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# Opportunities for Evolutionary Music Composition

Andrew R. Brown

Queensland University of Technology

[a.brown@qut.edu.au](mailto:a.brown@qut.edu.au)

## Abstract

*Traditional compositional techniques and many computer-assisted composition systems have been focused on the production of linear musical products. In an age where non-linear media are increasingly prominent there is a need to reassess these technologies in the light of new opportunities for making music with non-linear outcomes. This paper examines the current state of music making for non-linear media with a particular emphasis on evolutionary music and how and where it might be applied. In addition, some of the implications for computer-based tool design will be outlined.*

## 1 Introduction

Music making has long involved interpretation and improvisation, but with the advent of sound recording technologies musical outcomes could be frozen and reproduced unchanged. This development had many ramifications for the music community including the extension of commodification from scores and instruments to include recorded performances, and the establishment of musical styles and aesthetics where recorded products were the intended outcome. The freezing of sound as recordings is central to electroacoustic music that dominates the computer music community. However, despite the advent of programmable digital music systems where static reproduction was no longer required, the traditions of tape music persisted. Responding to the non-linear character of digital media, computer musicians reclaimed interpretive and improvisational practices as hybrid combinations of recorded and live elements in human-computer partnerships, often referring to this as interactive composition or interactive performance. The programming of systems that created music autonomously, generative music, was also pursued. Evolutionary music relates to these performative and generative traditions in a hybrid computer music form that could be labelled, generative improvisation. This paper explores the motivations for and techniques of evolutionary music and suggests that there is significant potential in this

form as a vehicle to invigorate computer music making.

Evolutionary music is music that changes over time or in response to external variations, such as interaction with a user or performer. Evolutionary music involves a feedback mechanism such that the current state is based upon previous states and circumstantial conditions, as distinct from traditional musical structures that are often deterministic. For example, traditional compositional techniques focus on the musical function of particular attributes, such as harmony, but research into artificial life suggests that behavioural emergence replaces traditional functional hierarchy (Hendriks-Jansen 1996). In evolutionary music systems, structural outcomes emerge from an iterative process in real-time, rather than being specifically designed from start to finish. Emergence, in this sense, involves the historical development of musical complexities from simple traits and forms of organization (Nagel 1961). The composer or designer of evolutionary music requires new techniques that focus on creating classes of musical potential, as opposed to existing techniques that describe predefined linear outcomes.

The rise of evolutionary music marks a shift in computer music research from the study of musical structures to an examination of the dynamic interaction between aspects of musical systems. There have been some significant advances in this area by researchers examining interactive performance, notably the work of Robert Rowe (1993, 2001), and evolutionary systems can build on this work and extend it into semi or fully autonomous systems. This shift requires the development of new compositional theories and techniques which are often influenced by biological evolutionary systems. These techniques support designers of both interactive and autonomous music systems. The need for a new class of compositional techniques is mainly due to the dynamic nature of most evolutionary music systems. In such systems musical structure becomes undeterminable the use of structuralist compositional paradigms is ineffective. The development of a new class of algorithmic compositional techniques will assist music making

with non-linear digital media, and add to the traditional musical forms and processes which assume a predefined linear musical narrative.

An example of the non-linear musical forms are those that have indefinite durations and unpredictable interruptions due to changing contexts or user interactions, in such cases evolutionary music systems can play a significant role. It is important to note that musical narrative is not lost in such systems, it is just not entirely predetermined, rather, narrative emerges as the music evolves. This emergent feature of evolutionary systems presents a new challenge to composers, system designers, and music theorists. This challenge is an opportunity for the developers of new techniques and tools to aid composers.

Activities in evolutionary artistic practice have a significant presence in Australia, as recently seen during the series of "Iteration" conferences held in Melbourne. Notable Australians working in this area include composers Rod Berry and Alan Dorin, visual artist Paul Brown and digital art social theorist Mitchell Whitelaw. Australian work builds upon international activity in evolutionary music in Europe, particularly by Eduardo Miranda at Sony CSL in Paris, by a individual researchers in America, in particular David Tudor, John Biles, Bruno Degazio, Robert Rowe, Gary Lee Nelson and David Cope. Evolutionary music is a field developing in the wake of the expanding interactive media explosion which has recently seen the computer game market exceed the film industry in gross sales, the recognised need for cultural content for broadband internet, and the current roll out of second and third generation mobile phone networks worldwide. It seems that it is now time for evolutionary music to flourish.

## 2 Evolutionary processes in the creative arts

The use of evolutionary metaphors for artistic purposes has been documented by Mitchell Whitelaw (2002) who traces its origins back to Richard Dawkins' work on *Biomorphs* (Dawkins 1987). *Biomorphs* is a program that generates and evolves graphical stick figures. This program inspired other evolutionary visual artists, including William Latham and Stephen Todd who worked on evolving two-dimensional images in the 1980s and 1990s (Todd and Latham 1992), and Karl Sims' work with three dimensional images in the 1990s (Sims 1994). Work in evolutionary art continues to be dominated by visual artists, with only a few researchers applying the techniques to music or sound. There are great opportunities to transfer the techniques from the visual to the sonic realm and move beyond the quite literal adherence to biological metaphors. In the visual arts, there has been recent deviation from the strict biological

metaphor where features of an entity are changed, to a more abstract evolutionary model where rules and structural constraints are evolved. An example of this work is the computational art works produced by Erwin Driessens and Maria Verstappen in the late 1990s, and presented at *Iterations 2* in Melbourne (Driessens and Verstappen 2001). Research into evolutionary music has begun to appear in the past decade, but was preceded by research into generative and interactive composition which addressed similar issues.

Despite the dominance of biological metaphors in evolutionary computation research outside of artistic fields, music and other evolutionary digital art are best considered as a cultural phenomena adhering to the characteristics of cultural change, such as being relevant to the short time spans to human perception and expectation, but acknowledging the longer time spans of changes in social preferences and cultural values. The differences between biological and cultural evolution are clearly articulated by Yri Lotman from the perspective of semiotic hermeneutics.

The evolution of culture is quite different from biological evolution; the word 'evolution' can be quite misleading. Biological evolution involves species dying out and natural selection. The researcher finds only living creatures contemporary with him. Something similar happens in the history of technology: when an instrument is made obsolete by technical progress it finds a resting place in a museum, as a dead exhibit. In the history of art, however, works which come down to us from remote cultural periods continue to play a part in cultural development as living factors. A work of art may 'die' and come to life again; once thought to be out of date, it may become modern and even prophetic for what it tells of the future. What 'works' is not the most recent temporal selection but the whole packed history of cultural texts (Lotman 1990:127).

In a cultural evolutionary model, musical material as conceived as *memes* (idea cells) rather than genes (Dawkins 1976). A notion of evolutionary music as stylistic morphing depicts compositions that change in musically meaningful ways as they adapt to different situational contexts. Techniques of evolutionary music have been strongly influenced by biological evolution as a metaphor and therefore computational processes from the fields of genetic algorithms, artificial intelligence, and artificial life (Langton 1989) have often been inspirational. The computational processes used include genetic algorithms, Markov transitions, genetic programming, fuzzy logic, and cellular automata, however, the primary goal of the evolutionary music system designer and researcher

is the development of new musical understanding and compositional techniques rather than the sonification of computational formalisms. New musical knowledge derived from the development of evolutionary music systems demonstrates that digital media can expand upon, rather than replace, the conventions of musical composition.

### 3 Identifying stylistic features

In order to generate appropriate musical material using evolutionary processes it is first necessary to establish features of the desired musical style and to set targets and bounds to assist the composer and algorithm to navigate musical space. Well-established theories of diatonic music and compositional texts based on composer experience have previously been used because they have provided useful guidelines in previous research (Towsey, Brown, Wright, and Diederich, 2000). Some research in this area has focused on superficial features, that Rowe in his book *Interactive Music Systems* calls "Level-1 analysis," including pitch, loudness, duration, contour, and harmony (Rowe 1993:122). Successful music evolution over several minutes or hours requires examination beyond this level of analysis, in particular consideration of the temporal nature of musical structure; as has been identified as crucial to musical development in studies of music theory (Lerdahl and Jackendoff 1983) and in computer modelling of musical style (Cope 1991, 2000, 2001). At an even larger scale, attributes of musical changes from one style to another could be examined, however, most research to date has focused on compositional evolution within one style and have paid attention to event organization (Miranda 2001), timbral evolution via changes in synthesis, or adjustments in performance interpretation, or interactive improvisation (Rowe 1993, 2001, Biles 1994).

Evolutionary music provides an effective means to tackle one of the aesthetic goals that all machine systems must resolve when simulating human action; the trade-off between *novelty* and *structure*. In short, evolutionary music systems can build on the structure of human compositional practice like rule-based systems, while providing techniques that offer emergent variations that add surprise and novelty, hopefully to an appropriate degree. Of course, measures of aesthetic appropriateness are at the discretion of the composers who create evolutionary music systems, and their audiences. As with all musical systems, evolutionary music is stylistically constrained by a set of compositional heuristics dependent upon the composer's preferences and intention. The success of evolutionary music systems should be judged against the aesthetic appropriateness of the music they produce and by their value to composers in

creating music for non-linear media. A challenge for the computer music community is to create evolutionary music systems that are successful against these criteria. The development of computer-assisted techniques will provide composers with a broader pallet of creative opportunities and reposition compositional practice so that it is ready to confront the non-linear media expansion sure to characterise the early part of this century. The introduction of evolutionary compositional processes will transform composition for digital systems to a degree comparable to the advent of audio recording which enabled music to be kept indefinitely static.

A significant challenge for designers of evolutionary music systems is to adequately represent a musical world in which to evolve. This is a problem common to artificial intelligence and artificial life researchers, which they commonly call the "frame" problem, describing how much of the context to represent such that the computational world is sufficiently comprehensive to enable relevant decisions to be made, but not so complex as to be unworkable. In the case of evolutionary systems, this manifests itself when system designers try to place appropriate constraints on pitch and rhythm values, make decisions about how much memory of prior musical events is maintained for future reference, decide how the events in one musical part should influence other parts, and so on. It is at times like these that computer musicians appreciate the enormous accumulation of knowledge and skill that an instrumental improviser performing in a live ensemble maintains.

A secondary challenge for designers is to appropriately map evolutionary processes to musical parameters. Having decided upon the musical representation and evolutionary model, for example using the jMusic data structure and emulating Darwinian selection, the task is to determine which aspects of notes, phrases or timbres will be important in judging fitness and by what criteria. In particular, the complexity of this task is increased because there is rarely a clear goal for musical outcomes. That is, there is not just one *good* musical solution to a given situation, and evolutionary processes often require such ranking of possible next steps. According to Margaret Boden (2002), an eminent writer on the philosophy of artificial life, evolutionary algorithms and processes have two characteristics. First, they have a way of changing or adapting their own rules and, second, a way of selecting from the array of possibilities available through change. Boden underlines the difficulty of establishing evaluative criteria for making selections from all possible changes, and automating this process in generative algorithms. She suggests that because humans design the algorithms, finally the key issue is

human preference and epistemology. In the field of music this relates to musical understanding and aesthetics, which is why evolutionary music system development is fundamentally a musical project, despite having interesting and necessary computational aspects.

These challenges notwithstanding, the field of evolutionary music has great potential that will only increase as non-linear modes of music delivery become more prevalent. In his summary of the future of music systems, the computer-assisted music specialist Paul Berg suggests that potential trends in composition include a "radical change in the non-linearity of current media" leading to a redefinition of the role of the composer. To meet this challenge he maintains that "useful musical generators are needed. They should reflect usable and general concepts that can be applied to create musical expressions" (Berg 1996:26). Evolutionary music system designers have an opportunity to meet this challenge head on by developing generative improvisational processes that can contribute to musical expression in non-linear musical circumstances.

#### **4 Compositional techniques for evolutionary music**

Techniques previously used in computer-generated music have predominantly been recombinatorial or knowledge-based and, as such, have been limited by their inability to introduce novelty and variation. The use of artificial intelligence techniques has provided some success in generating novelty, for example, the use of neural networks (Mozier 1991, Tudor 1995), augmented transition networks (Cope 1997), and genetic algorithms (Degazio 1996, Towsey et al. 2000, Biles 2002). There are opportunities to extend this work to include techniques of artificial life (Boden 1996, Resnick 1994, Miranda 2000) and add complexity by looking at emergent musical behaviour and dynamic environments where musical goals are linked to unpredictable situational changes.

The use of heuristic principles for automated music composition is well established in computer music (Moorer 1972, Laske 1992 ) but the use of heuristics based on cultural-evolution is less well established. In previous studies, the stylistic objectives have been based on a fixed historical style enabling Darwinian evolutionary fitness objectives to be employed, in particular in the use of genetic algorithms. Effective evolutionary music systems will need to move beyond imitative musical processes (however complex) to establish new techniques of composition that focus on generative music making (Miranda 2002), and move beyond simplistic notions of optimised fitness attainment to embrace broader directions for

progression as evident in cultural systems. Examples of evolutionary music systems can be described as falling under particular categories.

*Behavioral Recombination.* This style of system draws on aspects of previous musical examples, as for example in Ames and Domino's *Cybernetic Composer*, David Zicarelli's *M*, and David Cope's *EMI* software. These systems are generative and can become evolutionary if provided with a feedback mechanism, such as the readjustment of probability weightings in a Markov transition matrix at each iteration by adding the data from the just-generated score.

*Cellular Automata.* These systems have a number of elements (cells) that change state according to rules related to the state of neighbouring cells. These rules are applied at each iteration creating an ongoing variety of state situations across the system. Cellular automata processes were one of the earliest artificial life computation models. The cell and their state can relate to any musical parameter, but a feature of cellular automata is that change is progressive rather than revolutionary (unlike random changes), and at times oscillating patterns can occur that provide some stability. Examples of cellular automata musical systems include Eduardo Miranda's *ChaOs* and Kenny McAlpin's *CAMUS* system, and the closely related *Boolean Sequencer* of Alan Dorin.

*Genetic Algorithms.* Directly related to biological evolution, genetic algorithms process data as a string of 'genes' in a virtual genome. Changes to which are traditionally done by mutating the state of a gene at random, and applying crossover techniques where sections of one genome are recombined with a section from another. A population of genomes are created and some survival-of-the-fittest selection criteria ranks members of the population and keeps those that are fittest and discards those that are weakest. In a simplistic musical example the pitch of notes in a melody can be used as a genome (each pitch is a gene), and pitches mutated by transposition and fitness judged by melodic coherence to rules of voice leading. Examples of cellular automata music systems include John Biles' *GenJam* and the *Vox Populi* software of Artemis Moroni and his colleagues.

*Evolvable Hardware.* As well as the more prevalent software systems for evolutionary music there are also a few hardware-based systems. Evolvable hardware uses special chips which are reconfigurable and a software program, often based on generative algorithms, that iterates through various reconfigurations. The hardware is tested at each iteration to see if it performs the desired task; for example, playing or recognising a musical tone. Interesting results come from the fact that the system tries circuit design patterns that are unlikely

to be conceived by human designers, and interesting results (and sounds) can occur. An example of this work is *The Sound Gallery* by Woolf and Thompson.

## 5 Composing evolutionary music with a computer

Computer-assisted composition is an active area of musical, technical, and humanistic research. Evolutionary music systems do not need to be autonomous systems, but can also extend the role of computer-assisted composition to include semi-active participation through the automated-evolution of new and varied musical material. The computer has traditionally acted as a compositional assistant in numerous ways which can be differentiated as modes of compositional engagement (Brown 2000). Computer systems are generally used for musical presentation, usually in the form of notated scores, or audible rendering to MIDI files or audio recordings. They have been less commonly used for compositional support via algorithmic design, and rarely for the design of evolutionary algorithms.

Computer-assisted composition processes are used to some degree in almost all commercial, artistic, and academic music making. Typically, this involves the externalisation in some computer model which simulates either a printed score or an audio recording device. The composer can then manipulate the model in some way to produce a final composition. All current commercial systems are of this type. Commercial solutions that seek to address the non-linear nature of digital media are beginning to enter the computer game market; these include *Direct Music* (Microsoft), *MusyX* (Factor 5, Nintendo) and *Koan* (SSEYO/TAO). These commercial entrants highlight the growing interest in music for non-linear media. However, the current implementations employ recombinatorial and stochastic processes, rather than evolutionary processes. Active research into evolutionary music is underway at Sony CSL, in Paris (Miranda 2002) primarily focused on the use of cellular automata, and by isolated researchers in other locations (Biles 1994, Degazio 1996, Dorin 2000, Rowe 2001, Cope 2001, Todd & Werner 1998).

Musical systems that focus on evolutionary music have so far been limited to tightly constrained environments or they have dealt with limited musical material or concepts. Examples of the former include Rod Berry's works "Feeeping Creatures," "Gakki-mon Planet," and "Listening Sky." Each of these works in an intentionally limited musical domain with no intention to provide a general compositional pallet. There is clearly an opportunity for development of more

generalised evolutionary computer music tools for composers.

## 6 Conclusion

The field of evolutionary music shows significant promise as a branch of computer music for use in computer-assisted composition and generative music. The use of evolutionary music in non-linear delivery media is particularly pertinent given the general expansion of this style of music through platforms such as DVD and computer games. This paper has explored the history and current practice in evolutionary music and identified important issues and areas for future exploration in the field. Evolutionary music, and evolutionary art in general, can advance both artistic practice and contribute to artificial life research by introducing models of evolution that take into account cultural development that enhance existing models based on biological evolution. Evolutionary music adds computational improvisation to the expressive opportunities of the computer musician.

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