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Collaborative Music Making with Live Algorithms

Abstract

This paper discusses developments of ENSEMBLE, an interactive improvisation environment based on the Iterated Prisoner's Dilemma.

The main emphasis of this paper is on the interactive version of ENSEMBLE, and its development for the work 'fr@gm3nT' [fragment], a collaboration between the author and saxophonist Derek Pascoe. Some of the lessons learned from non real-time, generative versions of ENSEMBLE are also discussed, along with the implications of the approach for algorithmic composition and live interactive computer music performance.

Introduction

Although many impressive generative composition systems have been developed in recent times, relatively few allow for interactivity with musicians in live performance. The emerging field of 'live algorithms' addresses this situation through combining non-linear generative composition techniques with live electronics and a sense of 'strong interactivity' exemplified through the practices of 'free' improvisation (Blackwell and Young, 2005). Previous examples of live algorithms include George Lewis' 'Voyager' system (Lewis, 2000), Al Bile's 'GenJam' (Biles, 2002) and Tim Blackwell's 'Swarm Music' (Blackwell and Bentley, 2002).

From the outset of its development ENSEMBLE has aimed to model the social dynamics of music performance, drawing inspiration from the use of performance indeterminacy pioneered in the works of composers such as Christian Wolff, Cornelius Cardew and John Zorn (Harrald, 2005). Using a modified version of the Iterated Prisoner's Dilemma (Axelrod, 1984) ENSEMBLE aims to model a group of improvising performers whose actions are constrained by sets of simple rules.

George Lewis suggests that the emergence of structure in improvised music occurs in much the same way as structure emerges in our every day lives. We interact with our environment, navigating through time, place and situation, both creating and discovering form (Lewis, 2004). As the Iterated Prisoner's Dilemma has proven its ability to model a diverse range of social situations without the need to address the details (Axelrod, 1997), it is not such a leap to suggest that it may prove useful in modelling improvised music.

Background

The Prisoner's Dilemma and the Arts.

While the Prisoner's Dilemma has captured the imagination of philosophers through the rather bleak outlook it presents about basic human nature, it has been somewhat of a rarity in the arts. In a one-off situation, it suggests that whenever there is uncertainty on what your opponent is about to do, then the only rational option is non-cooperation. This idea led several of the US government's advisors, including members of the RAND Corporation and British pacifist Bertrand Russell, to advocate a pre-emptive nuclear strike against the Soviet Union in the late 1940's (Poundstone, 1992).

Aside from the some of the classic films dealing with the madness of the nuclear arms race, for example Stanley Kubrick's Dr Strangelove (1964) (whose main character would appear to be a caricatured blend of several of RAND's key figures), art dealing more directly with the Prisoner's Dilemma is fairly scarce. A notable musical exception was put forward in the early 90's by Nick Didkovsky. Based on Douglass Hofstadter's 'Luring Lottery' (Hofstadter, 1983) Didkovsky's work explores resource sharing through allowing performers to compete for control of musical events via a network of Commodore Amiga 1000s . (Didkovsky, 1992).

Another exception is Bohemian Productions' innovative theatre work 'A Prisoner's Dilemma'. Featuring a number of interactive scenes, the actors portrayed various Prisoner's Dilemma scenarios under the control of the audience. The outcome of each game altered the plot so that each performance was different (Bohemian Productions, 2007).

ENSEMBLE

Through the ENSEMBLE project, several software applications have been developed in Cycling 74's MaxMSP environment (Cycling 74, 2007) based around a common Iterated Prisoner's Dilemma (IPD) engine. The IPD engine is an agent model consisting of eight agents. The agents interact with one another through a series of rounds, according to strategies that are predetermined prior to the first round. There are only two choices: cooperate or defect. The agents' environment is made up of their interactions and they communicate solely through the sequence of their own behaviour. The Iterated Prisoner's Dilemma is implemented as a competitive tournament whereby the agents interact in randomly selected pairs and are rewarded points depending on the outcomes of their interactions. The key musical concept here is that through cooperation, the agents reinforce previously introduced musical materials, while defection results in a random selection of new materials. Through the competitive nature of the model, the other members of the group may reinforce each individual agent's musical initiatives or they may be ignored, mirroring the musical dilemma facing real life improvisers. A comprehensive overview of ENSEMBLE can be found in Harrald, 2005.

ENSEMBLE is a modular system and the addition of various modules has allowed for the simple development of applications to suit a range of performance situations and compositions. Its development has been conducted in a number of stages as various modules have been created, beginning solely as a demonstration of the Iterated Prisoner's Dilemma Game, morphing into a non real-time generative composition system (IPD Score Generator, figure 2), followed by real-time generative systems used in installation works, and finally the interactive system through the incorporation of a fuzzy logic pitch tracker allowing a performer to interact live with the agent ensemble.

It has been suggested that a way to fast track progress in the research of live algorithms would be to link existing units dealing with analysis, synthesis and generative algorithms, each of which is individually the subject of much current research (Blackwell, 2007). Certainly the modular development process of ENSEMBLE strongly supports this possibility.

Lessons from non-real time

IPD Score Generator

IPD Score Generator is a generative composition application that, as its name suggests, generates MIDI files that can be easily imported into scoring applications. As working in the MIDI domain and in non real-time was much less CPU intensive, several important developments were made with the score generator, allowing the agent's in the IPD engine to have control over a wide range of musical parameters.

This application was an important step in the development of ENSEMBLE, in that, unlike the real-time and interactive applications based around the IPD engine, *IPD Score Generator* allowed the generation of musical materials that are pinned down and can be more easily analysed and assessed. As the IPD model can be quite volatile, often the musical surface produced is very transitory in nature. Several works have been generated using the application, with instrumentation ranging from solo piano, to full orchestra.

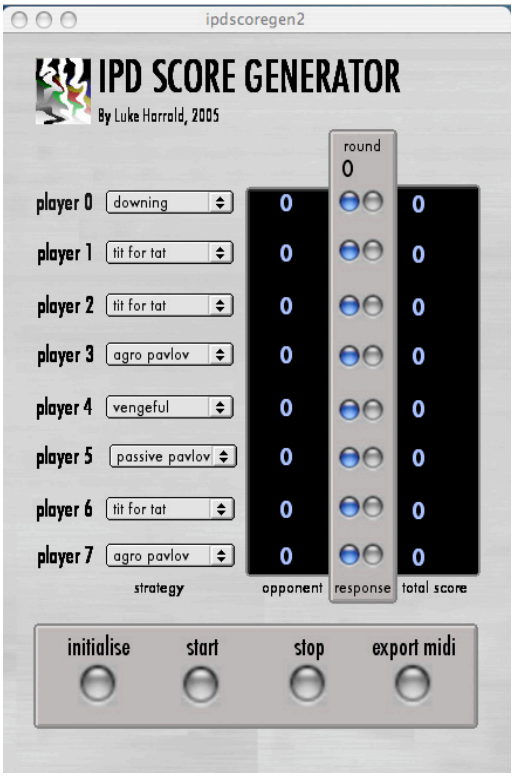

figure 1: IPD Score Generator (September, 2005) screenshot. On the left, drop down menus allow for user control of the agent's strategies (default is a random selection of strategies) while the panel on the right visualises the agent's interactions.

One of the most striking aspects of the musical works produced by IPD Score Generator is their immediate sense of phrase and directed motion, without any reference to traditional composition methods of thematic development or functional harmony. This sense of phrase occurs solely through the agent's interactions as they reinforce and abandon different musical materials. The score generator works at the meso- (or note) level of the work, and has no hierarchical operators to control other aspects of the form.

The Implications of Strategy

One of the key questions raised by IPD Score Generator is what combinations of strategies for interaction between agents can lead to the emergence of interesting musical structures? This is different in many ways to typical IPD research in that the main emphasis here is not on finding a 'best' strategy, but rather looking at the roles that different strategies can play in changing the dynamic musical state of the system. The current system implements seven rule sets (figure 2) that have been tweaked to suit the short memory of the agents; the agents only remember the preceding round.

Generally, in game theory, IPD strategies can be described as nice, or nasty, responsive or unresponsive. Nice strategies will never be the first to defect, while nasty strategies see cooperation as an opportunity to exploit their opponents in the next round. Similarly, responsive strategies will react to the actions of their opponent, while unresponsive strategies ignore their opponent's responses. A strategy's level of forgiveness refers to how quickly they will return to cooperation on their opponent's resumption of cooperation (Poundstone, 1992).

In a musical context, bearing in mind that in ENSEMBLE, cooperation reinforces existing musical materials, while defection results in a random selection of new materials, the rule sets can also be defined according to the roles they tend to play within the virtual ensemble. For example, nice rules can be thought of as 'passive', maintaining a state of equilibrium within the initial musical state, while nasty rules can be thought of as 'agitators' which push the musical state forward by introducing new materials. 'Responsive' rules tend to reinforce this push towards new states instigated by the agitators, while 'forgiving' rules can be considered 'dampeners', coaxing the responsive rules back towards cooperation and the reinforcement of the newly introduced musical materials.

Combinations of these musical behaviours are what give the music produced by ENSEMBLE its sense of phrase, and musical flow.

Name	Strategy	Attributes	Musical Role in the ensemble
TIT FOR TAT	Cooperate in the first round, mimic the opponent's response from the previous round in all subsequent rounds.	Nice Responsive Forgiving- once others cooperate	**Passive**- will maintain a stable cooperative musical surface. Once change begins to occur, it's responsiveness helps introduce new musical materials and consolidate these through cooperating with opponents once others begin to cooperate.
RANDOM	a random or irrational selection.	Unresponsive	Can play an important role as either an **Agitator** for the musical surface (in concert with nice, responsive rules) or a **Dampener** to pull the ensemble back towards more cooperative situations if there is a high level of defection.
VENGEFUL	co-operate until defected against , then defect for the next 5 rounds regardless of opponent's response.	Responsive Nice relatively Unforgiving	**Passive** until defected against, then major **Agitator**- spreads defection quickly through the ensemble, as the 5 rounds of retaliation effect multiple opponents. Can create a very chaotic musical surface punctuated by short cooperative periods.
COPYCAT	do whatever the player with the highest score did in the previous round.	Unresponsive tends to follow 1 round behind others	**Stabiliser**- tends to lag a round behind the other players. As such will allow sounds periods of mass cooperation and defection to linger a little longer than they otherwise would have.
PAVLOV	(traditional) win stay the same, lose change. counts a cooperate/ cooperate response as a loss (ie. opportunity to exploit, so will defect in the next round).	Responsive Nasty Forgiveness in order to exploit	Works well as an **Agitator**, cooperation is an opportunity to exploit! Also takes on the **Dampening** role will pull the musical surface back towards more cooperative states (before exploiting again).
PAVLOV	(passive) as above, but counts the cooperate cooperate result as a win and will not defect until defected against. Unlike TIT FOR TAT, a defect/ defect result will cause cooperation.	Responsive Nice, Forgiving- will hold out the olive branch	**Passive + Dampening-** tends towards cooperative states, and promotes them through holding out the olive branch in periods of high defection. Will retaliate on the first defection though, and continue to do so until it gets a defect/ defect result.
DOWNING	do what the most players in the previous round did.	Unresponsive to specific players, but responds to the overall state	**Stabiliser**- holds the musical state towards either mass cooperation or defection depending on the majority. The downing strategy can play an important role in pushing players towards one state or the other. Use with care- too many Downing's cause the system to get stuck!

Figure 2. Table of currently implemented rule sets and their roles as musical agitators, pushing the musical surface towards new states, consolidators, pulling the musical surface towards previous states and stabilisers, holding the ensemble's behaviour towards either cooperation or defection en masse.

fr@gm3nT [fragment]

Incorporating the performer's actions

In order to incorporate the performer's actions into interactive versions of ENSEMBLE, one of the agents was removed from the system, and the performer effectively 'wired into' the agent's place in the tournament. As such, the performer collaborates with (or competes against) an ensemble of seven agents.

The interactive versions of ENSEMBLE draw inspiration from the notions of performance indeterminacy pioneered by the New York School (see Cage, 1961), in that they aim to push the performer outside their comfort zone to create new musical experiences rather than drawing on the performer's previous knowledge. Although the improvising ensemble is a mode of music making that the system draws inspiration from, it was never intended as a replacement for a human ensemble, but rather as something that offers an experience similar in some ways, but with an emphasis on opening up new possibilities for collaborative music making. To this end, initial systems focused heavily on game play, and in particular 'gaming'. A Graphic User Interface was developed, effectively creating a 'video game '(figure 3), where the performer took on the agents in a competitive musical IPD tournament.

While this graphically oriented system generated some interesting musical results, and certainly is quite a departure from the normal experience of improvising, once work began with Derek Pascoe on the piece *fr@gm3nT* it became clear that when working with experienced improvisers, the interface was not really necessary, or particularly desirable. Pascoe found that he could beat the agent's scores much more often if he abandoned trying to play the game through the graphic interface, and concentrated on listening to the musical output of the system, responding to what he heard. This also made for a far more cohesive musical result. As improvisers generally have highly trained listening skills, and are very attuned to the actions of the other improvisers in a group situation, this was hardly surprising, but certainly an interesting observation.

One of the challenges of the interactive versions of ENSEMBLE has been the incorporation of pitch recognition which is based around Tristan Jehan's 'pitch~' object (Jehan, 2001). The biggest hurdle

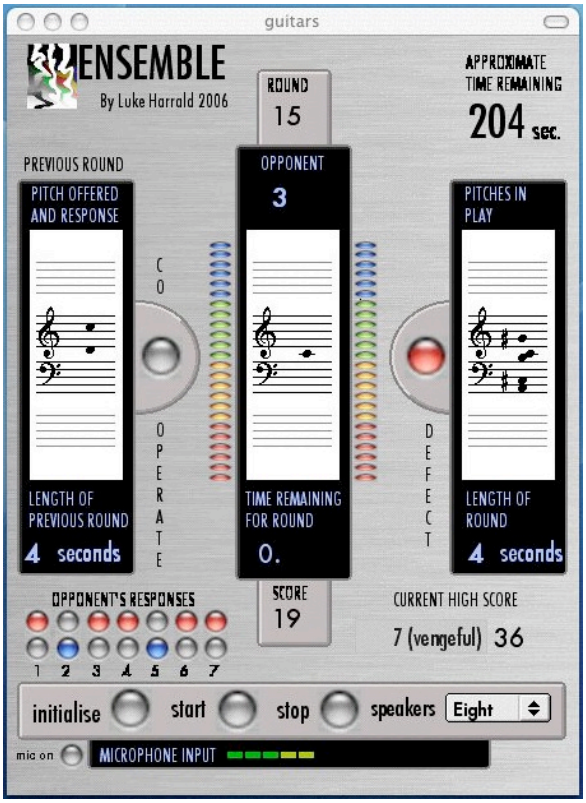

Figure 3: initial version of the interactive ENSEMBLE 'video game'. The performer takes on the ensemble of agents in a five minute battle to see who can get the highest score; generates a new composition at the same time. (May, 2006).

was getting the raw data from the pitch tracker into a useful format that could be understood by the agents. This was compounded a little for *fr@gm3nT* as the work incorporates saxophone multi-phonics and extended techniques. The solution lay in the development of several fuzzy logic operators that allow different aspects of the sound to be tracked, and categorised so that rather than precisely tracking individual sonic events, snapshots of the performer's actions are taken, and then a higher level 'type' of musical material is approximated. Although it may seem counter intuitive, this actually led to a far greater accuracy in recognising different sonic events, and also simplified the system considerably.

Fr@gm3nT makes use of a palette of 28 saxophone samples that are split up into eight types of sound, in some ways reminiscent of Cage's Gamut technique (Pritchett, 1993). In each round of the game, the performer's actions are compared to an offer from an agent. This determines whether the agents see the performer as cooperating with or defecting against their musical initiatives, and shapes their responses in subsequent rounds (figure 5).

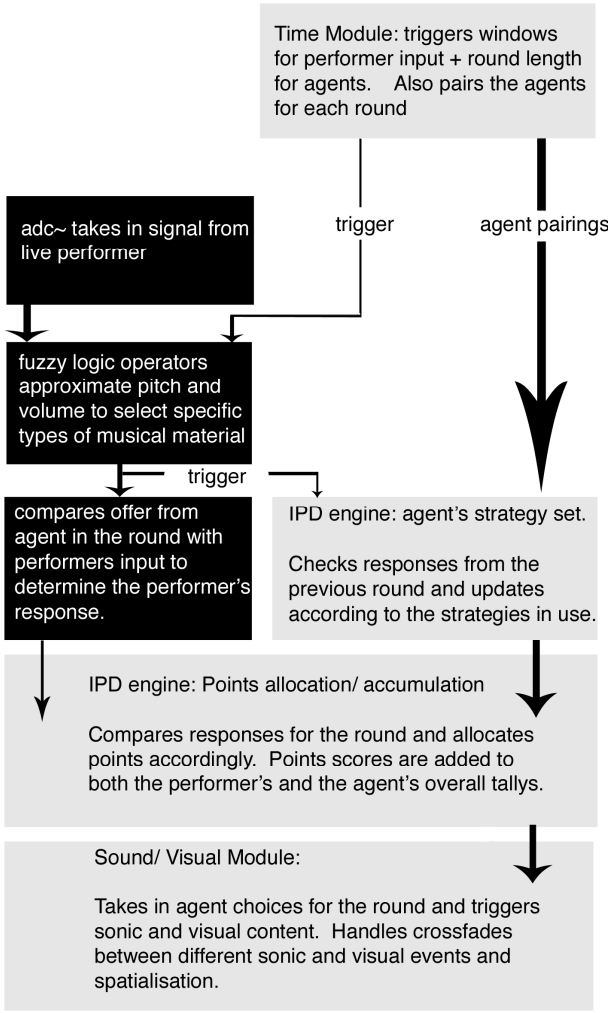

figure 4: modular structure of the ENSEMBLE application as used in fr@gm3nT.

Useful strategies for live performance

The current strategies used in ENSEMBLE are deterministic in that once the game begins the agents are unable to modify their behaviour to attempt to improve their performance in the IPD tournament. This was considered important to allow for a level of clarity in the interactions between the live performer and the agents, allowing the performer over time to become familiar with how different agents behave and how different combinations of strategy affect the global dynamics of the ensemble. Working with Pascoe in this area has been very interesting, as he generally uses a strategic approach to his own improvisations, and has a keen sense of strategy when interacting with fellow (human) improvisers.

The form apparent in the works generated by IPD Score Generator hinges on combinations of strategies that promote global behaviours oscillating between high levels of cooperation and high levels of defection. During periods of high levels of cooperation, the agent's musical choices converge towards a single sonic event, while high levels of defection lead to randomness and a rapid introduction of new musical materials. The speed that the system oscillates between these two states affects the volatility of the music produced.

While these formal considerations are certainly very useful in the live situation, as the performer is effectively also an agent within the system it is fruitful to consider the ensemble's behaviour with regard to the input from the live performer. In this sense, high levels of cooperation within the virtual ensemble are likely to lead to the reinforcement of the performer's musical initiatives (providing the performer has achieved a relatively high score in the tournament themselves), while defection will move the ensemble's output in other musical directions.

Modifying the system to allow the agents to change their strategies, or indeed evolve new strategies, to attempt to improve their performance in the IPD tournament as the game is played have been considered, although Didkovsky's work with the 'Luring Lottery' suggests that modifying the agent's behaviour to improve their overall performance in the tournament may not have a desirable musical effect.

Didkovsky found through his system that in a group of human performers, several behaviours developed in rehearsal prior to the performers having a full understanding of his system that did not occur in the actual performance of the work. These included 'arms escalation', as performers defected against one another to try and gain control of the musical events; 'de-escalation', as they realised that this method did not actually enable anyone make significant changes to the musical events; 'peace', as performers basically gave each other an equal chance of control; and 'destabilisation', as once peace was established, performers would try to take control through defecting from time to time. Unfortunately, the performance was rather tame as once the performers understood how the system worked they tended to work cooperatively as a group without any of the 'social storminess' of the rehearsal. (Divkovsky, 1992). As ENSEMBLE relies on these kinds of retaliatory behaviours to generate form, changing the agent's strategies to improve their performance during the tournament would appear likely to lead to the production homogenous global behaviours, and static music.

The aesthetics of interaction

Much of the music generated through ENSEMBLE draws on the tension and release paradigm, albeit without any reference to traditional compositional devices such as thematic development or functional harmony. As the user is free to choose the agent's strategies, the system is certainly not limited to this approach. Behaviours could be chosen that lead to completely cooperative states, creating either a drone or silence, or equally, unresponsive rules could be chosen to create random works.

Conclusions and future work

ENSEMBLE has proven its value as an algorithmic composition system through various works composed with the IPD Score Generator application. These works demonstrate a sense of musical phrase and form solely through the agent's interactions as they reinforce and abandon different musical materials. This process echoes the way in which form emerges in 'free improvisation' where there are no pre-determined structures, suggesting that the Iterated Prisoner's Dilemma offers a vehicle for modelling the interactions between improvisers without the complexity of attempting to incorporate a performer's musical training or cultural background.

These ideas have transferred across to the interactive system, with the agents able to reinforce or work against the input of a live performer. While the system used in fr@gm3nT is far less advanced than the system used in IPD Score Generator, it is hoped that future interactive systems will lead to the incorporation of a wider range of musical parameters to create more complex modes of interaction.

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