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Generative Music in Live Performance

Abstract

This paper describes a generative score display system for algorithmic composition and score presentation developed for use in the author's work "Appearances." A performance of the work requires musicians to sight-read scores that are generated during the performance and displayed as common practice notation on screens. The paper outlines the approaches to score generation and display then discusses the practical considerations of performing "Appearances" using the system.

Introduction

The use of recent advances computing power for generating real-time audio has become increasingly common however, despite this, the less computationally demanding task of real-time score generation is not as common. This paper describes a system designed for generative score display that can be used to create works for acoustic ensembles. The details of the generative and display systems are described in this paper along with some discussion of the implementation and performance considerations that arise when using the system. An early work written for this system, *Appearances* for saxophone, violin, viola, double bass, and piano is used as a case study throughout the discussion.

Algorithmic processes are used to generate the score material and the details and musical mapping of these processes are discussed.

The system was developed in Java using the jMusic library that provides the musical data structure, common practice score display, client-server networking architecture and MIDI file saving of generated scores.

Background

There is considerable research literature on generative musical systems. This literature can be classified into two groups, that which focuses on generative composition such as the work by David Cope (Cope, 1996), and that which concerns itself with generating computer performances and improvisation as, for example, collated by John Sloboda (Sloboda, 1988). The system used for *Appearances* aligns with the former category by focusing on generating scores, not generating performances of those scores.

Other related areas of activity include real-time computer improvisation where computer-based analysis and synthesis processes interact with musicians (Rowe, 2001) (Winkler, 1998) (Tokui and Iba, 2000) a process described as HyperImprovisation by Roger Dean (Dean, 2003). Also related are systems that support performance through programming on-the-fly (Wang and Cook, 2003), and those based on evolutionary musical installations (McCormack, 2003).

The system described here differs from these in that it is not interactive (except in a trivial start-stop way), it does not involve computer analysis of input nor playback and, although generative in character, it is not an independent sound sculpture or installation.

The system of generative score display is concerned with score composition for acoustic performance, but is not interested in publishing and the associated details of score presentation. Rather, the system provides for real-time updating of scores during playback. In this regard it is somewhat related, in practice, to a growing number of screen-based score display technologies used for ensemble performances (digital music stands) (Graefe et al., 1996), but it is quite distinct from these in its generative capacities.

The generative element of the system is based upon random walks and other stochastic processes which have been used extensively for algorithmic music making in the past (Xenakis, 1992) (Serra, 1992).

Networked score presentation

Enabling the performance of *Appearances* is a networked score presentation architecture that can generate and display the music for a number of ensemble members using a series of networked computers. At the centre of this system is one computer that acts as a score generator and server, the algorithmic music is created in sections of 4 bars duration which are sent to each musician's computer for display by a client application as common practice notation (CPN). An example of the score appearance is shown in Figure 1.

Figure 1. *The score view, as seen by each performer.*

The score view shows two staves that display a continuous monophonic musical line that is sight-read by the performer. Each stave updates alternately while the other is being read.

The computer running the server software maintains a generative part for each performer, each client computer registers to one of these parts. It is possible for a full score to be displayed by the system for a conductor, but for *Appearances* the ensemble is small enough not require a conductor.

Performance considerations

Using this generative score display system to perform is somewhat challenging in a number of respects. Not least of which is the requirement to sight-read the scores during performance. In an attempt to make this less difficult the algorithmic rules are described to the performers so that they know what music to expect and what pitches or rhythms are unlikely or impossible. As well, limiting the number of notated values and minim duration of a quaver enhances the rhythmic readability, by making the score less dense and intricate in appearance.

The score regeneration and display-update are triggered by one of the performers, enabling the ensemble to remain in control of tempi.

The coherence of the performance using this system relies on normal ensemble interactions as there is no computer performance, click track or other mechanical reference to synchronise with. A variety of dynamic and articulation indicators, or text comments, can be displayed on the scores and these can be controlled manually or generated automated.

The generative music is, by definition, never ending however the performance must conclude, and there could be a number of strategies to handle this. In *Appearances* the lead performer triggers the system to produce a final algorithmic section that is designed to sound conclusive, after which the system stops.

Because the score varies in unpredictable ways each time it is generated there is no way a performer can memorise the score, nor even have a clear idea of what direction the material will lead next. As a result, normal rehearsal practices are significantly disrupted. However, because the nature of the generated music is tightly constrained, the more familiar the performer is with the processes of the algorithm, either as a result of analysis, explanation or experience performing it, the more comfortable they become with the stochastic nature of the work.

Mapping Generative Data

Originally *Appearances* used a cellular automata (CA) process to derive the musical material, however, the patterns of pitch and rhythm that result from simple mappings of CA were found to be too uneven for performers to comfortably sight-read. In the final incarnation, random walks are used to generate the pitch values combined with pulse-sensitive probabilistic rhythmic values. This results in phrases that displayed smoother voice leading and were easier for performers to follow. To add some variety to the melodic contours and rhythmic predictability, probability calculations employ Gaussian, rather than linear, distributions. Interestingly, while the use of random walks made a significant difference to the readability of individual parts the general texture of the combined ensemble varied minimally between the CA and random walk mappings. However, the increased pitch continuity in individual parts increases the sense of counterpoint as opposed to a more homophoinic texture produced by the CA mappings.

A consistent harmonic language is maintained by simply constraining notes to pitch class sets. These sets were selected by the composer and are probabilistically selected at regular intervals during performance. Pitches within a part are also constrained to ranges appropriate for the instrument assigned to that part.

In a similar fashion, rhythmic material is generated by probabilistic selection from a note duration array. The mean location for a Gaussian selection within the array is determined by the note's metric position. This enables choices to statistically tend toward clear delineation at pulse boundaries, increasing the rhythmic stability of the phrases. Rests are added using similar principles. All phrases are cropped to sixteen beats in length before being displayed.

A number of techniques are employed in *Appearances* to enhance structural cohesion and provide relief from the continuous stream of stochastic polyphony. These include occasional unison sections, the buffering and reuse of phrases, and the varying of textual density by dropping parts in and out. This latter technique had the added performance advantage of giving performers, particularly woodwind or brass, rests during the piece.

Extensions and future work

The system includes a visual mapping of the generative data, using either CA or random walks, that creates patterns of colourful geometric shapes. This visual work has been developed collaboratively with the visual artist Daniel Mafe and several exhibitions of the visual work using CA data have been held. The visualisation of the data set may be projected to accompany the performance. Both the visualisation and musical scores are renderings of the same generative data and have no effect on each other and can operate independently.

Another feature of the system is that complete scores of a performance session are captured as a matter of course and can be saved as a standard MIDI file, if required. This feature points toward the possibility that the system could act as a computer-assisted compositional tool quite apart from the live performance uses for which it was designed, where composers save sessions as MIDI files to their hearts content then edit and collage them off-line into a final score.

Enhancements

There are a number of future directions for the system that are being considered. There are plans to add a facility for additional messages to be displayed on the musicians' screen to assist the performance; these messages may be musical or extra-musical in nature.

There could be the opportunity for the composer, or other musician, who is not performing to control the algorithmic processes in real-time thus shaping the composition in an improvisational manner. This type of interactive composing could develop into a rich interactive collaboration between composer and performer as they build experience in working together in this way.

Clearly the system can be adapted so that a different algorithmic process is used to generate the scores, and it would be interesting to see how different algorithms lend themselves to the production of sight-readable material. To some degree, this performative constraint provides a rigor that seems to tend toward musically pleasing generative designs, probably because musical conventions have developed around these acoustic performance constraints.

Conclusion

A system for the performance of scores generated in real-time has been described. This generative score display system uses algorithmic processes to regularly produce short musical phrases in real-time that are displayed as common practice notation on networked computers and sight-read by performers. The displays are regularly updated to maintain a consistent musical flow.

The system was used to create the work *Appearances* that, at first, experimented with the use of cellular automata algorithms but shifted to constrained probabilistic and random walk processes because they generated more human-readable material.

This use of real-time generative music for instrumental performance provides a situation in which the degree of unpredictability and surprise can be as exciting on each rendition for the performer and composer as it is for the audience.

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