APPLICATION OF MULTI-AGENT WHALE MODELLING TO AN INTERACTIVE SAXOPHONE AND WHALES DUET

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ABSTRACT

'Fast Travel' is named after a Blue Whale call, and is both a scientific experiment in computer-modelling of schools of artificial singing whales and a live performance for saxophone and electronics. The audience hear a live surround sound interaction between a saxophonist and artificial schools of whales. The whales hear the sax as if it is another whale. The audience are surrounded by at least four speakers and a sub-woofer with a saxophonist in the middle. The whale sounds, driven by a computer model, move from speaker to speaker, as the invisible but audible artificial whales move within an invisible sea - the audience are "underwater" with the schools in this "sound sea". The artificially intelligent whale models sing synthesized electronic sounds, evolving new songs live based on hearing each others' performances. The composition title is not just because of the Blue Whale-type song, but because of the way it speeds up the evolution of the whales' song-tuning. Decades are compressed down into the 12 minutes as the audience time travel through the evolution of the underwater music. But the song evolution is driven here by the saxophone, rather than solely by other whales or man-made acoustic phenomena. The scored saxophone is audible to the whales, and influences their tunes through imitation. Although the majority of the saxophone music will be pre-scored, the behaviour of the whales is not 100% predictable because of complex interactions, thus the performance will differ each time.

1. INTRODUCTION

The term "Fast Travel" refers to the songs blue whales sing when they are moving fast rather than, for example, their "milling" songs [1]. The Fast Travel calls come in repeated A-B pairs. The B songs were found by recent research to have the extraordinary property of perfect tuning to the key of C, having dropped a major 3rd from the key of E in the last half century[2].

The performance is called "Fast Travel" not just because of this inspiration but because of the way it speeds up the evolution of the whales' song- tuning. Decades are compressed down into the 12 minutes as the audience time travel through the evolution of the underwater song. But the tuning evolution is driven here by the saxophone, rather than solely by other whales or marine acoustic phenomena. The saxophone is audible to the whales, and influences their tunes through imitation. Hence the saxophonist was able to use a score to move the whales' songs from its initial tuning down to a lower tuning. Within this time whales communicate and learn pitches from each other too. The artificial whale schools are not limited to the deep calls of Blue Whales, but extended to include Humpbacks, renowned for beautiful social singing. The reason for this was that Blue Whale song is not so interesting from a pitch variation point of view, and from a pitch adaptation point of view, and its pitch range verges on the subsonic [2].

Whereas Humpback whales songs have a wide range and variation, and are so beautiful they have been released on many CDs. Humpback song appears to be culturally adaptive in interesting ways as well [3].

2. WHALE SONG

Blue Whale males sing, with the purpose of this singing having both been considered as being for echo-location and perhaps social [4]. Recent research has shown that certain part of blue whale songs – the second part their "Fast Travel" calls - are incredibly closely tuned to the key of C, though it is not clear why this should be the case [5]. There is evidence that Blue Whale song used to be in the key of E and has lowered to the key of C over the last 50 years.

Blue Whale song is in a large part subsonic, and the most famous form of Whale song is in fact heard from male Humpback whales. The first in depth examination of Humpback whale song was done by Roger Payne [6] and led to the release of best-selling record. One of the most interesting aspects of Payne's analysis was the proposal of a form of hierarchical musical structure in the Humpback Whale song. This is shown in Figure 1. As well as having a musical structure, Humpback whale song appears to actually change over time as a result of interaction between the whale songs [3].

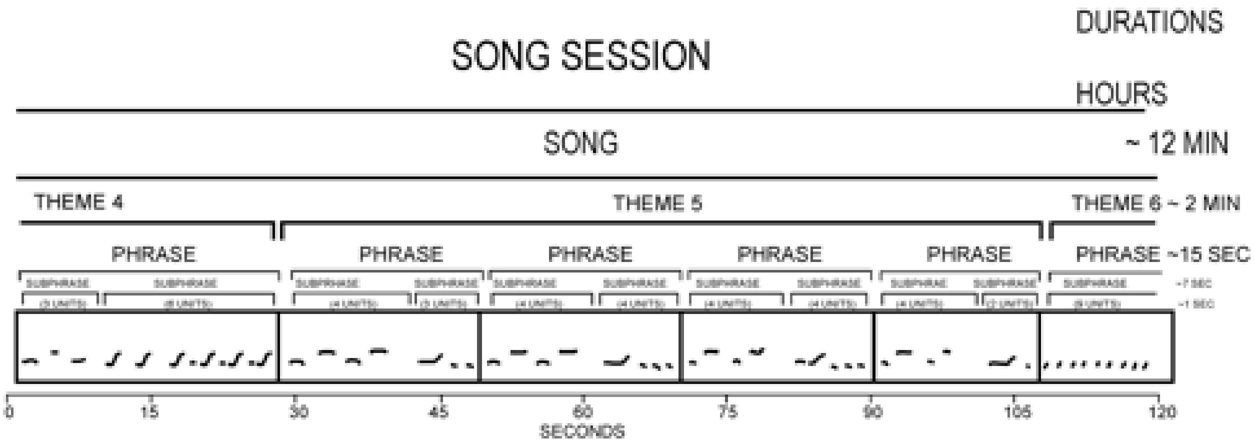

Figure 1. Humpback Whale Song Structure

3. MULTI-AGENT SYSTEMS

The precise definition of multi-agent systems has been approached in different ways. For example [7] focuses on agents that are situated in an environment, with each agent autonomous, and with explicit goal-directed behaviour – not purely reactive. However there are a number of multi-agent system where the agents have a central controller [8][9], and there are a number of researchers who include reactive-based systems as multi-agent. This paper will take this second, more wide-ranging approach. We will focus on one particular area of MAS, where the agents are provided with Biologically-inspired constraints – often called Instance-based Models (IBM) [10].

One of the first was investigate such systems in the context of modeling musical culture is [11]. The system generates musical motifs in a way designed to study the evolution of culture. In this case the agents use a two-way imitation procedure to bond socially. Agents can store a repertoire of tunes and have a basic biological model of an adaptive voice box and auditory system. Agents pick other agents to interact with randomly. When two agents A and B interact the following process occurs: if agent A has tunes in its repertoire it picks one randomly and sings it, if not then it sings a random tune. These tunes are three notes long and do not grow in length. Agent B compares the tune from A to its own repertoire and if it finds one similar enough, plays it back to agent B as an attempted imitation. Then agent B makes a judgement about how good the imitation is. If it is satisfied with the imitation it makes a “re-assuring” noise back to agent A, otherwise it does not. Based on the success of the imitation Agents A and B update their repertoires and their voice box settings to try and improve their chances of socially bonding in later interactions – e.g. by deleting or re-enforcing tunes, or making random deviations to their voice box parameters. The aim of the system is to see how the repertoire is generated and affected under such social pressures. As a result of the social bonding interactions a community repertoire begins to emerge. There are other approaches utilizing this basic idea, such as [12].

There has been some research into modeling and synthesizing of whale song [13] but not into whale song interaction. So how closely these multi-agent modelling approaches relate to humpback or blue whale tune interactions is unknown, but is being investigated in projects we are developing. The Fast Travel system differs to those approaches in a number of ways, including the fact that the agents in Fast Travel are embedded in an artificial sea. Thus the impact that whales’ songs have on each other is dependent on their relative position. Furthermore the system allows a heterogeneous agent to be inserted externally – in this case a human saxophonist. For the purposes of this project, the focus was on the artistic result rather than accurate whale modeling at this stage. Hence a relatively simple whale model has been produced, which will then be augmented in future research. Furthermore the whale song synthesis algorithm was not designed to model whale biology but to produce an artistically convincing sound.

4. WHALE MODEL

For the first implementation of the "Fast Travel" multi-agent system (FTMAS), a generic artificial whale agent (AWA) model was used for all agents of the whale school. This is similar to the approach taken by Anwar et al[14] to simulate human-whale interactions in the St. Lawrence Estuary in Quebec, Canada. No differentiation was made between the 12 species of marine mammals in the estuary because the main focus of their research was on the behaviour of whale-watching tour boat operators. In "Fast Travel" it is the whale songs which are of most interest. The sounds of both Blue and Humpback whales are included in our model, with more of the Humpback type sounds being used because of the well documented musicality of these. Also in contrast to the multi-agent system designed by Anwar et al., the human aspect of the FTMAS is derived from real-time audio analysis of the live saxophone performance, rather than being simulated. The AWAs react to each other, to their environment, and to the saxophonist

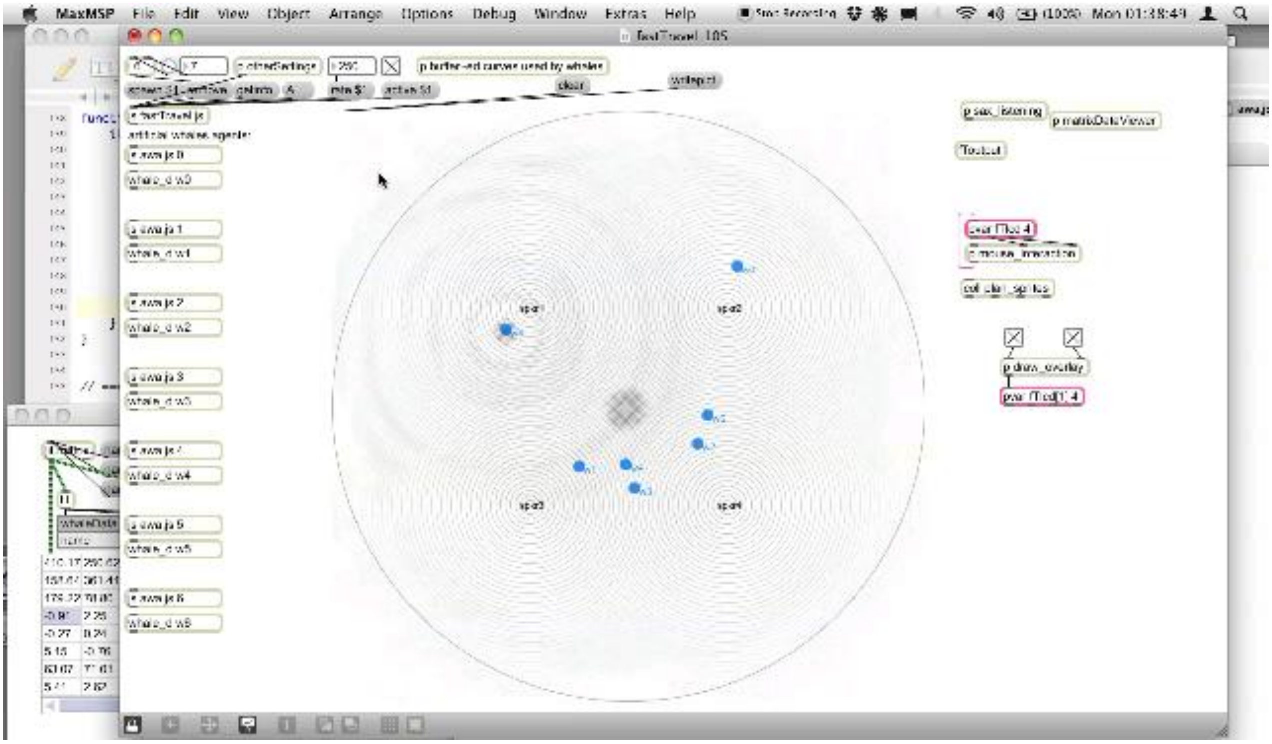

Figure 2. Fast Travel Model Display

with behavioural models for both navigation and aural interaction (listening and singing).

There are two modes of navigation. The first is based on social interaction between the whales, and in which an agent will move either towards or away from another whale using a number of short term personal tendencies to decide which other agent (looking first for the nearest), and which direction. The second mode represents migrational movements of the whales. A parameter is used to set the balance between these two modes of navigation.

In this mode the trajectory of each AWA is determined by the agent's current location within the environment in conjunction with an unchanging personal tendency to move in particular direction. Each AWA is initialised with its own 'pitch centre'. Pitch tracking analysis of the audio input from the saxophone assigns an ever changing pitch centre to the input. The AWAs are aware of the input pitch as well as when the input is and is not 'singing'. The AWAs are also able to 'hear' each other in terms of pitch and singing-or-not. A set of probability weightings is used by each AWA to determine not only if they will sing or not, but also what they will sing. An AWA will change its own pitch centre in reaction to those of the last heard pitch of the input, of the whale they are currently focused on for social navigation, and of the last AWA to have started singing. A subset of whale song audio used by the composer to derive the scored saxophone part is used in a granular sound engine to give voice to the artificial whale agents. This engine allows the agents to alter the duration of a whale sound independently of an evolving pitch envelope of the same. The AWA model is written as a JavaScript for Max/MSP/Jitter (awa.js), and a second JavaScript (fastTravel.js) is used to dynamically create and control agents.

	Saxophone	**Whale parameter evolution**
1	Slower tempo, low loudness. When score complete, finish with 60 seconds improvisation, focusing on call and response interaction with whales.	Humpbacks only. Low density. No whale song overlap allowed
2	Medium tempo, medium loudness.	Low density Humpbacks and Blue Whales. Overlap of songs allowed. Non-pitched songs allowed.
3	No saxophone for first 90 seconds. Then 60 seconds extended saxophone improvisation, imitating non-pitched whale sounds.	High density Humpbacks only. Full overlap allowed.
4	Faster tempo, loud. At end of scored notes, 60 second improvisation, imitating non-pitched whale sounds.	High Density. Humpbacks and Blue Whales. Full overlap allowed. On last score page allow density to fade down.

Table 1. Overview of the composition “Fast Travel”

5. COMPOSITION STRUCTURE

A database of humpback whale song was collated from available recorded song; some pitched and some rhythmic. Out of these, half were incorporated into the whale song synthesis algorithm, and half were utilized in the saxophone composition. The sound files were de-noised and cleaned. A series of “building block” phrases were written for the tenor saxophone. This was done with the help of a pitch tracking algorithm [15] to transcribe the rhythms and pitches found in the Humpback whale database. These phrases were then ordered, repeated and transformed based on the composer’s preferences. Part of the process involved taking into account leaving space for the whales to respond either in serial or in parallel; and taking into account the fact that the whales start off quietly in the distance and move closer, attracted by the sound of saxophone. The general structure of the piece is shown in Table 1.

6. CONCLUSION

Humpback whale song is incredibly beautiful, especially when heard echoing underwater by divers lucky enough to be near a school. Most of us will never get to swim amongst singing Humpbacks. Also most of us will never get to hear the deep throbbing and subsonic blue whale song. Through the use of sound diffusion techniques in MAX/MSP and whale song modelling it becomes possible to immerse the audience not only in an artificial whale environment, but also in a musical composition. The scored saxophone is audible to the whales, and influences their tunes through imitation. Although the majority of the saxophone music will be pre-scored, the behaviour of the artificial whales is not 100% predictable because of their complex interactions, and so the performance will different each time. Fast Travel was commissioned by Peninsula Arts, University of Plymouth. The technologist is Samuel Freeman, University of Huddersfield; the Marine Mammal Consultant is Simon Ingram at the Marine Institute, University of Plymouth. As a result of the initiation of Fast Travel as an artistic project, a new project is being developed in the purely scientific arena for humpback whale modelling. This is an unusual example of an artistic project being the inspiration for a hard science project, rather than the other way round.

7. REFERENCES

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