Gestural Control of Sonic Swarms: Composing with Grouped Sound Objects

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***Abstract* — This paper outlines an alternative controller designed to diffuse and manipulate a swarm of sounds in 3-dimensional space and discusses the compositional issues that emerge from its use. The system uses an algorithm from a nature-derived model describing the spatial behavior of a swarm. The movement of the swarm is mapped in the 3-dimensional space and a series of sound transformation functions for the sonic agents are implemented. The notion of causal relationships is explored regarding the spatial movement of the swarm and sound transformation of the agents by employing the physical controller as a performance, compositional and diffusion tool.**

I. Introduction

Since the introduction of models of Artificial Life into the field of Artificial Intelligence there has been artists fascinated by their outputs and eager to use them for the generation of their work. These A-life systems rely on models of systems found in nature that often exhibit emergent qualities. In an attempt to reproduce the necessary conditions for emergent behavior to occur, these models employ 'bottom-up' strategies through the definition of simple rules that govern the behavior of agents at a local level in the hope that some higher-level structures will be formed. Swarming or flocking behavior as exhibited for example by birds, bees or fish is one such example of emergent behavior in action. In this scenario a self-organised structure is formed through interactions between the flocking agents and their nearest neighbors.

A swarm can be described as a 'dynamic pattern of individuals in space' that has the ability to 'self-organise into spatio-temporal structures' [2]. Parallels can be drawn between the 'spatio-temporal' structures exhibited by a swarm and those found in the structures of music and thus there has been an increasing amount of swarm models utilised for music creation. The swarm-based systems that currently exist seem to be mostly concerned either with the similarities found between the self-organising structures created by the swarm and those generated by musicians in an improvisational context [3], or for the generation of material for granular based synthesis methods [4]. Such systems employ a notion of 'swarm intelligence' to search a system space of musical possibilities considered ‘suitable’ either for the generation of macro musical structures as in the Midi output of ‘Swarm Music’ [3], (other examples see [11],[14]), or micro structures such as the grain cloud generation technique found in ‘Swarm Granulator’ [4].

The afore mentioned macro-level approaches deal with note pattern generation or recognition mechanisms, that function in terms of melody, harmony and rhythm, often trying to replicate the output of a human instrumentalist. Hence, this approach does not take into account the implications that nature-derived systems can have in the electroacoustic domain where the sound itself and its transformation through time along with the polyphonic structure are of primary importance.

In contrast, the system created by the authors attempts to explore the relationship between the spatio-temporal properties inherent in swarms to the timbral transformation of sound objects diffused in 3-dimensional space. This system, which is controlled live by input from a few sensors, potentiometers and a computer keyboard, introduces interesting compositional lines of enquiry relating to the gestural control of swarms of sound objects.

In this way the notion of causality between space and timbre is being addressed. No sound, or in other words no agent of the swarm, can be in two places of the 3-dimensional space at the same time. It requires some time to travel from one position to another and traveling imposes sonic changes. Consequently the performer/composer cannot think in terms of sound diffusion, or timbral transformation separately but only in a connected manner.

II. The Sonic-Swarm Controller

A. 3-Dimensional Swarm Spatialisation

The *Sonic Swarm Controller* is built around a 3-dimensional swarm algorithm implemented by one of the authors as a mxj object in the programming language Max/MSP [9]. The author’s mxj object is based on a java applet by Brooks [6], and draws inspiration from Singer’s Boids [14] object for Max/MSP. The root of all the above is Craig Reynolds Boids algorithm [13], which uses just three simple rules to model the self-organising swarm.

1. Collision Avoidance with nearby flockmates.
2. Velocity Matching with nearby flockmates.
3. Flock Centering with nearby flockmates.

In the author created mxj object, there are a number of parameters that can be altered by the user in real time.

1. Number of swarm agents.
2. Minimum and maximum speed range for the agents.
3. Strength of avoidance.
4. Strength of flock centering.
5. Strength of velocity matching.

This implementation of the Boids algorithm also includes the concept of a 'leader'. The ‘leader’ does not act as a centralised controller for the flock but rather as a centre of mass for the flocking behaviour. The position of the center of mass for the flocking behaviour can be controlled by user input and thus is the main control parameter for the diffusion of the swarm in space. The user has the ability to turn off the flocking of the swarm and to adjust the level of 'desire' for the agents to be near the centre of mass, as demarcated by the position of the leader. In this way the relationship between the degree of grouping of the sound objects and their interaction with the leader can be explored in a performance context.

The *Sonic-Swarm Controller* currently exists in two versions. One for controlling 3-dimensional diffusion within SARC's Sonic Laboratory, using 24 speakers split over the four levels, and a second 2-dimensional quad speaker version, for use as a practice tool in the studio. Each sound object in the swarm has its own sonic identity and is spatialised individually. The spatialisation itself is implemented in Max/MSP using the object vbap~ [12].

B. *Gestural Control of the Sonic Material*

It is not the aim of this paper to discuss issues regarding the relationship between the composer and the realisation of the musical work by means of specific technology. Yet, one could claim that the use of standardised technology probably imposes a social control on the compositional choices, favouring some processes and possibly discarding others [17].

Over the past years there has been an increasing interest in the development of more flexible software and new interfaces for musical expression taking into account the gestural data from a human performer by means of sensors [5]. One of the things that people may find particularly interesting in the physical aspect of the musical performance is possibly interpretation, which is "for both the performer and the audience, a significant further avenue for the exploration of sound" [7].

The *Sonic-Swarm Controller* can be used as an improvisational/performance tool in the concert hall or as a compositional tool in the studio. It gives the ability to spatialise the flock of sounds in the 3-dimensional space and perform transformations of the sonic material by means of physical gestures of the right hand, while the left hand is free to engage and disengage a specific parameter of interest via the computer keyboard and alter the values of some parameters by means of 3 potentiometers mounted on the box of an A/D convertor.

Each agent is represented in Max/MSP by a sound file loaded into a buffer through which parameters such as volume, playback speed, pitch, equalization, number of the flock, cross fade duration, onset time, windowing and so on can be controlled. These parameters can be turned on and off via interaction with the computer keyboard and can be mapped to the data coming from the controller. An indicative setup for the available parameters and their corresponding mapping is illustrated in Table 1.

TABLE I. PARAMETERS AND CORRESPONDING MAPPING.

Parameters	Mapping
Start/Stop Soundfile(s)	Keyboard Function
Swap Leader/Agent	Keyboard Function
X-Fade New Soundfile(s)	Keyboard Function
Freeze Spectrum(s)	Keyboard Function
"Sample Leader"	Keyboard Function
X-Fade Time	Potentiometer 1
Envelope	Potentiometer 2
Mathematical Functions	Potentiometer 3
Volume of Soundfile(s)	Vertical Position
EQ [Cut Off Point]	Vertical Position
Pitch of Soundfile(s)	X-Axis Tilt Accel.
Onset Time	X-Axis Tilt Accel.
"Scrub Through Leader"	X-Axis Tilt Accel.
No. in Swarm	Y-Axis Tilt Accel.
Duration of Windowing	Y-Axis Tilt Accel.
Scatter Onset Time	Y-Axis Tilt Accel.

The rotation of the joint of the wrist and vertical movement of the right hand, controlling the spatilisation of the sonic swarm, is mapped using Max/MSP to different parameters affecting the individual agents/sound files. The right hand outputs only 3 streams of data at any given moment coming from the 2-axis accelerometer measuring tilt attached on the wrist of the operator and the infrared sensor measuring distance on the vertical axis. The idea is that the performer is able to interact with the sonic material in a physical way by manipulating a sufficient amount of parameters but without having to control a great deal of sensors. In order though for the device to be expressive and flexible, the performer is able to dynamically assign the 3 streams of data to different parameters at the same time. In this way the same sensor can be responsible for manipulating more than one parameter at once but not necessarily in the same way by using different functions.

Fig. 1. Photo of prototype Sonic Swarm Controller.

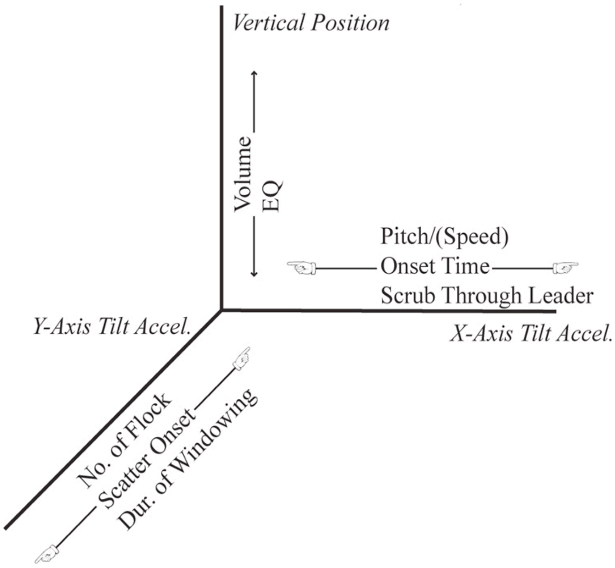

Fig. 2. Parameters altered by means of sensors.

Whether the use of few data streams in our case, favors or restricts the compositional/performance process is debatable. Yet, it is reasonable to assume that greater physical engagement has an impact on the expressiveness of the instrument and consequently on the actual performance [18].

Any soundfile, or even the entire swarm of sounds, can be substituted at any time with a new one. In the former case the performer should be thinking in terms of "families of sounds" rather than in terms of individual sound objects. Complex rhythmical patterns can be also realised with the *Sonic-Swarm Controller*. The performer is not just following the unfolding of the sonic material, instead he/she is able to pull back some of the events by using certain envelope functions, and have time to breathe, think, plan and respond accordingly.

As the swarm of sound moves in space, if any of the available parameters is engaged, then spatialisation will bring about timbral changes. A cause and effect relationship can be established in this way between sonic movement and timbre of the swarm. The performer is able to interact with pre-composed families of sounds, or even perform real-time sampling, and manipulate the sound in a physical way, thus receiving immediate aural feedback from his/her gesture and interact accordingly.

III. WORKING WITH A SWARM OF SOUND OBJECTS

There are probably certain compositional issues that need to be addressed when working with a swarm of sound files. Below we consider some rather important ones.

The first one springs from the very essence of the swarm. The internal movement of the swarm has a life of its own, behaving as a group and governed by nature-derived postulates. Hence any attempt to control the spatial movement of the swarm explicitly fails. The swarm is a family of individual sound files that behave in an interactive way and share common attributes. Consequently, the choice of working with a swarm of sound objects presupposes that the performer is not interested in controlling explicitly the microstrucutre of the swarm; rather he/she is interested in the aggregate impression. The application of simple rules in the generation of complex global behavior is a very common thing in nature-derived models but the current text will not go any further towards this direction; however, for an artistic masterpiece demonstrating the power of an aggregate behavior but in an entirely different context, see [8].

Additionally, even though, in general, a single sound file may have inherently many layers, working with a sonic swarm imposes a multi-layer approach by definition. The performance of a preconceived piece or the performance of an improvisation using a sonic swarm, requires thorough spectral design before hand, explicit knowledge of the gesture-based controller and a well thought performance in order to avoid frequency masking.

A sonic swarm may be thought to suggest a different approach to the norm of sound diffusion in electroacoustic music. In general, "in the 3D field the increased number of simultaneously perceptually identifiable sounds allows the composer a richer counterpoint in both spatial and non-spatial terms" [1]. Yet, within a sonic swarm, even though the scattering of the sonic agents can be manipulated, the flock functions as an entity. Since the spatial separation of the members of the swarm is not explicitly controlled, the spectral qualities of the individual sound files can easily blur, which even though under a certain aesthetic approach may be beneficial, in general, it is something requiring attention if the performer does want to retain the "temporal-textural difference between simultaneous sounds" [1].

The transformation techniques that are available within the *Sonic-Swarm Controller* may lead us to think in terms of events and development whereas the polyphonic structure of the swarm probably more in terms of relationships. Since no agent, in general, can separate itself from the swarm and adopt a completely individual behavior, the composer/performer is forced to think hard about the initial material and how the different voices (i.e. agents) will work together. Hardly the operator of the *Sonic-Swarm Controller* can think in terms of only one event at a time, even though this is also possible. In this way the change of the spectromorphology [15] of the sound object through time is equally important to and bound with the polyphonic structure[1].

IV. DISCUSSION

A problem that emerges from the use of a device aimed to control a swarm is the value behind centralizing some parameters since its emergent behavior is exactly what makes it interesting. The current system though does not destroy the emergent qualities of the swarm. Still the basic rules that govern the self-organization continue to hold. The performer is able to control only the aggregate movement of the flock without any precision over the individuals. Obviously by authorizing a single agent (the leader) to guide the entire swarm, the later is no more entirely autonomous, but this is exactly what makes the present device a controller. The reason behind utilizing a nature-derived swarm for sound diffusion is its straightforward application to a group of sound files, providing a novel approach to sound spatialisation. Additionally the sound transformation functions embedded in the system do not alter the very nature of the flock, rather they establish an audible relationship between space movement and timbral quality. So far the system has only been used informally, mainly in an improvisational context and to a lesser extent in short scale compositions but has proved to work stably. Serious compositional problems will probably emerge in long scale compositions. Issues such as structure and notation can be of primary importance in a substantial piece of music but it is unknown yet if the system, with the current design, is capable of facilitating the compositional process macroscopically.

Moreover, using multiple sonic swarms and performers at the same time is a natural step forward. In this case polyphonic structures acquire a different content and the synchronization of the performers may be an interesting aspect to explore.

Different ways to control the 3-dimensional movement of the swarm and the parameters can be explored further by use of different kinds of sensors along with a computer program that would allow a greater range of transformation functions (and probably greater precision).

The parameters presented in table 1 fall in general within two categories affecting either the timbre of the sound files or providing control over the polyphonic form. The question arising at this point is why the particular parameters were chosen to be controlled by the performer, it is obvious that there are many sound transformation functions that can be included in the system. The ones implemented so far were chosen because they provide a fairly adequate control over the timbral quality of the sound and the polyphony by allowing the user to manipulate a small number of data at any given moment. It does not entail that the device is easy to use since the mapping of different parameters to the same sensors can be fairly tricky. Saying this, it may seem natural to use the 3-dimensional movement of the hand to physically control the spatialisation of the swarm; on the other hand, the choice of the particular mapping strategy for the parameters in question will require more attention if the system progressively includes more options for sound manipulation.

Finally, the design of the system is simple and materially cheap and consequently can be easily reproduced to allow for a multi-sonic-swarm performance. Since the system is easily customizable and has not been designed specifically to assist in the creation of a particular electroacoustic work it is hoped that it can be used efficiently by others and not only by the designers.

V. CONCLUSIONS

In this paper we presented an alternative controller for real-time manipulation and sound diffusion of a sonic swarm. We have suggested that the musical implications of nature-derived models can be expanded to embrace the field of electroacoustic composition by incorporating aspects of physical interaction as well as pre-composed sonic material and their transformation through time. We have tried to address some of the compositional issues that emerge from the use of the particular devise, which also apply to the electroacoustic genre in general when working with swarms of sound objects.

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[1] The notion that electroacoustic techniques invite us to think more in terms of events whereas polyphony more in terms of relationships was exemplified by Alejandro Vinao in a personal conversation with one of the authors.