A Multi-agent Interactive composing system for creating "expressive" accompaniment.

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ABSTRACT

This paper describes the approach and an application that the author has adopted for creating real time performance systems whose musical output is created by the interactions of a human performer and a multi-agent system that acts as an ensemble of software "performers". The music produced typically consists of several distinct textural layers, where all the sounds produced are transformations of the sound made by the human performer. This type of system can be thought of as an "extended" instrument, where the performer effectively "plays" the ensemble. This approach has been used with notated compositions, improvisation performances and for creating installations. This paper focuses on a composition that utilises a notated score, and is concerned with how the score is interpreted in the context of the musical output of the agent ensemble.This system makes use of two broad categories of agent: performers and controllers. Performer agents transform the live sound in various ways, while controller agents' work at a higher structural level. They specify goal states and determine which agents are currently heard. Each performer agent has a way of transforming the audio input, and has its own internal strategies for determining what it does. The complexity of the performer agents note choice strategies ranges from simple harmony generators, to algorithmic composition systems.

1.   INTRODUCTION

"Musings" is a notated, five-movement piece for Flute and Computer. The computer is running a Pd [1] patch that implements a multi-agent based interactive composing system that transforms the sound of the flute performance in a variety of ways, creating a multilayered musical texture. [2] Each layer adds its own acoustic signature which compliments the other layers present. An important aspect of the piece is the expressive relationship between the human performer and the response created by the multi-agent system. Each movement has its own distinct

flavour, which is the result of the particular strategies implemented in the agents, the type of timbre the flute sound is transformed into, and the use of different musical scales.

2.   COMPOSITIONAL APPROACH

2.1. Overview

This piece grew out of many years of improvising with multi-agent interactive composing systems. When working in an improvisation context, the focus of the multi-agent system development was always on achieving a balance between the amount predictability and the amount surprise in the response by the system. Achieving the right amount of unexpected behaviour in the multi-agent systems response was important in creating a sense of collaboration with the ensemble of agents. "Musings" makes use of this element of uncertainty in a slightly different way than when working in the context of improvisation. A primary element of this piece is that the live performer is affected by the musical contribution made by the multi-agent system   when interpreting the pre-composed score. The multi-agent system is set up in the composition phase to strike a good balance between consistency and variety   from performance to performance, forcing a fresh interpretation every time it is played.

Early versions of the piece made use of software synthesizers to realise the parts composed by the agent software, but it didn't create the intimate, expressive feedback loop that the composer felt was essential for expressive interpretation. It did not create the necessary feeling of control over the multi-agent systems output. To overcome this problem, the original synthesizers were replaced by a collection of signal processing systems that transform the sound of the live flute signal. This allowed the multi-agent system to control the pitch and duration of the sonic events in the textural layers,   producing a variety different timbres,   while still providing some expressive control linked to the dynamics, articulation and phrasing of the performer.

2.2. Extra-musical aspects

The piece was inspired by an artificial reservoir that was created by flooding a coastal mangrove swamp in the 1970s. It forms an intersection between several different ecosystems. On the east side, there is still an area of mangrove, and an short estuary leading to the sea, the north side has high rise housing estates, and to the south and west there is a dense industrial estate containing a variety of businesses, including logistics hubs, small scale manufacturing and some oil and chemical processing. This combination results in an unusual intermingling of natural and man made acoustic phenomena. "Musings" is supposed to reflect this interaction between the sounds of nature and man made sounds, to some degree. The sound of the flute is represents the natural world, and the multi-agent system contributions mainly represent the man made sounds. (There are some agents that are suggestive of natural sounds.)

2.3. Basic composition procedure

The basic procedure adopted to create each movement of the piece is an iterative process:

- Create a draft of the solo flute part, based on manipulation of motivic melodic material. Each movement makes use of a distinctive rhythmic profile, and is based on a particular scale. The flute material deliberately adopts some idiomatic characteristics of commonly performed flute repertoire written in the early twentieth.
- Assemble the multi-agent interactive composing system. The composer has developed a collection of different agents that perform different roles. Appropriate agent designs are chosen to form an initial ensemble of agents. The choice of agents is a major compositional decision, and is explained further below.
- Use the playback of a recording of the flute part to approximately set the various parameters that control the agents behaviour.
- Practice performing the piece with a flute, making adjustments the various agent parameters.
- Iterate. Often the agents need to be modified or substituted. Sometimes entire new agent designs were developed.   The flute score flute score always needed to be altered in the light of the musical context generated by the multi-agent system.

2.4. Agent Design

There are two broad categories of agent that make up the multi-agent interactive composing systems used in "Musings": performer agents and controller agents. Performer agents transform the input sound in various ways so as to create a new layer in the musical texture. Controller agents either determine which agents are heard by the audience, or specify goal states that determine the behaviour of the performer agents.

2.4.1.Performer Agents

Performer agents continually monitor to the live audio signal produced by the human performer. The instantaneous pitch and amplitude data, as well as cumulative statistical data, are used in the agents' decision making process to determine how an agent alters the live input signal.

There are two broad categories of performer agents. The simplest agent apply common signal processing effects to the live signal. These effects include echo, chorus, flanging, spectral delay and ring modulation. Most of these processes produce timbres that are recognisably transformations of the live input signal. Some agents in this category use combinations of DSP processes to produce output that is suggestive of common natural sounds, such as birds, thunder and wind. As each agent makes use of an analysis of the live flute signal to alter the controls of these DSP effects, the musical output of the agent is directly affected by the input signal. Performer agents using this design are frequently used to shape the overall ambience the ensemble output.

The other type of performer agents perform more of a textural/structural role. They take the live flute signal and transform it into new, distinct musical lines. Each agent is optimised to perform particular musical functions , and may drastically alter the flute input waveform, creating timbres that are not flute-like at all.

The signal processing techniques employed in this type of performer agent range from pitch shifters (implemented using granular synthesis) to synthesizers that implement the Karplus-Strong plucked string algorithm. Using these techniques , the live signal can be transformed into drones, parallel harmonies, melodic lines, ambience effects, and pointillistic clouds of sound. Also, as the resulting audio output is a transformation of the live input signal, the human performer maintains an element of control over the entire ensemble sound.

The basic operating principle of this type of agent is:

- Determine the current pitch of the live signal.
- Calculate the next pitch the agent will play, using some strategy specific to that agent.
- Calculate the interval between the input pitch and the calculated pitch.
- Transform the live signal so that it has the required pitch using the signal processing technique built into the agent.
- Calculate the length of the new note.
- Play the note for the required duration.

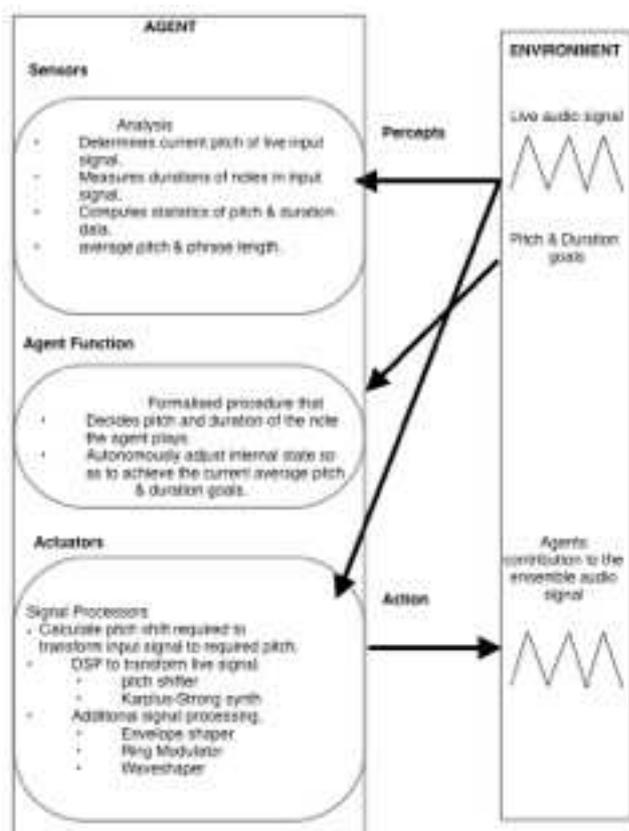The structure of this type of agent is shown in figure 1.

Figure 1. Structure of a performer agent.

There are a variety of algorithms employed in the various performer agents used in "Musings" that determine exactly how the agent will create the pitch and duration of the notes it plays. The algorithms implemented include stochastic algorithms, such as Gaussian random number generators[3], and tracking and evasion algorithms. Many agents are implemented using a design built around two blocks of memory (arrays) which store the outputs of the chosen compositional algorithms. One array contains data representing the note duration, and the other one contains data for the pitch. An algorithm that makes use of the contents of the duration array to derive an index to read data from the pitch array which is then transformed with with some simple mapping functions, determine an agents musical output.

An important aspect of the design of the performer agents is their ability to adjust themselves so as to exhibit specific musical behaviour. They achieve this by modifying their internal states (the contents of the two arrays)so as to meet externally specified targets. The two targets used to control the musical output of agents in "Musings", are average pitch, and average duration. In order to enable an agent to readjust its internal state so as to meet any particular supplied target, a simple form of gradient descent learning is used. Each agent periodically calculates the current average values of the data stored in the pitch and duration arrays, and compares these to a target average pitch and a target average duration. This produces two error measurements: one for the pitch and one for the duration. The two error measurements can then be used to alter the contents of each array slightly, so as to reduce the error. Periodically repeating this process several times

a second, eventually results in the agent to converging on the target behaviour.

2.4.2.Controller Agents

The multi-agent systems in "Musings" also make use of two higher-level agents that affect the overall musical output. One agent supplies the target parameters that are used by the various agent performers to individually adjust their internal state (the pitch and duration targets). The other agent acts as a "mixing engineer", and determines which performer agents are heard by the audience. Both of these agents are implemented as finite state machines that use of an analysis of the live signal to determine their state, and thus shape the musical output. Finite State Machines are very simple to design, and are very efficient. They have been used for many years in creating simple Artificial Intelligence systems in computer games. The two controller agents in "Musings" can each be in one of eight different target states, and each state is chosen in the composition process to create a different musical effect.

When creating a new composition with this system, for each movement, the composer needs to:

- Determine the eight different target states for each performer agent. These will be vectors consisting of target average pitches and average durations. Setting these states is an extremely important compositional decision, as these states collectively determine the behavioural extremes of the piece.
- Determine the eight different target states for controller agent that controls the mix. This sets the target volume levels for each agent and has a major impact on the resulting musical textural possibilities.
- Assign each state to a 3D coordinate. (These correspond to the different corners of a cube and will be used in the decision making process).

In operation, these agents:

- Periodically derive three values between -1 and 1 from the live signal. This is done using a mapping function, fine tuned for each specific movement, that manipulates the pitch and duration data to produce these values. The three values are combined to form a 3D coordinate that is dependant on what the human performer has played. The exact mapping function is a significant compositional decision that needs to be made for each piece, and usually the result of an iterative trial and error process. The basic analysis data, that is fed into the mapping function, is obtained from the input signal is using a fiddle~ (or sometimes sigmund~) object. This data is accumulated for a particular time interval, and then some sort of statistical analysis is performed and then is periodically transformed by the mapping function. For example, the system could be set up to that for a particular time interval, the mean input pitch is determined, the duration of the last phrase is measured, and the melodic range of the flute part in the current time interval are scaled to become a value in the range -1 to 1, and then combined to produce the 3D coordinate.
- Calculate the Euclidian distance of this 3D coordinate from each of the vertices of the cube.
- Set the system to the state that has the smallest Euclidian distance from the 3D coordinate.

The fact that this is a deterministic processes means that there is an element of predictability in the behaviour of the system. This means that similar musical input gestures will tend to produce similar musical ensemble output, which enables the human performer to learn how to shape the response of the agent ensemble.

2.3. Restrictions imposed on the multi-agent system for "Musings".

It should be noted that the multi-agent interactive composing systems in "Musings" have been optimised to achieve the aims of the piece. Many constraints have been imposed to create a particular type of musical result. For examples, there is no constraint on the input waveform used to drive the system. "Musings" was written for flute, but the multi-agent system can be used with any type of input. The author has used these systems in public performance with voice, saxophone, analog synthesizer and collections found objects. It is also possible to adapt this type of system to have multiple inputs. Another effective way to use the multi-agent system is to a use its output to be the live signal input via unidirectional microphone, creating a feedback loop which can be controlled by the positioning and orientation of the mic.

"Musings" also restricts the pitch of the output of the multi-agent system, constraining it to a particular scale. This restriction was a compositional choice, which required additional programming to achieve. Usually, when using this type system with input devices such as analog synthesizers and found objects, the scale mapping system is turned off, producing an output that makes use of the pitch continuum.

The timing of the output of the multi agent system is quantised to a time grid. In some movements of "Musings" this was set so as to provide a clear pulse for the performer to play with (or against). This was also a compositional choice. Its is possible to set the temporal resolution fine enough that any timing quantisation on the musical output is not perceivable

3. AESTHETIC PLACEMENT AND STYLISTIC PREDECESSORS

3.1. Motivic transformation and musical phrases

Each movement of "Musings" has a pre-written flute part, whose style is consciously influenced by flute works written by composers such as Debussy, Faure, Poulenc and Hindemith. They aim to have a lyrical character, and have clear sectional forms that achieve cohesion by traditional motivic transformation techniques, making use of standard techniques such as sentence and period constructions. Each movement gets some its character due to the (almost) exclusive use of less commonly used scales. Rhythmically, the pieces are characterised by frequent use of triplets, quintuplets, sextuplets and septuplets. There is some use of metrical changes, usually to elongate or contract the current melodic phrase.

3.2. Interactive composing elements

The interactive composing systems used in "Musings" are directly influenced by Joel Cahdabe's [4] ideas about interactive composing, developed in the late 1970's. A human performer controls high level aspects of the piece, while the compositional algorithms make the low level, note to note, decisions which are realised using a synthesizer in real time.

Another very strong influence on the piece is the tradition of applying interactive real-time signal processing to a live instrumental performance. This has been practiced in a variety of forms for over half a century. Techniques range from simply manipulating the controls on a collection of simple guitar stomp boxes, to complex computer based systems using sophisticated user interfaces, hardware controllers or artificial intelligence systems. Usually, a large amount of attention is focused on operating the signal processing, and one or more performers may focus on this exclusively.

An attractive feature of both of the above approaches is the immediacy of the systems response to the performers gestures. The "Musings" signal processing systems are an attempt to create a responsive system that combines these two approaches. It makes use of algorithmic composition techniques to create the "score" for various musical layers and uses real-time signal processing to realise them. A feature of the piece is that the sound of the flute performance acts as both the high level performance controller, and is also the origin of all of the sound heard in the piece. Analysis for the musical material performed controls the compositional algorithms, creating the high level musical features of the agent ensemble output, while the subtle flute performance nuances have a significant impact on the sound of the ensemble.

4.   CONCLUSIONS

The application of a multi-agent interactive composing system to create an accompaniment for a fixed score composition has been demonstrated to be a viable approach. It enables a balance of predictability and surprise, allowing room in each performance for happy accidents, each performance being a fresh interpretation.

5.   REFERENCES

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