Sound visualization through a swarm of fireflies

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Abstract. An environment to visually express sound is proposed. It is based on a multi-agent system of swarms and inspired by the visual nature of fireflies. Sound beats are represented by light sources, which attract the virtual fireflies. When fireflies are close to light they gain energy and, as such, their bioluminescence is emphasized. Although real world fireflies do not behave as a swarm, our virtual ones follow a typical swarm behavior. This departure from biological plausibility is justified by aesthetic reasons: the desire to promote fluid visualizations and the need to convey the perturbations caused by sound events. The analysis of the experimental results highlights how the system reacts to a variety of sounds, or sequence of events, producing a visual outcome with distinct animations and artifacts for different musical pieces and genres.

Keywords: Swarm Intelligence; Computer Art; Multi-Agent Systems; Sound Visualization

1 Introduction

Although sound visualization has been an object of study for a long time, the emergence of the computer, with graphic capabilities, allowed the creation of new paradigms and creative processes in the area of sound visualization. Most of the initial experiments were done through analogical processes. Since the advent of computer science, art has taken significant interest in the use of computers for the generation of automated images. In section 2, we present some of the main inspirations to our work including sound visualization, generative artworks, computer art and multi-agent systems.

Our research question relies on the possibility of developing a multi-agent model for sound visualization. We explore the intersection between computer art and nature-inspired multi-agent systems. In the context of this work, swarm simulations are particularly interesting because they allow the expression of a large variety of different types of behaviors and tend to be intuitive and natural forms of interaction.

In section 3 we present the developed project, which is based on a multi-agent system of swarms and inspired by the visual nature of fireflies. In the scope of our work, visualization of music is understood as the mapping of a specific musical composition or sound into a visual language.

Our environment contains sources of light representing sound beats, which attract the fireflies. The closer a firefly is to the light, the more emphasized is its bioluminescence and higher is its chance of collecting energy (life). Using Reynolds' boids algorithm [?], fireflies interact with the surrounding environment by means of sensors. They use them to find and react to energy sources as well as to other fireflies. In section 4 we present an analysis and corresponding experimental results of the systems behavior to 5 different songs. Lastly, in section 5 we present our conclusions and further work to be done.

2 Related Work

Ernst Chladni studied thoroughly the relation between sound and image. One of his best-known achievements was the invention of Cymatics. It geometrically showed the various types of vibration on a rigid surface [?]. In the 1940s Oskar Fischinger made cinematographic works exploring the images of sound by means of traditional animation [?]. His series of 16 studies was his major success [?]. Another geometric approach, was made by Larry Cuba in 1978, but this time with digital tools. "3/78" consisted of 16 objects performing a series of precisely choreographed rhythmic transformations [?].

Complex and self-organized systems have a great appeal for the artistic practice since they can continuously change, adapt and evolve. Over the years, computer artifacts promoting emergent systems behaviors have been explored [?] [?]. Artists got fascinated with the possibility of an unpredictable but satisfying outcome. Examples of this include the work of Ben F. Laposky, Frieder Nake, Manfred Mohr, among many others [?].

3 The Environment

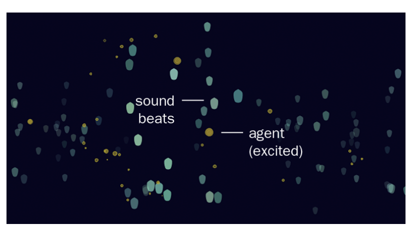

Fig. 1. Systems behavior and appearance example. Best viewed in color.

In this section we present a swarm-based system of fireflies and all of its interactions. In this environment, fireflies are fed by the energy of sound beats (rhythmic onsets). While responding to the surrounding elements of the environment, they search for these energies (see Fig. 1). The colors were chosen according to the real nature of fireflies. Since they are visible at night, we opted for a dark blue in the background and a brighter one for the sound beats. As for bioluminescence, we used yellow.

The environment rules and behaviors, plus the visualization were implemented with Processing. The mechanism for extracting typical audio information was made with the aid of the Minim library, mainly because it contains a function for sound beat detection.

3.1 Sound (energy sources)

Sound Analysis. To visualize sound, a preliminary analysis is necessary. A sound is characterized by 3 main parameters: frequency, amplitude and duration. Frequency determines the pitch of the sound. Amplitude determines how loud the sound is. Duration can define the rhythm of music and also the instant in the music where sound beats happen.

We perform sound analysis prior to the visualization, in order to promote a fluid animation and convey the perturbations caused by sound events. We compute the main sound characteristics (pitch, volume, sound beats) and export them to a text file. Sound beats are detected note onsets. They are related to the temporal/horizontal position of a sound event.

Although the mechanism used to extract audio is not novel and remains simple, we think this approach is adequate to the goals of our system. It fits in the amount of expressiveness that we intend to represent in our visualization, as visual simplicity characterizes the fireflies natural environment

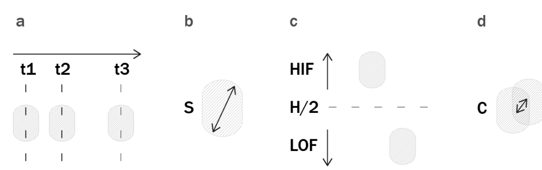

Fig. 2. Graphical representation of sound objects. a - Sound beats instants, b - Amplitude, c - Frequency, d - Collision.

Sound's Graphic Representation. After the sound analysis, all the properties of sound are mapped into graphical representations. Sound beats are mapped into instants (t1, t2, t3,...) which defined the objects horizontal position as shown in Fig. 2a. Each sound object has a pre-defined duration, meaning that it is removed from the environment at the end of its duration. Amplitude was translated into the objects size, i.e., the size is directly proportional to the amplitude (Fig. 2b). Lastly, frequency is mapped into the objects vertical position in the environment (Fig. 2c). High frequencies (HIF) are positioned on the top of screen and low frequencies (LOF) emerge in lower positions of the vertical axis. A fourth characteristic presented in the graphical representation of sound objects is collision (Fig. 2d). This last one is not directly related to sound, only to sound object's physics. When a object collides with another one, a contrary force is applied between these two, separating them from each other.

3.2 Agents (fireflies)

Agent behavior. Because the sound beats are presented from the left to right, fireflies are initially born on the left side of the screen, vertically centered. Agents are provided with a specific vision towards the surrounding environment. A vision angle of 30°and a depth of 150 pixels were considered as optimum values (Fig. 3), because the agents could have a high amount of independence and resemble to their original behavior. Agents motion is based on the "Boids" algorithm. They walk randomly until they find something that may affect their behavior, such as source of light or other agents.

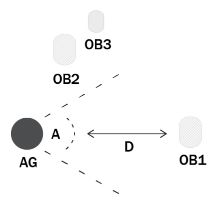

Fig. 3. Agent field of view: angle (A) and depth (D).

The closer they are to a source of light, the more attracted they get to it, meaning that there is a force of attraction towards it. Along with that, agents have a swarming behavior, meaning that neighbor agents can see each others and follow them through flocking behavior rules [**?**].

These rules were presented by Reynolds with a computational model of swarms exhibiting natural flocking behavior. He demonstrated how a particular computer simulation of boids could produce complex phenomena from simple mechanisms. These behaviors define how each creature behaves in relation to its neighbors: separation, alignment or cohesion [**?**].

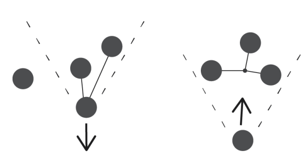

Fig. 4. Left image: separation. Right image: cohesion.

The swarming behaviors present in this system are: separation and cohesion (Fig 4). Separation gives the agents the ability to maintain a certain distance from others nearby in order to prevent agents from crowding together. Cohesion gives agents the ability to approach and form a group with other nearby agents [**?**]. No alignment force was applied. Alignment is usually associated with flocking behavior, like birds and fishes do. Swarm behavior – like the one found in bees, flies and our fireflies – does not imply alignment.

Additionally, the life and death of each agent is also determined by the way it interacts with the environment. The agent begins with an initial lifespan, losing part of its energy at each cycle. If the agent gets close to an energy source, it gains more energy and a longer lifespan; otherwise, it keeps losing its energy until it dies. There are no mechanisms for the rebirth of agents, as we intend to keep a clear visualization and understanding of interactions among agents.

Agent's Graphic Representation. Fireflies use bioluminescence to communicate and attract other fireflies. As an agent gradually approaches the light emitted by a sound object within its field of view, the more excited it gets and the more it emphasizes its bioluminescence (Fig. 5, left image). This will temporarily influence the agents size because it gets intermittent. The real agent size will be as big as the energy (Fig. 5, right image) that it has at a certain instant. When an agent dies, it disappears from the environment.

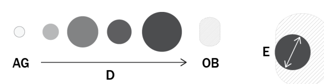

Fig. 5. Left image: agent approximation to an object (AG→OB). Right image: agent growth (E).

4 Results and Discussion

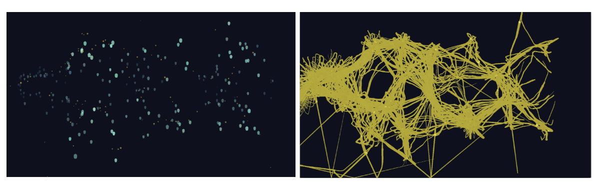

Fig. 6. The music that generated this response is characterized by a variety of intensity and big density of beats.

This section presents an analysis of the systems behavior in response to 4 different songs or melodic sequences (from track 1 to track 4). These tracks vary in rhythm, intensity and frequencies, allowing us to illustrate and highlight how the system reacts to different sound stimuli.

Unfortunately, conveying the overall feel of an animation[1] in a paper has its difficulties. To circumvent this issue and to ease our analysis, first we analyze a complete visualization of the track so we can perceive the differences inside each one. Secondly, we present the trajectory made by the agents of the corresponding music to better analyze their behavior in the different tracks. We present only one example of those figures due to space constraints.

Track 1 corresponds to a piece with high density of beats and low contrast of intensities. This promotes a higher chance of having a longer lifespan. However,

[1] A demonstration video can be found at http://tinyurl.com/ky7yaql.

the low contrast of the intensities implies that they do not gather so much energy at once. Track 2 (Fig. 6), is also characterized by a high density of beats, but in this case the contrast in intensities make swarms gain more energy. Track 3 has a low contrast of frequencies and a balanced density of beats. For Last, Track 4 as opposed to almost all of the other examples so far described, has a strong contrast between high and low frequencies. Adding to this, the low density of beats results in a reduced lifespan for swarms as they have a short field of view.

From the observation of these patterns created by our system, we can conclude: (i) fireflies have a tendency to follow the pattern created by the sound beats as we could see in the example depicted in Fig. 6; (ii) there is a bigger concentration of fireflies in the sources that contain more energy; (iii) tracks with a lower contrast between frequencies promote a more balanced spread of the fireflies in the environment; (iv) tracks with a high density of beats give fireflies a longer lifespan because the agents have a narrow vision field and thus they can collect more energy even if it is in small pieces of it.

5 Conclusions and Future Work

We presented an environment to visualize audio signals. It was inspired by the visual nature of fireflies and based on a multi-agent system of swarms proposed by Reynolds. In this environment, sound is mapped into light objects with energy, which attract the virtual fireflies. When fireflies are close to light they gain energy and, as such, their bioluminescence is emphasized. The flocking behavior of the group emerges based on simple rules of interaction.

In real life the presented technique may be useful for people with low understanding of music to take part in musical events. In further work we will expand our system by introducing more sophisticated mechanisms for the sound analysis, which allow the representation of higher-level concepts and musical events. On the other hand, we also wish to explore alternative visual representations to offer the user a wider array of choices. Finally, a user study should be performed to assess the strengths and weaknesses of the different visualization variants and evaluate the system.