values assigned to cells. The set of all possible global states of these cells is termed the 'state space'. The set of all possible rules for any particular CA architecture is termed the 'rule space'.

An extensive amount of research by the scientific community has been conducted towards producing behaviour prediction parameters to discern the structure of rule space. Unfortunately, as the size of the rule space is increased the total number of rules becomes astronomical and the amount of chaotic behaviour increases dramatically. This problem continues to engage the scientific community and is the subject of much debate. In confronting systems of such behavioural complexity for the purpose of art, the artist is placed in a possibility space of truly vast proportions. Given that the potential for random behaviour increases with rule space size, choosing rules at random does not represent a successful artistic strategy, unless one is actively seeking randomness. This problem has great implications for the use of CA in both scientific and generative arts practice.

I approached the problem of rule space structure from an artist's perspective in the context of generative music practice. From an artistic viewpoint, I assumed that all CA behaviours are interesting depending on application, whereas the music practice problem is to find a mixture of behaviour from the overwhelming chaos. This is in contrast, but not opposition to, the scientific approach of predicting behaviours in order to locate complexity within rule space. In terms of reflective practice, a problem setting 'theme', 'frame' and 'repertoire exemplar' were identified, and the 'fundamental method and overarching theory' area had been defined. The overall view in this reflective practice context is shown in Figure 1.

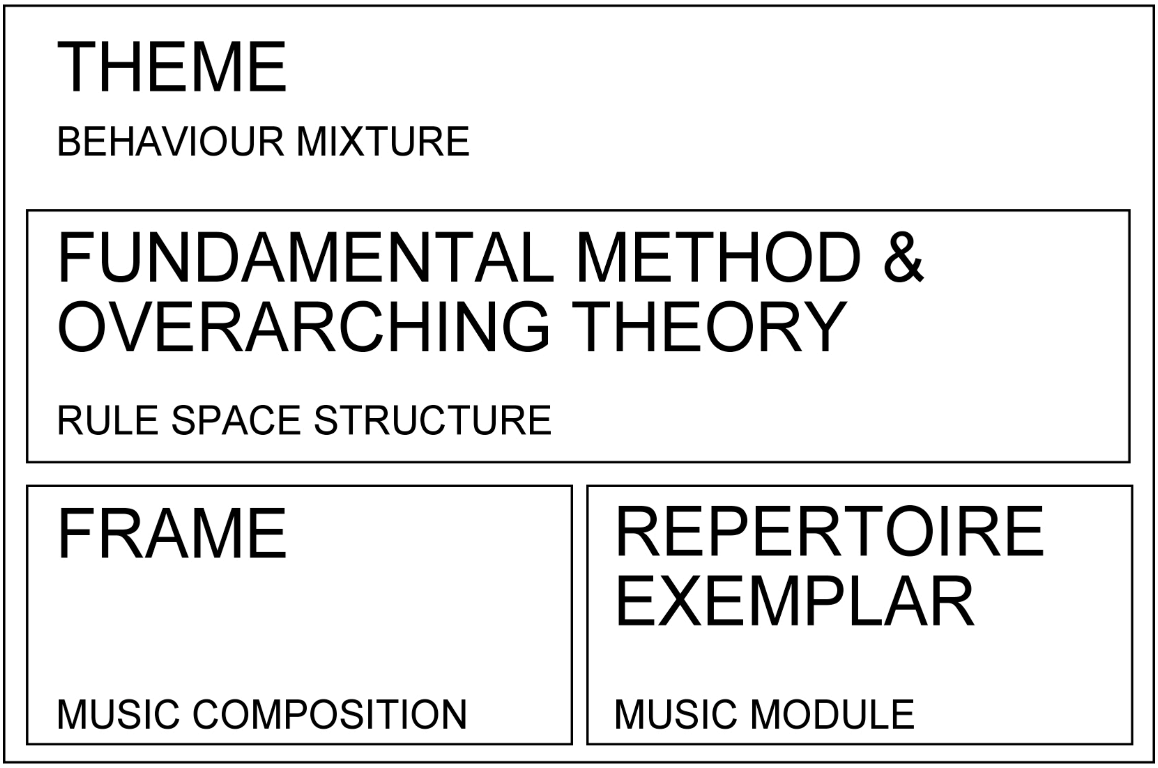

Figure 1. Reflective practice context of Generative Music and Cellular Automata

Creating mixtures of behaviour from rule space introduces the key problem-setting *theme*. The bounds of the work are *framed* by music composition, and music modules are the *exemplar* drawn from previous practice-based experience with modular music synthesizers. *Fundamental methods of inquiry and overarching theory* are designed to provide new insight into rule space structure. In particular, it turned out that a concrete and navigable graph structure for rule space can be created using CA state space graphs. My initial investigations were done manually, by printing out sub-trees and examining the resultant rule groupings. Much to my surprise, I discovered that CA dynamics are perfect for constructing structure within their own rule spaces.

Figure 2 MANIAC – a prototype generative music based synthesizer module

As part of this work, I have been independently developing my own prototype CA instruments for many years. A number of electronic music technologies have identical behaviours to well known CA, providing a fundamental link between the fields with familiar points of reference for both artist and scientist (Burraston, 2006). In addition to musical aspects, it is intended that this hardware be also used for real-time investigation and navigation of the rule space and associated dynamics, where there is a clear potential for further discoveries and application to other artistic projects. An example of one of these prototypes (*MANIAC*) is shown in Figure 2. In the photo there are three main panels offering various interface and control functions, including composite video output for display, stereo audio, synthesizer triggers, MIDI (Musical Instrument Digital Interface) and a standard PS2 keyboard interface for extended functionality.

CA have great potential in music, taking the composer from the familiar to the exotic, by simply changing the rule. A musical instrument based on CA is capable of simplifying the technological requirements of existing and future electronic instruments. This affords exciting possibilities for music, sound and other media technologies of the future.

***Rainwire*: Environmental Sonification of Rainfall**

The use of algorithms, and CA in particular, in the production of music is one approach to musical practice. Another is to use environmental processes as the starting point. In both cases, an evolving pattern is used as the basis of the generation of music. In both cases, an art/science perspective informs the practice.

Sonification is the presentation of data or information via sound (Kramer, 1994). The *Rainwire* project forms part of an art/science initiative to investigate environmental 'sonification'[iii] of land based natural rainfall using large-scale long wire instruments. A central environmental and climatic problem of 21st Century science is the protection of freshwater resources. Availability of freshwater for human consumption, agriculture and industry is both a national and international concern. The main source of freshwater is rainfall, and underground water sources are also ultimately dependant on this same source. Solutions to the complex problem of understanding natural rainfall events are vital for informed sustainable land management, as well as fundamental research in complex systems, climatology and meteorology.

Australian composer, Alan Lamb, originally created the long wire instruments for the sonic art project from disused sections of telegraph wires. He developed new construction methods for these large scale installations by using high tensile fencing wire constructed in single or multiple spans across an area of the landscape, usually in rural locations

(Lamb 1991, WIRED Lab, 2011). Spans of long wire instruments can range from tens to hundreds of metres, up to a total multi-span length of several kilometres or more, usually supported by poles or attached to very large rocks. Spatial arrangements have often been in the form of a single line, angled lines, parallel lines, radial lines from a central point to compass points (e.g. NE/SW), although many types of configurations are possible. Construction of long wire instruments has taken place on flat land, across gullies, down hillsides, over complex terrain and sections of water. Long wire spans are classed as 'suspended cables', which exhibit a complex variety of non-linear dynamical behaviours, and are an archetypal complex system with applications in many fields of engineering e.g. mechanical, civil, electrical, ocean and space.

Suspended cables have significant research interest, in particular the investigation with random excitation and rain-wind induced vibration, is a vital area where new studies and results are important (Ibrahim 2004). Rainfall event properties are key requirements for research in environmental processes, agricultural processes, flood management, rainfall simulation and modelling, built environment and urban drainage (Dunkerley 2008). Research in understanding and detecting global and regional environmental change require these rain event properties to be analysed in high resolution at the sub-daily level.

Generally, methods of sonification of environmental data for scientific application to date have been based on digital sound generation from data, as opposed to analogue means. In such projects, the phenomena under examination have been sampled to create data sets that are subsequently 'mapped' in an arbitrary way to sound synthesis engine parameters that produce audio output. However, the more the data is mediated, the less direct the relationships are between the stimuli and responses. The resultant audio in typical sonification bears a somewhat arbitrary relationship to the source phenomena because the process is abstracted through the creation of a data set.

Long wire instruments differ fundamentally from existing data based sonification processes and rainfall measurement devices by generating sonic events directly from rainfall patterns in real-time through induced cable vibrations. Piezo[iv] transducers are used to convert mechanical vibration into audio signals for recording, measurement and analysis, effectively 'sonifying' the rainfall patterns. An example of a set of pickups attached to the wires for a recording is shown in Figure 3. A test sonification of a rainfall event using a long wire instrument is available online (Burraston 2010). This sonification demonstrates the feasibility of the system to be able to capture rainfall events and convert them to sonic information without any data abstraction. Additional recordings of rainfall events that were captured purely for artistic and music composition are also available online at WIRED Lab 2011[v].

Figure 3 Piezo pickups attached to long wire instrument at WIRED Lab

Environmental sonification and earlier artistic composition of rain-induced sounds with long wire instruments, have resulted in a wide range of unique, audibly recognisable features. An example spectrogram makes some of these features visible in Figure 4 showing time horizontally, frequency vertically and intensity by shading. Such features appear highly connected with rainfall event properties e.g. duration, intensity, event profile and drop size. These unique sound properties can take the form of high frequency crackles, sizzling, high to low frequency swept zaps similar to the sounds produced by a sound synthesizer, metallic pings, strange percussion and clicks. All of these features exhibit dynamic amplitude and spectral characteristics depending on the rain type and environmental conditions.

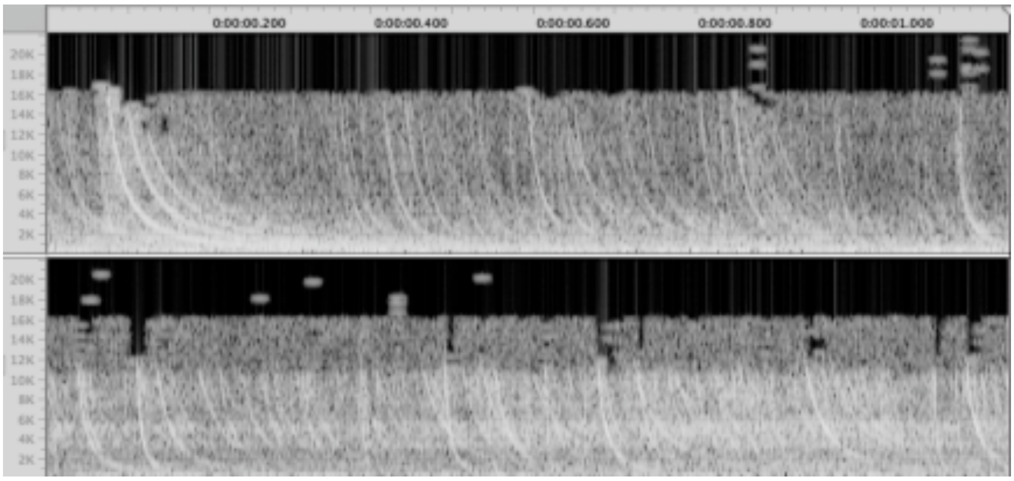

Figure 4 Spectrogram of *Rainwire* recordings

Acoustic analysis using Digital Signal Processing[vi] techniques have been successfully applied to rainfall measurement at sea using underwater acoustics for decades. Initial research was conducted during the Second World War when rainfall was discovered to impact on military sonar. Techniques were subsequently developed for acoustic rain gauges [vii] to identify rainfall events through unique frequency spectrum characteristics. The unique characteristics of rainfall hitting water are created by the initial impact and the subsequent formation of an underwater bubble for certain raindrop sizes. These variable drop impacts produce different frequency signatures as a result of this unique mechanism, which can be used to deduce important rainfall parameters (Amitai and Nystuen 2008).

Detection, analysis and quantification for *Rainwire* are inspired by the underwater acoustics methodology used for acoustic rain gauges. However, it should be noted that the physics of the two processes are completely different resulting in different spectral responses and signatures for rain induced vibrations on wire / suspended cables compared to water surfaces. Future research will therefore require the detection of new spectral signatures associated with long wire systems, as well as the identification of any potential background noise or tones, and identification of any potential limitations. As with underwater acoustics, background sounds will need to be identified. A land based long wire instrument can potentially be subject to a number of unwanted sounds through the sensitive piezo transducers such as: insect collisions on the wire, spiders, birds (both collisions and perching), tree and leaf debris, wind noise and Aeolian tones[viii], man made interference sounds such as electric cattle fences and radio transmission beacons.

Complexity measures can provide a measure of a system's organizational complexity (structure, regularity, symmetry and pattern). Complexity measures are an important complimentary addition to quantifying degrees of randomness, because measures of randomness cannot measure the structure or organisation within a system.

The reflective practice strategy being developed is based on the following context. The key problem setting theme is the creation of rainfall induced environmental sonification recordings. The bounds of the work are framed by music composition, the same frame as applied to Generative Music and Cellular Automata. The long wire instrument forms the exemplar drawn from previous practice-based experience with this instrument. Fundamental methods of inquiry and overarching theory are designed to encompass stochastic vibrations and non-linear dynamics of suspended cables.

The *Rainwire* project will enable a bidirectional influence between the artistic and scientific investigations of long wire instruments. Some more details are presented in (Burraston 2011) and part of the future work of this project will be to extend the reflective practice aspect of the research in order to enhance this bidirectional influence.

Conclusions

A new approach to experimental music and complex systems has been presented in a reflective practice context under the general notion of creativity and complexity. A description of the main aspects of a reflective practice methodology was presented in this context. Experimental music experiments have the capability to both produce music and inspire further development of complex systems research. The connection between creativity and complexity has positive implications for future work in both science and music. This will serve to encourage interdisciplinary collaboration between the arts and sciences in that task. Environmental sonification of natural rainfall events for the production of music, have formed the impetus for preliminary scientific investigations. *Rainwire* has the potential to contribute to the complex systems research knowledge base and a reflective practice methodology for this project is currently being developed.

Acknowledgements

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[i] Steve Reich: an American composer who pioneered the style of minimalist music. His innovations include using tape loops to create phasing patterns http://www.stevereich.com/

[ii] CA (Cellular Automata): a collection of "coloured" cells on a grid of specified shape that evolves through a number of discrete time steps according to a set of rules based on the states of neighbouring cells. The rules are then applied iteratively for as many time steps as desired. von Neumann was one of the first people to consider such a model, and incorporated a cellular model into his "universal constructor."

[iii] Sonification is the use of non-speech audio to present information. An early application of sonification was the Geiger counter, a device measuring ionizing radiation. The number and frequency of audible clicks are directly dependent on the radiation level in the immediate vicinity of the device.

[iv] The term 'piezo' is derived from the Greek piezein, which means to squeeze or press. It is a prefix used in piezo pickups.

[v] The W I R E D Lab is a project that will consolidate and expand upon the 30 years of research by Dr Alan Lamb into an instrument and device he calls The Wires. Lamb is an artist, biomedical research scientist and General Practitioner and his investigations of The Wires have their foundations in site-specific installation, experimental audio and sound composition: http://wiredlab.ning.com/

[vi] Digital signal processing (DSP) is a modern technique for processing signals by a sequence of numbers or symbols. A CD player operates on digital signals, a cassette player operates on analog signals from tape. It allows complex operations to be performed cost effectively through the use of microprocessor-based integrated circuits.

[vii] Acoustic Rain Gauge: An instrument designed to determine rainfall over lakes and oceans. A hydrophone is used to sense the sound signatures for each drop size as rain strikes a water surface. Since each sound signature is unique, it is possible to invert the underwater sound field to estimate the drop-size distribution within the rain. Selected moments of the drop-size distribution yield rainfall rate, rainfall accumulation, and other rainfall properties: http://www.termwiki.com/EN:acoustic_rain_gauge

[viii] Aeolian tones Sound, usually in the band of audible frequencies, associated with wake-eddy, vortex-produced pressure fluctuations resulting from air-flow around obstacles, such as wires and twigs.