Cybernetic principles and sonic ecosystems

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ABSTRACT

The theoretical basis for the installation Oscilloscope *is discussed in this paper along with a description of the applications of these ideas in the practical implementation of the work. It is argued that, despite the different idioms these practitioners work in, there are conceptual commonalities in the generative music of Brian Eno and the musical ecosystems of Agostino Di Scipio. Both these artists' work is influenced by principles of cybernetics, in particular the notion of emergence where the composer's role is not on designing outcomes but on designing systems whose component interactions produce desirable outcomes. A synthesis of these ideas are also applied in the design of* Oscilloscope*, demonstrating how a system that is relatively simple technologically and with fairly trivial sonic and visual material can be tuned to produce interactions that generate complex results that provide a rich, engaging experience for the viewer. In addition, this discussion critiques the notion of interactivity in electronic music.*

1. INTRODUCTION AND SYSTEM DESIGN

An installation, by necessity, establishes a relation to its setting which, either through reinforcement or contrast, reveals conditions or characteristics of the environment and indeed of the artwork itself. It can therefore be said that installations, to some degree, interact with their environmental setting. Where installations contain dynamic, non-corporeal phenomena, such as sound and video, deeper forms of interactivity are afforded.

Oscilloscope is an installation featuring sound and computer animations generated in real time in response to image data of the installation's environment captured from a camera. This work was developed for the launch night of the city of Coventry's UK City of Culture Bid 2021 and was first presented at Warwick Business School in the Shard in London in June 2015. The original animation was made in Apple's Quartz Composer software, which reads image data from an attached camera and from which individual pixel data is used to stimulate the movement of the graphics as well as controlling the playback of audio loops in Ableton Live on a second computer. Subsequently, however, the generation of the graphics has been changed so that it is now performed in Processing 3. Inter-application communication is achieved using Open Sound Control. The system design is shown in figure 1.

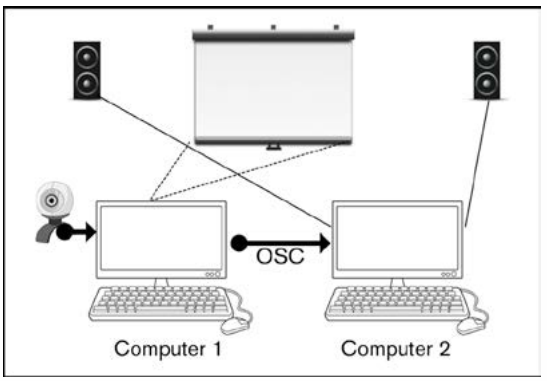

Figure 1. System design for *Oscilloscope*.[1] Computer 1 reads in image data from a USB webcam and reads pixel values using Apple's Quartz Composer software. Within Quartz Composer, these data increments the phase of sinusoidal functions, the outputs of which are sent via OSC to Processing 3, which generates the visuals to be projected. At the same time, when the outputs of these functions reach threshold values, trigger messages are sent via OSC to the second computer running Ableton Live to play or stop looped tracks.

This work, and in particular the interactive sound texture, draws influence from composers who have utilised principles of cybernetics, systems theory and complexity theory in their compositions, notably Brian Eno and Agostino Di Scipio. The work seeks to combine ideas utilised in Eno's generative music systems with Di Scipio's musical eco-systemic design. The ease with which these two technologically differing systems may be integrated is a testament to the shared cybernetic ontology that underpins the work of both composers. The focus of emphasis in the creation of this musical work is the cybernetic process, which significantly differs from usual approaches to computer music making.

2. CYBERNETICS AND ENVIRONMENTAL INTERACTION

Cybernetics is the science and study of systems and in particular how information flows between man, machine and environment in a matrix of feedback loops that may form emergent behaviours. While both composers have explicitly cited cybernetics as an influence on their work (Eno in [1], Di Scipio in [3]). They have also made explicit other composers who have utilised cybernetic techniques that have influenced their compositional process. Of particular interest to this paper, both composers build on compositional ideas espoused by Xenakis (Eno in [1], Di Scipio in [2] and [3]).

In 1963 Xenakis attempted to 'generalize the study of musical composition with the aid of stochastics' [4]. To this end he utilized the methodology found in W. Ross Ashby's 1956 book, *Introduction to Cybernetics* [5]. From this extrapolation of Ashby's work Xenakis further postulated that 'second order sonorities' would emerge from the interactions of sonic grains: the idea that the interactions of grains over time in the compositional process, at a 'micro level', would form timbres and compositional gestures at the 'macro level' (i.e. the grains, when combined in a certain way, would exhibit emergent behaviours). Xenakis first implemented his granular compositional technique in *Analogique A* (1958) for string ensemble and *Analogique B* (1958–59) for tape. Although both Eno and Di Scipio have criticised Xenakis' approach (Eno in [1], Di Scipio in [2]), the idea that emergent (musical) behaviour can arise from composed interactions underpins both composers' working methods.

At root both Eno and Di Scipio share the desire to create autonomous musical systems that are modelled on the way in which living systems generate complexity and that are also able to display emergent behaviour. Both composers reject the linear design ontology of the majority of interactive computer music systems in favour of ecosystemic systems design; a constructivist ethos in which the design of interactions of a system's components, prior to performance, takes precedence over a macro musical design, shaped by a composer in realtime during a performance. Di Scipio notes that, '[t]his is a substantial move from interactive music composing to composing musical interactions, and perhaps more precisely it should be described as a shift from creating wanted sounds via interactive means, towards creating wanted interactions having audible traces. In the latter case, one designs, implements and maintains a network of connected components whose emergent behaviour in sound one calls music' [3].

Eno first encountered cybernetics as an art student in Ipswich in the early 1960's under the tutelage of the telematic artist and cybernetics enthusiast Roy Ascott. Eno later read the cybernetician Stafford Beer's book *Brain of the Firm* (1972), from which he has extensively quoted and used as a justification for his compositional approach [6]. Eno States that: 'the phrase that probably crystallised it most [Eno's cybernetic approach to music]…says "instead of specifying in full detail; you specify it only somewhat, you then ride on the dynamics of the system in the direction you want it to go". That really became my idea of working method' [1]. Thus we may see a preoccupation with systemic deign in composition; one which is reliant on the setting of some initial parameters but equally relies on a medium which provides dynamic interaction. Pickering notes that, 'such systems can thematize for us and stage an ontology of becoming, which is what Eno's notion of riding the systems dynamics implies' [6]. Eno observes that this type of system generates 'a huge amount of material and experience from a very simple starting point' [7], further emphasising the cybernetic tropes of becoming and emergence.

Eno's generative music systems have been realised by a number of different technological means, including the VCS3 synthesiser, analogue tape manipulation and the KOAN generative music software. The method emulated in this composition takes inspiration from Eno's tape based composition *1/2*, from the album *Music for Airports* (1978). The design of *1/2* consists of individual vocal sounds (wordless "aaahhs" in the key of F Minor) recorded onto separate lengths of tape between fifty and seventy feet long [8]. To facilitate these long loops, the tape was spooled around metallic studio chair legs. Eno then recorded these non-contiguous loops back onto the multitrack tape: 'I just set all these loops running and let them configure in whichever way they wanted to.' [9] The complexity of the piece arises from the five-second vocal recordings, recorded on to tape loops of differing lengths, at times coalescing to form chords and shifting melodies and at other times leaving silence or only individual notes. The aesthetic effect is of a rather sparse angelic choir but producing a texture that is predetermined but not predictable. There is no meter or pulse but the notes appear to interact in a knowing and predestined way; the structure seems designed but at the same time beguiling.

The aesthetic effect of this piece demonstrates Eno's preoccupation with what Nyman called the 'cult of the beautiful' [10], but it also sees him engaging in the 'new determinacy' [10] techniques employed by his contemporary, English experimental composers, such as Gavin Bryars and Cornelius Cardew. However, Eno's version of the new determinacy is a strictly technological one, in which the timing and tone of the piece is mitigated by technological means. This is also a probabilistic process, but specifically designed to produce a class of goals. It is also noteworthy that the environment is active in the technological process. This is seen in the long tape loops, which are passed out from the tape recorder and spooled around objects such as metallic microphone stands and chair legs, the friction of which will alter the timing of each loop in a slightly unpredictable way.

Di Scipio's design ethos is one that encompasses the environment in the man/machine interaction, and thus embraces a tenet that is central to the cybernetic ontology. In fact he makes his cybernetic approach explicit when discussing interactive computer music: 'I try to answer (the question of interactivity) by adopting a system-theory view, more precisely a radical constructivistic view (von Glasersfeld 1999, Riegler 2000) as found in the cybernetics of living systems (Maturana and Varela 1980) as well as social systems and ecosystems (Morin 1977)' [3] With this paradigm in mind, Di Scipio approaches the question of interactivity from an ecological

viewpoint: 'The very process of interaction is today rarely understood and implemented for what it seems to be in living organisms (either human or not, e.g. animal or social), namely as a by-product of lower level interdependencies among system components. In a different approach, a principal aim would be to create a dynamical system exhibiting an adaptive behaviour to the surrounding external conditions, and capable to interfere with the external conditions themselves [sic]' [3].

He further states that the system should be capable of being a 'self observing system' (independent from an agent/performer), one that is capable of tracking what happens both externally and internally and making adjustments accordingly. He sights Gordon Mumma's *Hornpipe* (1967) as a pioneering example of such a system [3]. Here, interaction is no longer agent acts, computer re-acts, as in the linear model; instead it becomes a fundamental structural element from which a system may emerge. The flow of energy in the system is no longer one way (i.e. from the composer in real time); energy may be derived from the environment and a composition may be self-sustaining, with little real-time input from a composer/performer. It becomes obvious that in such a system the design of the interactions between all the components are fundamental to the construction of the composition; without a considered, eco-systemic design, interactions will simply not occur. He states, 'I think that these interrelationships (between elements of a system) may, instead, be the object of design, and hence worked out creatively as a substantial part of the compositional process' [3].

Di Scipio is keen to assert that the vast majority of interactive computer music conforms to the aforementioned linear model and as such the eco-systemic, cybernetic approach reflects a "paradigm shift" in compositional approach [3].

3. SYSTEM IMPLEMENTATION

The emulation of Eno's tape-based system is achieved using the Ableton Live software. Loops of tape are substituted with non-contiguous loops of audio samples, which, when played simultaneously, never repeat the same sequence twice. Thus a complex, laminar and ephemeral compositional emerges. The sound materials that make up these loops reflect the aesthetics of the visuals. It must be stressed that in terms of this paper the resultant musical structures, while they may be considered aesthetically pleasing, are of secondary importance to the generative process through which they were constructed and how these are resultant of, and interact with, the environment and the visual material.

The shifting geometrical shapes in the visual material are made from two "rings", each constructed out of a triangle strip, joined together end to end. Figure 2 shows how the structure of one ring is made up with the shading removed and the lines of each triangle made visible. Alternate vertices of each ring's triangle strip define a closed loop and so the whole shape can be described by three loops, two at either end and a loop common to both

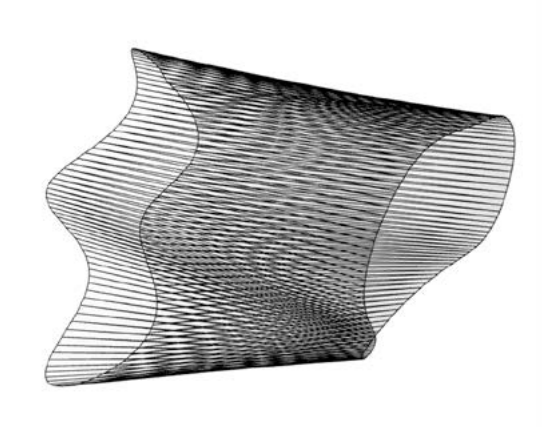

Figure 2. One of the rings that make up the moving shapes of the image. Lines connecting the vertices have been made visible to show how a ring is made from a triangle strip joined at both ends.

rings at the shape's centre where the rings join. The shape, as seen in the animation, is shown in figure 3.

A closed loop such as a circle or ellipse is defined by a two-dimensional sinusoidal equation. Therefore, the animation of each of the loops can be achieved through modulation of the amplitudes and frequencies of their sinusoidal components. In figure 2 it can be seen that these equations determine the location of vertices in the y and z planes, but in addition a third sine wave component is used to vary the x positions of the vertices and thus modulate the "width" of the ring. In this work, these amplitudes and frequencies are themselves modulated by sine waves of fixed amplitudes but whose phase is incremented by pixel values from the image data obtained from the camera. Through this process, arbitrary motions can be created in response to the environment but within limits set by the creators of the work.

Complex motions can therefore be achieved with fairly simple mathematical processes similar to AM and FM synthesis processes familiar to the computer sound designer. Thus, although the basic shape is very simple, the layers of modulation processes on the shapes structure create complex bio-mimetic movement giving the visual effect of a highly-abstracted sea creature. However, the point of interest here is that this bio-mimesis arose, not from a 'top-down' design that seeks to emulate the totality of complex movements, but from the set up of multiple modulations whose unpredictable interactions generate patterns that can be seen as an emulation of the motion of a living organism. As a result of this mimesis, sound samples that have a direct correlation to water are used which reflect the emergent properties of the animation.

Further generative interactions were designed and inspired by Di Scipio's compositional method. Di Scipio's design ethos has been adhered to in the creation of this piece via the interactions between the environmental input of the camera source and the musical and visual software. A grid of twelve discrete point sources is derived from the incoming image produced by the camera and changes in light intensity of these sources indirectly trigger individual sample loops to play or stop. Intensity values increment the phase of sinusoidal functions of the

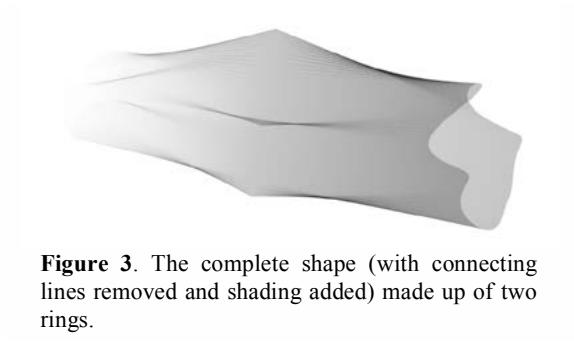

Figure 3. The complete shape (with connecting lines removed and shading added) made up of two rings.

visual material, which outputs "play" or "stop" messages to individual sequencer tracks once threshold values are crossed. In this way, the twelve light point sources are mapped to thirty sample loops to create a matrix of non-linear triggering possibilities. Thus, the rate of change of individual sonic and visual components within the installation are constantly changing in response to light conditions in the surroundings as read by the camera. The speed of one loop of the visual material also determines the tempo of the sequencing software so that a higher speed will generate more triggering opportunities. Many of the samples are also subject to real-time digital signal processing techniques which are controlled by automated control envelopes. The speed at which the envelopes move through their control cycle is determined by the tempo and thus changes with alterations in overall light intensity. Thus, through these structured interactions an autonomous autopoietic musical and visual system is achieved.

4. CONCLUSIONS

Although it is recognized that this installation is conceived in the digital domain, the title *Oscilloscope*—referring to a form of analogue computer display, was chosen to reflect the critique of common assumptions of digital technology that this work represents. The processing of discrete bits of information facilitates linear mapping formulae where a single input value produces a related output value. With such an approach, there is a tendency to produce complexity through accretion; either the accumulation of more inputs and outputs or the linear chaining of mappings between a single input or output. With this work, the aim was to avoid such linearity between the visual input data and the resulting material through the designing of low-level interactions between simple materials. The sounds and visuals of the piece are therefore not a mere sonification or visualization of input data but the result of processes driven by that data.

It is important to state that the system's interactions are only indirectly implemented, as Di Scipio puts it, interactions are the 'by-product of carefully planned-out interdependencies among system components, [which] would allow in their turn to establish the overall system dynamics, upon contact with the external conditions' [3]. He also believes that this type of construction is akin to the mapping in living organisms that allows emergent behaviour to occur. The further coupling to the Eno system to Di Scipio's increases the complexity of the interactions and further enhances the possibility of emergent musical behaviour.

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