Turing and the Innovative use of Reverb in the film score of *Blade Runner*

Jenny Game-Lopata[1]

Abstract. In 1982 composer Evangelos Odysseas Papathanassiou (Vangelis) generated a vast spacial distance in his soundtrack to Ridley Scott's science fiction film Blade Runner by running his instruments through the first commercially available digital reverberation sound processor (the Lexicon 224). By using digital reverb to add depth and space to his instrumentation, he generated a rich musical milieu to complement the film's futuristic cityscapes, and redefined meanings associated with a reverb in music. The process by which reverberation algorithms were applied to an audio input signal was enabled by Alan Turing's digital computer outlined in 1936. Just as the Turing machine proved a harbinger of the digital age, Vangelis was a pioneer user of digital delay, which he helped to make famous in his soundtrack to Blade Runner. His use of digital signal processing and delay processes that imitate analogue audio signals and natural reverberation, parallels Blade Runner's narrative, which explores the replication of human behaviour in bio-machines or Replicants. Vangelis achieves this with a multi operational process of composition that relies on a highly interactive, creative spontaneity more than a clearly defined or imitable structure.

1 INTRODUCTION

When discussing the concept of digital computers in 1936, Turing explains, "these machines are intended to carry out any operations which could be done by a human computer" [1]. (The human computer referred to at this time is a person who does computations). His notion involves using the digital computer as a tool to relieve the human computer of arduous, or impossibly complicated mental tasks. The notion that the digital computer is a tool that automates and mimics human thought processes brings us to the realm of behaviour. In the film Blade Runner [2], Replicants (genetically engineered bio-robots) are comprehensive human tools; slaves, used for their physical and mental abilities to relieve humans of arduous mental and physical tasks. By imitating human activities and thought processes, the Replicants behave like humans. Turing's Imitation Game[2] tests whether or not a digital machine can behave in a way that is indistinguishable from humans. He argues that the best strategy for the machine is to "try to provide answers that would naturally be given by a man (person)" [1]. Blade Runner's Replicants achieve this with enough sophistication to demonstrate intense passions of romantic love and life itself.

In his score to Blade Runner [2], composer Evangelos Odysseas Papathanassiou (Vangelis) uses music on a number of levels. He uses it to: communicate ideas, in particular the notion of physical space; to enhance the emotive impact of the drama and to represent the themes, notably the idea that machines can imitate human behaviour. John Jacques Nattiez asserts, "a musical work is not merely a whole composed of structures. Rather, the work is also constituted by the procedures that have engendered it (acts of composition), and the procedures to which it gives rise: acts of interpretation and perception" [3]. We shall see that although Vangelis views his compositional process as constituting an organic, highly spontaneous, interactive method, it also involves numerous complex operations.

Music may be considered a universal activity not by its surface structure but in something deeper in the human psyche that is common to all cultures. It exists as a symbolic form, with the "capacity (with all other symbolic forms) to give rise to a complex and infinite web of interpretants" [3]. While music is not inherently narrative, it can be incitement to make a narrative, or to analyse. Composers and listeners will make their own associations and connections. Furthermore, we will see that many associated meanings in music are the result of acculturation.

This paper looks at the first commercially available digital reverb machine, released in 1978, the Lexicon 224 used by Vangelis in Blade Runner [2]. The ability to represent spaces, such as concert halls, landscapes and moods by adding artificial reverb to recordings, has imbued it with associated meaning. In Blade Runner, Vangelis's application of the vast new capabilities of digital reverb not only enhances the representation of a futuristic world populated with Replicants but also redefines and alters the perception and association of reverb in film music.

We will see how Vangelis' use of digital sampling and delay in the soundtrack is analogous to the on-screen story. Vangelis' use of a machine, which replicates human processes to communicate meaning through music, parallels the film's theme about Replicants; bio-machines that imitate human operations and desire human qualities.

[1] School of Arts, University of New England Armidale, NSW, Australia. Email jgamelop@une.edu.au

[2] The Imitation Game is played using: person 1 (A), a digital computer (B), and person 2, an interrogator (C). The interrogator is in a separate room and through asking questions, is required to determine which of the other two is the man and which is the digital computer

Communication via the transmission of radio signals had been extant for little more than 50 years and the recorded music industry was barely decades young when Alan Turing's concept of a digital computer heralded the electronic microcomputer. His vision was of a universal digital machine "that can mimic any discrete state machine" [1] to replicate human computers and by extension, their behaviour or as Turing states, "C [a particular digital computer] can be made to play satisfactorily the part of A in the imitation game, the part of B being taken by a man" [1] has since seen numerous applications. Digital signal processing (DSP), being just one of these applications, particularly as it is applied to digital reverb, is a focus of this paper. From Turing's notion that instructions can be broken down into discreet units we arrive at sampling. Sampling breaks an audio wave into small segments that can be represented digitally before being processed and reconstituted as analogue audio. As such, through DSP, the Turing machine is applied to replicate the human desire to communicate using music, a sophisticated human behaviour. Story telling in the form of film, another significant communication medium also utilises music to communicate, enhance drama and to represent themes.

In Blade Runner [2], the generous application digital reverb from the Lexicon 224 is used by Vangelis to magnify the city and the airspace above it, to give it an innovative highly surreal, space-age ambiance. By running audio signals from his analogue synthesisers, acoustic instruments and percussion (both analogue and digital) through the Lexicon 224 digital reverb machine, he also generated previously unheard sounds that added depth to the internal spaces of the futuristic city. Before digital reverb, natural spaces and relatively awkward analogue machines were used to generate limited echo effects.

The historical application of reverb in film and other forms of recorded music had earned it a somewhat poor reputation among audiophiles, and an association with 'schmultz' or soft focus scenes in the film world. In Blade Runner [2], Vangelis applied the Turing machine in the guise of digital reverb to challenge existing perceptions and, as a result, influenced the use of effects in film and recorded music to date.

In terms of Turing's conception of the digital computer, (Store, Executive unit and Control [1]) extant in today's microprocessor, we now have machines that can accept an audio signal, then sample, measure, store and filter it before outputting it as music. In this case, music that represents Blade Runner's dramatic themes focuses on the ability of Replicants to imitate human behaviour.

The term 'electronic music' includes electronic musical instruments, as well as electronic music technology. Analogue signals are commonly measured, filtered and compressed in the recording process. DSP in electronic music represents discrete audio signals as numbers and then processes them. Digital reverb is added to a signal to alter the output or sound of the audio signal, the resultant music.

2 DIGITAL SIGNAL PROCESSING

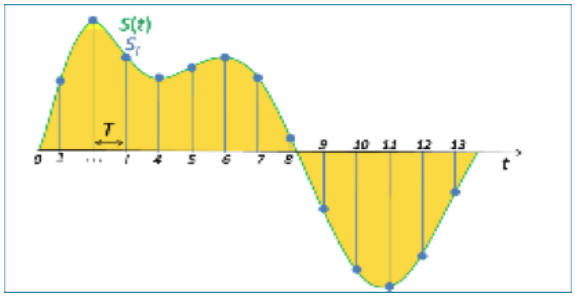
Turing refers to the digital computer's store as corresponding to the human computer's paper, and that "in so far as the human computer does calculations in his head a part of the store will correspond to his memory" [1]. He goes on to surmise that it "must be possible to write into the store any one of the combinations of symbols which might have been written on the paper" [1]. This connection between digital and human memory is explored in Blade Runner [2]. The Replicant known as Rachel is better able to imitate humans, taking longer to be detected as a Replicant in the film's version of the imitation game, as she has an implant containing false memories. She 'remembers' a childhood and family, even how to play piano.

The Replicants in Blade Runner are also superior in physical strength and mental abilities, as they are what Turing termed 'universal machines'. He reasoned, "provided it could be carried out sufficiently quickly, the digital computer can "mimic the behaviour of any discrete state machine. ... The imitation game can then be played with the machine in question (as B) and the mimicking digital computer (as A) and the interrogator would be unable to distinguish them" [1].

Similarly, the aim of digital signal processes is to measure, filter and/or compress continuous analogue signals, a tool, or machine, used for human communication, rather than an actual human behaviour. The first step is usually to convert the signal from an analogue to a digital form by sampling and then digitizing it using an analogue-to-digital converter (ADC), which turns the analog signal into a stream of numbers. The output signal, usually another analog signal, requires a digital-to-analogue (DAC). This digital computing process is more complex than analogue processing and has a discrete value range, but it has superior error detection and correction in transmission as well as data compression [4]. In this way the Turing machine is used to replicate the human activity of signal transmission.

The Australian built CSIRAC (Council for Scientific and Industrial Research Automatic Computer), one of the world's first stored-program, electronic-digital computers, is thought to have been the first computer to play music, as early as 1950-51. Originally known as the CSR Mk 1, Geoff Hill programmed it to play a musical melody, albeit with very crude sound production. Raw pulses of the computer's data words, the bit stream pulses, were sent directly to an audio amplifier with a loud speaker attached. The music was produced in real time, as there was no mass storage (such as magnetic storage tape) available at this time. Other challenges to overcome included significant timing issues and the mastering of complex sound generation processes, before a stable, pre-determined frequency output was generated [5].

Computers deal with numbers, or digits, and sound consists of continuously varying electrical signals. The challenge was to accurately link them together for direct computer sound synthesis. The waveform needs to be represented such that it can move and undulate in a seemingly infinite variety of ways, but with a finite string of numbers, with a finite number of digits. To achieve this, the wave is divided into a large number of segments, each being short enough in time that the waveform (or shape) does not change very much during the segment. The average amplitude of the waveform over each segment can then be converted into a number for the computer, and vice versa. The smaller the segments, the more accurate the imitation will be (see figure 1).



Source: Robertson.

Figure 1 Sampling as a continuous signal (the wave line) is reduced to a discrete signal (the vertical lines).

To convert sound waves into numbers, the waveform is sampled with a balanced modulator (or its equivalent). The sample pulse amplitudes are then measured with an analogue-to-digital converter (ADC), which is a fast voltmeter. Each sample thereby becomes a number that may be processed by a computer. Provided that the spectrum of the waveform has no frequency components above half the sampling rate, no information about the curve and undulations of the waveform are lost. As some natural sounds have energy above the audible range, a low pass-filter is needed to prevent these high frequencies from reaching the sampler and ADC. If signal frequencies higher than half the sample rate enter the sampler, the resultant copies will overlap the original spectrum causing alias distortion (where signals become indistinguishable) [6].

Conversely, the digital to analogue converter (DAC) accepts numbers one at a time from a digital source and generates one voltage pulse per number with a height proportional to the number [6]. Therefore, a DAC calibrated in volts would generate a voltage pulse of 2.758 volts in amplitude, if it were given the numerical input 2.758. The pulse width is constant, but will vary with different types of DAC[3]. Each pulse, or the number it represents, is called a sample, as it gives the waveform amplitude at a sample point in time. The frequency of the pulses is called the sample rate [6]. Figure 2 shows the process of analogue to digital and back again.

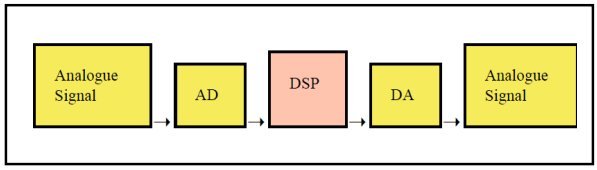


Figure 2. The process of analogue to digital and back again

In 1982, when Vangelis composed his score for Blade Runner [2], DSP applied to music was in its infancy. However, the effect of natural reverberation or echoes on the human voice and musical instruments was well known. People had been exploiting and trying to capture or replicate this effect in music for some time (see below). This is because the addition of reverberation (reverb) to musical sound can enhance the sound quality, and the affective communication of music. The human desire to imitate nature, a 'natural effect', for entertainment and communication through music, was strong enough to inspire the invention of analogue machines to capture the effect. Replicating reverberation using digital technology is a further application of the Turing machine. It demonstrates the universality of the digital computer or its ability to be programmed to imitate other machines. As a part of digital signal processing, reverb algorithms are applied to audio signals to alter the sound. The effect can simulate the reverberation of different rooms and spaces that in turn alters the musical atmosphere or milieu. We will see how this ability to replicate spaces and generate associative atmospheres was seized upon by Vangelis in his score for Blade Runner [2]. This human desire to replicate nature (reverb) with machines, and then machines with other machines in order to communicate music, correlates to the central theme of Blade Runner [2], as the Replicants increasingly seek to imitate more human behaviours. It is thereby fitting that Vangelis exploits the new digital reverb technology to represent and enhance this theme.

3 REVERBERATION

Musicians have responded to the reverberation levels and general acoustics of a given performance space for some time. For example, Gregorian chants and organ music are considered effective in medieval cathedrals, known for long-reverberation times. Some of the music of classical composers such as Mozart and Haydn was intended for performances in highly furnished chambers, and for smaller, intimate audiences. This music can be less effective when performed in highly reverberant spaces [7]. In addition, musical instruments were designed to capture reverb. For example, the Broadwood Piano Company of London introduced a 'sustain pedal' mechanism in 1783. Sympathetic vibrations would resonate throughout the full set of strings and across the soundboard. The success of these pianos was such that soon pianos everywhere came equipped with a pedal [8]. The ancient hammered dulcimer, some Baroque instruments (such as the lute), and many non-western instruments, such as the Indian sitar have sympathetic stings that generate resonance.

In the late 19th century early attempts to design a concert hall or opera house to achieve optimal acoustics began. The American Physicist Wallace Clement Sabine first measured natural reverberation, the result of sound reflecting off surfaces in a confined space, in the late 1890s [9]. He established the connection between the quality of a room's acoustics, the size of the chamber, and the amount of absorption surfaces that were present. His formula for calculating reverberation time is defined as the number of seconds required for the intensity of the sound to drop from the starting level by 60 decibels. This reverberation time is still used for gauging a room or space's acoustical quality. The sabin is the modern unit of sound absorption, is also still used architectural acoustics [9]. Sound emanates from its source at around 340 meters per second (the speed of sound),

[3] Resolution is the most important converter specification in data conversion technology (DAC/ADC). Resolution is measured in bits. It is the measure of the number of different voltage levels that a DAC can produce. For example, a 3-bit DAC accepts 3-bit binary numbers as input and can produce more than eight different voltage levels as its output See Ref 6.

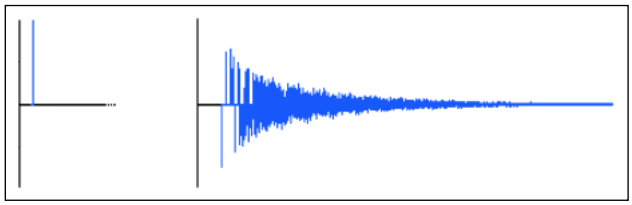
as sound strikes wall surfaces it will reflect, or echo off them at various angles. The sound then slowly decays, or decreases in amplitude. Some echoes will reach a listener's ears immediately while others continue to bounce off other surfaces before being heard. Hard, large surfaces, such as concrete walls, reflect the sound with modest attenuation, while soft surfaces will absorb a lot of sound, in particular the high frequency components. Consequently, it is the combination of a room's size, the complexity and angle of its walls, the room's contents (including people) as well as the density of the surfaces that will determine a room's individual acoustic or sound quality [7]. The optimum reverberation time for music depends on the instruments and style of music being played.

Before digital processing, reverb was created in a natural echo chamber or room. Audio was played through a loudspeaker and picked up with a microphone. This method is effective (and still in use), but reverb time cannot easily be adjusted, so rooms must be sound- proofed. Other methods involved transducers, similar to the driver in a speaker, to generate vibration in a metal plate or spring. While the spring was the most portable and affordable option, it was less effective as a device [7].

Turing may not have conceived of digital reverb, however in 1950 he believed that "in about fifty years' time it will be possible to program computers, with a storage capacity of about 10^9, to make them play the imitation game so well that an average interrogator will not have more than 70% chance of making the right identification after five minutes of questioning" [1]. He clearly conceived of the possibility of programmable digital machines that could store and execute complex operations such as those involved in DSP and digital reverb. In the digital environment, delay time is only contingent on available memory, while the number of reflections and simulation of frequency-dependent effects (filtering) is determined by processing speed [7].

Digital reverb is a dramatically more effective way to generate the effect than the previous analogue systems. It has enabled producers to easily place music into a variety of different rooms or spaces (acoustic environments). While Vangelis did not play a role in the invention of digital reverb, he quickly understood its potential and contributed its innovative application in the recording process.

Reverb is a time-invariant effect, that is, it does not matter when a sound (or note) is played, the same reverberation will result. Time-invariant systems can be completely characterised by their impulse response. The impulse response of an acoustical space (such as a room) can be measured to provide information regarding its acoustic qualities, such as the intensity of its reverberation and how long it takes to decay or die out. In its ideal form, an impulse is an instantaneous sound that carries equal energy at all frequencies, zero width, infinite amplitude and finite energy content. The echo, in the form of reverberation, is the room's response to that instantaneous, all-frequency burst [9]. A test signal such as a handclap, or a popping balloon, for example, can serve as an impulse. Signal analysis shows that after some density build-up at the beginning, the signal decays smoothly toward zero (see figure 3).



Source: Redman.

Figure 3. An impulse and its response.

Smoother sounding rooms show a smoother decay. In the digital domain, each sample point of the response can be viewed as a discrete echo of the impulse. Since, ideally, the impulse is a single non-zero sample, a series of samples or a sound played in a room is the sum of the responses of each individual sample at their respective times. Consequently, with a digitised impulse response, the exact room characteristic could be added to any digitised dry sound. By multiplying each point of the impulse response by the amplitude of a sample, a room's response to that sample could be calculated. If this is then applied to each sample of an audio signal, a collection of overlapping responses is generated that can be added together to generate reverb [9]. With the measurable formula for reverb in place, it would appear to be inevitable that a Turing machine will be able to perform these calculations and replicate the reverb effect. This may be so, however the calculations are immense. As it would entail an enormous number of multiplications, it has proved more practical to use multiple delays and feedback to build up a dense series of echoes that die out over time.

The simplest digital reverberator is the delay of 30 msec or more inserted into the signal path where delayed and un-delayed sound can be mixed. The audible effect is an echo [6]. Parameters for the echo will include the size of the delay as well as the relative amplitudes of the direct and delayed sound. Multiple echoes can then be simulated by feeding some of the delayed output back into the input of the delay unit [6].

Mixing in similar delays of different sizes would increase the echo density and get the effect closer to natural reverberation. In practice, however, it takes too many of these hard echoes to make a smooth wall of reverb. The delay lines with feedback (or comb filters) result in frequency cancellations that can mimic room effects, but can also result in ringing and instability. While useful, these comb filters alone are not effective [9]. In 1962 Manfred Schroeder developed a feedback/feedforward technique whereby the resulting delay line had a flat frequency response. This is now referred to as an *allpass* delay. Parallel comb filters and a series of all pass reverberators results in a constant echo density.

When the filter is stable, the signal is seen as a series of identical impulses decreasing in amplitude. Consequently, the response sounds like the original signal decaying over time. Real rooms or acoustic spaces have an echo density that increases with time. By placing the all passes in a feedback path, a more natural reverberation decay is created.

Variations in this process and how the multiple delays are stacked together, give particular digital reverb units their characteristic sound. The earliest digital reverbs units, the

EMT-250 and Lexicon 224, made use of several series all passes at the inputs of the reverberation algorithms to increase the echo density. The innovation of putting *allpass* filters inside delayed feedback loops was not only fundamental to the algorithms of Lexicon 224; it is still used today [10].

Particular reverb units have their own unique sound qualities and the sound from Lexicon 224 the sound is realistic and extremely spacious. Its DAC and ADC converter cards contain two input transformers (stereo) and four larger output transformers to enable quadraphonic operation. The transformers are balanced directly on the cards. The quality of the Lexicon 224 algorithms[4], the older-technology 12-bit converters and the transformer isolation for the analogue audio signals are all thought to contribute to its sound [11]. Steve Lenham suggests that the older ADC may also contribute to its unique sound, as the Lexicon's 12-bit successive-approximation converter is old technology. This architectural difference is thought to affect the sound. Lenham also suggests that the transformer isolation of the analogue signals (used by few more modern/lower-end pieces of equipment due to the high cost) could contribute. He points out that passing the signal through a soft iron core gives a subtle distortion, similar in effect to analogue tape [11].

Turing's concept of 'store' (discussed earlier) advanced enough in thirty years to support DSP for music. The digital memory or DMEM card contains the working memory for the discrete DSP 16K words of 16-bit wide storage and is implemented using 4116 DRAMs (dynamic random access memory) that requires three supply voltages. The base of Turing's 'executive unit' [1] is seen in the arithmetic logic unit (ALU) in reverb systems, including a 16-bit, fixed point DSP constructed predominantly from 74-series logic integrated circuits (ICs). Finally, the idea of Turing's 'control mechanisms' [1] include a timing and control card that provide all clock and control signals for the discrete DSP. A bank of 6810 static random access memory (RAM) devices store the program to be executed [11].

A single-board computer card (SBC) holds the microprocessor and associated peripheral ICs. These include a small amount of RAM and a bank of erasable, programmable read only memory (EPROM) for program storage. The Lexicon 224 has interchangeable programs to simulate different chambers, plates and rooms. The SBC card manages the unit, handling the user interface and loading the DSP with the selected effect algorithm. With a 20kHz sampling rate the audio bandwidth of the original 224 was around 8kHz [11].

With the Lexicon 224 Vangelis had access to a digital device capable of simulating natural reverberation. He was innovative in his use of the Lexicon throughout his score to Blade Runner [2]. He infused the score with digital technology that helped to tell a story that reverberates with themes of machines simulating people.

[4] The sample rate in the Lexicon 224 digital reverb machine is 20 kHz, and the DSP executes 100 operations per sample. The DAC and ADC converters contain the input, buffer/gain trimming circuitry, anti aliasing filters and 12-bit audio converters. See Ref 11.

4 EQUIPMENT

Vangelis owned his own studio (Nemo Studios) that contained much state of the art equipment [12]. While the EMT250 released in 1976 was the first digital delay unit; it was expensive ($20, 000) with only 250 units were built [13]. The Lexicon 224 was released in 1978 with the more affordable $7500 price tag (with two programs, four cost $7,900). It was the brainchild of Dr. David Griesinger, a nuclear physicist/musician/classical recording engineer. He had studied artificial reverberation (plates, springs and multiple head tape systems) and had been working on a digital solution when the EMT 250 as released. He merged an S100 microcomputer with his reverb design and included a separate control unit for parameter adjustment and program [14]. Vangelis was the one of the first producers to use digital reverb buying the first Lexicon 224 in 1980. It had the serial number 0002 (the first unit remaining with Lexicon) [15].

The Lexicon 224 was used prolifically and was a big part of the '80s music sound [16]. 'The Concert Hall A' program in particular is said to be one of the finest reverbs ever made, and its plate programs played a major part on creating the '80s drum sound. In addition to playing a significant role in Vangelis' ground breaking Blade Runner [2] soundtrack, the Lexicon 224 was part of the sound of highly influential classics such as Talking Heads' *Remain In Light*, U2's *Unforgettable Fire* and Peter Gabriel's *So* [16]. The significance of the Lexicon 224 can also be demonstrated by the fact that it is still in use, as well as being available as a plug-in.

Vangelis applied a generous amount of reverb, particularly to his (analogue) sythesisers and percussion instruments. The effect of this was to add depth and space to the music and enhance Blade Runner's [2] vast, futuristic landscapes. The dynamic was changed for the viewer, becoming more experiential and absorbing. Until Blade Runner [2], the music underscoring science fiction films had been more effect-oriented with gurgles, beeps and high-pitched sounds etc. Vangelis generated an emotive score with maximum atmosphere and depth. He had a large number of synthesisers and sequencers (much of his gear was analogue, such as the renown Fender Rhodes and Yamaha CS80), and he put them all through the Lexicon 224.

He had two other pieces of digital equipment at the time, including an early Japanese electronic toy. The electronic noises in the scene where the principle characters Deckard and Rachel meet come from one of the first hand-held electronic games, a device called the Bambino UFO Master Blaster Station [15]. The early 1980s also witnessed the introduction of digital keyboard samplers where a single musical note (or any sound) could be sampled and played back using different notes on a keyboard. Vangelis's first sampler (which he used in Blade Runner) was the E-mu Emulator keyboard. Vangelis originally intended it to replace his Linn LM-1 drum machine and make drum patterns and sequencers using his own drum samples. The E-mu Emulator could also store samples internally. The Emulator keyboard's reaction time was too slow, however, and on Blade Runner [2] it was used primarily as a percussive sampler providing more sounds ready at Vangelis' fingertips [12]. These Emulator samples are featured in the bar scene.

There is a clear connection between the concept of digital sampling and replicating of sounds and effects for musical reproduction and the notion of Replicants that feature in Blade Runner [2]. Vangelis used digital replication of human communication via music to represent Replicants, who in turn desired the full gamut of human behaviours. The next section looks at some ways sound can communicate meaning.

5 ENHANCING THE DRAMA

This section demonstrates that by the time Vangelis produced the music for Blade Runner [2] in 1982, there were established ways of using reverb. Nevertheless, with the more realistic, and spacious digital version, he was able to extend and help re-define its application.

Reverb had been part of the recording process from its inception. By the time the major recording interests in the US and Britain began to adopt the electrical recording methods developed at Bell laboratories in the 1920s, radio broadcasting had already been using microphones for some years. The technical know-how and aesthetic premises for early music recordings came from radio broadcasting [17]. Microphones could pick up some room ambiance, but sound sources, whether vocal or instrumental, tended to be recorded directly in to the microphone (on-mic) in an acoustically dead (no reverberation) studio environment. The instruments and voices were approached the same way, with all voices recorded evenly. In radio dramas, sound effects were sometimes recorded slightly off-mic to produce an effect of aural depth (sounds would appear to be further away). This attaching of small amounts of reverb provided a life-like roominess to the recording.

The simulation of reverb as a part of radio communication points to the significance of abstract, symbolic imitation in human communication. By constructing tables of behaviour with his language of instruction, Turing was modelling the affective responses of the human mind. What about human reactions? Does this suggest that responses to abstract symbols might also be programmed into machines? This idea has creative expression in Blade Runner's Replicants. These bio-machines have human responses; they demonstrate fear of death in their quest for a longer life span as well as sexual responsiveness and love.

When Vangelis was adding digital reverb to his score for Blade Runner [2], he was contributing to and extending meanings previously associated with it, to the history human of responses to reverb. Through Vangelis's innovative application of reverb, Turing's universal machine is impacting the human experience audio entertainment. "Many meanings that we perceive as 'natural' are the result of codified systems to which we have become acculturated [3]." The early close-up flat-plane approach to recording mentioned above, was more intimate in style and led to popular music's crooner in the 1920s. It was the producers of classical music that first took advantage of the sense of physical space that 'off-mic' techniques enabled. The high art, concert going listeners, gravitated to the reproduction of reverberation as it simulated the concert hall. The extra-musical narrative of late romantic, program music was well suited to reverb. The sense of depth and space suggested by reverb suited the notions of program music and its allusions to countryside, wide landscapes and nature [17]. The continued influence of program music on film music is evident in Vangelis' application of reverb to enhance the vast futuristic city within which Blade Runner [2] is set.

This association of reverb with landscape was also evident in some early popular music. The crooner Gene Austin released My Blue Heaven in 1927 that sold more than five million copies. In stark contrast to the majority of popular recordings of the time, he used the off-mic and more reverberant technique for the instruments while still recording the vocals dry, on-mic [17]. The accompanying lyrics describe a soft twilight landscape which, when enhanced with the reverberation, deepens the sense of space.

Throughout the 1940s, reverberation effects were also selectively used to suggest dark spaces in horror movies such as Cat People, I Walked with a Zombie and The Body Snatcher [17]. Significantly, science fiction movies also tended to reflect outer space as a source of horror. This is evident in the early 1950s films such as It Came from Outer Space, Killers from Space, War of the Worlds, Man From Planet X, Phantom From Space and Invasion of the Body Snatchers. While the use of reverb in science fiction movies was not new, in his score for Blade Runner [2], Vangelis was able to undermine its association with horror spaces and extend its association with outer space to represent the future, thereby generating a subtle a paradigm shift.

Reverb also accumulated gendered meaning as it became associated with screen beauties in the soft focus shot throughout the 1950 and 60s. The term 'soft focus' originated in cinematography and refers to the fuzzy effect generated by diffused lighting. Soft focus shots were often used as the camera focused on a beautiful woman and was usually accompanied by high reverb music [8]. This standard coupling served a feminising function for filmmakers. Similarly, in Blade Runner, Vangelis applied generous amounts of digital reverb to the saxophone underscoring the romantic/sex scene between principal protagonists, Rachel and Deckard.

Western popular music of the 1950 and 60s also began to feature lush string arrangements that relied on heavy reverberation, as did 1970s mood music. These reverberent styles were enabled by the development of artificial reverb machines such as the plate and spring devices discussed above. This empahsised the hi-low art split, this time with audiophiles shunning the "distortion of authentic sound" [8]. Between 1953 and 1972, Annunzio Paolo Mantovani worked with Decca studio engineer Arthur Lilley to produce over 50 chart topping albums. A large part of this was due to the maximisation of echo effects applied to Mantovani's already lush, rich string arrangements. Lilley removed all absorbent materials, such as carpets and positioned ten or twelve microphones throughout the 28-piece string ensemble to reinforce direct and reflected sounds [8]. Hi-fi enthusiasts regarded the high amount of artificial reverberation such as that on Mantovani's recordings, to be excessive, deceptive and frivolous. By way of example, notable audiophile R. D. Darrel wrote in a 1953 article for Saturday Review that extrapolates on a letter from Mozart to his wife, where he commented on the immense enjoyment he received from hearing a performance of his music when seated close to the orchestra. Darrel imagines them engaged in a modern argument over hi-fi speaker placement: "I'd like to think that

Wolfgang's predilection for ‘close-up’ sound would ensure his voting for a wide-range corner horn and an easy chair.... But, undoubtedly, Constanze would crave, like so many others nowadays, the ‘diffused’ sound-source effect obtained by listening to a speaker in another room or oriented so that the high frequencies reached her ears only by ‘reflection’ . . . The great ‘high fidelity’ movement we helped to promote, but have been unable to control, is now winning a mass public only by reshaping its attractions so as to appeal to the Constanzes rather than the Wolfgangs” [8]. Darrel, with ideas typical of the mid-century audiophile, asserts that diffused sound is somehow tasteless.

This is the environment into which Vangelis launched the music to Blade Runner [2] and helped pave the way for digital reverb. With his application of the more powerful, extra long delay enabled by digital reverb, he managed to alter its perceptions and associations or even re-program the listeners’ responses. His use of heavy reverb on synthesisers and a wide variety of percussion gave the futuristic cityscapes a depth and majesty never before witnessed. The highly spatial digital reverb increased the dramatic integrity and visual impact of the film. Vangelis embraced the power of digital technology, dismissed the notion of the reverb as somehow unsophisticated, negative or overtly gendered to generate evocative, new sounds and spaces.

6 COMPOSITIONAL PROCESS

While Vangelis was innovative with his use of reverb, he was building on the history of reverb and its associated meanings. We will see that he also used the saxophone and Middle Eastern music in ways that take advantage of established associations. Coker observed, “it is expected of the composer that he conceive the music’s gestures and attitudes because he wishes to affect the behaviour of performers and listeners, and he knows these gestures affect him when he adopts the attitudes of other interpreters. Such role taking is needed for musical communication on the composer’s part.... Music is, above all, addressed to us as listeners or performers, and intended to affect us” [18].

Vangelis did not prepare a detailed record of his compositional process while underscoring Blade Runner [2] in 1982. He had no desire for it to be stored or replicated. There is an amount of irony here considering Vangelis’ organic against Turing’s digital computer. He describes his process as “spontaneous and instinctive” preferring to use his first takes whenever he could, even if the recording contains small mistakes [19]. This might explain why, for example, he used the E-Mu Emulator keyboard as a sampler with sounds at the ready, rather than programming sequences. The compositional process for Blade Runner, outlined on Vangelis’s Nemo Studios website, reveals a composer who believes “music is a natural creation, and, therefore... cannot be created as a consequence of past or active human thoughts” [19].

Nevertheless, musical composition entails a multiplicity of processes that can be perceived as complex systems involving different levels of operation. Vangelis’ spontaneous and instinctive processes might also be seen as containing levels of operation including a dependence on previously stored easily retrieved knowledge, such as his knowledge of collectively understood musical systems and styles, as well associated meanings and interpretation. For example, in Blade Runner [2], the associations of reverb, the sensuous application of the blues scale to underscore the exotic, sexy, snake-dancer or the incorporation of aspects of Arab music to represent the Middle Eastern character who replicates snakes.

There is no compositional process without the use of some manner of representational processes. Musical ideas can manifest in many ways, including as Turing-inspired sets of instructions, or algorithms. However, even the role of algorithms in music is contingent on intervention or interaction from the listener/composer in the process of composition. Composers interact with computers while using them to process audio and generate musical outcomes. Vaggione comments that interaction is “an important feature of musical composition processes, giving room for the emergence of irreducible situations through non-linear interaction” [20]. Vangelis composed using a highly interactive process. He would play a scene from Blade Runner [2], and if he felt a strong connection to the moving images, he would create a composition as he considered the music to be integral and inseparable from the images [19]. If he wanted to add layers later, he would rewind the tape and add layers of sound electronically, through his synthesisers, percussion and acoustic effects. Actions and perception are clearly at play here. Choices are made contingent on musical arguments, musical systems and subjective interpretations of the composer. Vangelis composes as he responds to the music, in a kind of feedback loop not unlike the feedback/feedforward technique used to generate digital reverb. As such, composers can reduce or enlarge their operational categories at will or their field of control, producing and applying musical guidelines as well as making creative choices throughout the process(es). Vaggiona observed, “Musical processes can be produced using formal tools (algorithms) as generative and transformative devices, yet other compositional instances call for strategies relying on interaction in order to control and qualify results and choices. Using computers drives musical activity to an expansion of its formal categories” [20].

Vangelis’ music in Blade Runner [2] was not created through a rigorous process where ideas and musical arguments are methodically thought out and arrangements are carefully laid down. For Vangelis, the acts of composing and performing are indistinguishable from each other. With this improvisational, organic approach, he acts as a participant in the film responding instinctively to the scene to allow his music to be driven by his first impression of the images [19].

7 CONCLUSION

Though subtle, and without the viewing public’s conscious awareness, the Turing machine reverberates throughout Vangelis’ Score for Blade Runner [2]. The music in Blade Runner underscores the film’s themes of questioning human behaviour in bio-machines, while in turn, using applications of the Turing machine to replicate human behaviours. Turing revealed that complex human operations could be imitated and performed by machines. Blade Runner’s Replicants explore this notion demonstrating complex human behaviours and responses. Through digital sampling [21] (discussed in section 2), and the processing of audio signals, machines have been created to facilitate and enhance musical

communication. Vangelis used the then new digital reverb machines to alter the sounds he generated to represent the themes in the film and to communicate new meanings. Using the extra long delay times that digital processing and reverberation algorithms enabled, he generated a previously unheard sense of depth and space to magnify Blade Runner's futuristic cityscape and milieu. Vangelis' compositional process embraced the digital machine and formal musical processes while using interactive strategies in a perception and action feedback loop to alter the musical outcomes.

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