Exploring Artistic Multi-Agents Systems
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Abstract

This paper discusses the use of multi-agent systems concept for artistic creation. While single agent systems have been explored in different artworks, the design of multi-agent systems provides some new interesting design questions. We describe the conception and development of the system used in the audio-visual performance Multiple Realities. In this artwork, images and sounds are generated in real time through dynamical systems that control and evolve virtual organisms. We discuss the issues surrounding interaction design, agency, and system feedback.

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Exploring Artistic Multi-Agent Systems

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Abstract

This paper discusses the use of multi-agent dynamical systems for artistic creation. While single agent systems have been explored in different ways, the design of multi-agent systems provides some new interesting design opportunities. We describe the conception and development of the system used in the audio-visual performance Multiple Realities. In this artwork, images and sounds are generated in real time through agents controlled by dynamical systems. We discuss the trade-offs related to design flexibility and emergent characteristics.

1. Introduction

Generative techniques have been used to create musical compositions, images, and other visual elements. By using them, artists give up some direct control of the final result to a system. The system itself may be seen as an agent, since it executes actions that create the artwork on behalf of the artist. Agents normally exhibit some level of autonomy and awareness of their environment; however, their level of perceived intelligence can vary.

An agent can perform complex tasks by making use of knowledge about state of the environment where the task happens. For example, a painting robot can keep track of what has already been painted to avoid painting one object over another. If more than one agent is involved in a task, not only knowledge about the environment is necessary but also shared information about goals and internal models. The lack of complete information, however, can lead to interesting opportunities for creativity. One example is the *cadavre exquis* technique, in which collaborators draw in a folded piece of paper without seeing the whole picture. The result from this method is often nonsensical drawings, that bind together parts in unexpected ways. That was viewed by surrealists as Simone Kahn and André Breton as a way to break out from an ordinary mode of thinking. As Kahn writes: "the game became a system, a method of research, a means of exaltation as well as stimulation, and even, perhaps, a kind of drug".

In this paper, we explore how we can increase the creative potential of simple agents by combining them together to create a single artefact. We describe the system developed for the audiovisual performance Multiple Realities, which uses dynamical systems as agent models.

2. Related Work

Previous work has looked into human-robot collaboration and also into systems with multiple components. Burkovski et al. present a robotic platform for collaborative painting [1]. In this system, several users can remotely control a painting robot by moving smartphones for 10 seconds. Each user is assigned a single axis of the robot arm and the final motion is a result of the sum of the individual joint movements. In this project, the robot is just a passive tool, however, the composition step is similar to our proposition since there is no central coordination mechanism.

The Game of Life [7] is a cellular automata that takes place in a grid in which each cell can be dead or alive. From a given grid configuration, the next generation can be obtained by following two rules: 1) if a cell is alive and it has two or three adjacent neighbour cells alive, it stays alive. Otherwise it dies. 2) if a cell is dead and it has exactly three alive neighbours, it becomes alive. Cellular automata like this have been used for algorithmic composition, after a careful specification of the rules, evolution of the system, and mapping of state behaviours to music parameters [9].

Depending on how the output of the automata is used, it can be viewed either as multiple agents (each cell) coordinating through the medium, or as a single agent composed by cells. In spite of the simple rules, the game can generate complex behaviours such as oscillators and patterns that move throughout the grid. These patterns maintain their organization within the grid by self-producing their components (e.g., a glider consists of 5 live cells in a particular configuration). From a cybernetic perspective, these are characteristics that can be ascribed to living organisms [8].

The dynamical hypothesis of cognition regards it as the result of the evolution of a system in the space-state [2]. Interestingly, connectionist systems often mentioned in the context of intelligent agents, can also be viewed as a realization of a dynamical system. In this case, we view the trained network as one specific configuration of the "activation space" that leads to the problem solution [3]. Self-organization can also appear when ensembles of dynamical systems are coupled through short range interactions. This configuration has been used to investigate emergence from primordial soups of large macromolecules [10, 11] and has been linked to the origin of inference capabilities [11]. This is similar to the strategy we present here.

The connection between the agent behaviour complexity and the quality of production is more evident in the problem of music composition. An interesting music is neither completely predictable nor completely random [4, 5]. One way to ensure that a composition fits within those limits, is to evolve populations of parameters and perform selection based on how close the features of an individual are to the desired style (Differential Evolution). Kaliaktsos et al. present an analysis of the fitness of different dynamical systems to support music composition [6]. Several iterative maps were used as tone generators, fitted to rhythmic patterns of target pieces, and optimized using differential evolution. The reconstructed space-state of the target pieces (Bach, Mozart, Beethoven, and general jazz) incorporated many dimensions, indicating that dynamical systems to generate them should also have a large number of dimensions as well. In our work, instead of using a high dimensional dynamical system, we use several unidimensional ones interacting with each other as agents.

3. Exploring Multi-Agent Systems

The system developed for the Multiple Realities performance combines the ideas previously discussed to create an audio-visual experience. It consists of three components: a generative director, a visual generator, and an audio generator. The system can be configured in real-time or in the beginning of each performance (if desired) to yield unique experiences.

2.1 Generative Director

The role of the Director is to orchestrate the different visual elements of the performance and drive the corresponding musical composition. It consists of several agents controlled by independent dynamical systems running in parallel. Although it is treated as one component, each agent is independent and there is no central coordination mechanism. Each agent has a single numeric output that can be connected to a pre-defined visual parameter (for example, scale) or to an audio parameter (frequency or duration).

The agents exist and move in 3D space. In every time step, the agents move close to another agent within the visibility radius. If they get too close, they slowly move apart until a predefined separation distance is reached. Agents also grow and pulsate following the internal evolution of the dynamical system. When an agent gets in contact with another, there is a 50% chance that a cross-over will happen, effectively switching the parameters of involved dynamical systems. This causes each agent to move to a different part of the state-space and potentially initiate other exchanges. Similar to a cellular automaton, some configurations can generate stable oscillatory patterns (Figure 1).

Our system is not completely offline and was designed to be manipulated by a human performer. Using a virtual reality interface, the performer can move agents to new positions in 3D space. This changes the connection topology, allowing new patterns emerge. If an agent is placed outside the visibility radius, it will evolve without interference. Agents in close proximity will change the state more often, leading to synchronized patterns and smaller periods. Human interaction is possible but not necessary: if left alone, the system will evolve by itself. Figure *3* shows how agents can be distributed and move through space.

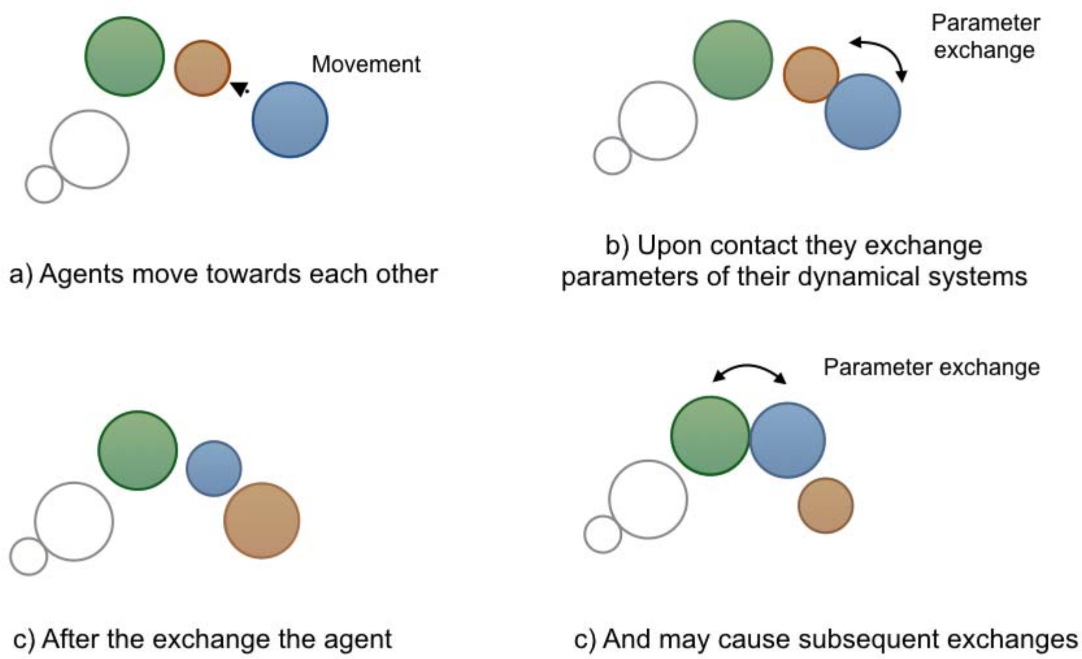

Figure 1 – How patterns that arise from the interaction among dynamical agents

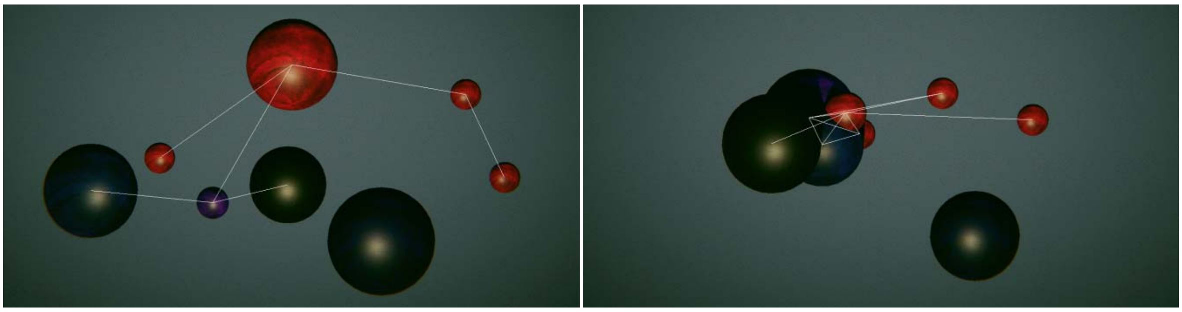

Figure 3 – Left: Initial configuration of the agents in space. Right: Configuration after some time has passed. Lines indicate pairs which are moving closer.

For the inaugural performance, we chose the logistic map as the internal dynamical system for all the agents. The logistic map is a simple unidimensional quadratic function that is a discrete version of the continuous logistic equation of population growth (Equation 1).

$$x_{n+1} = rx_n\left(1 - x_n\right) \quad (1)$$

The logistic map has a single parameter which defines the behaviour of the system. For values of X within the unit interval, it reaches chaotic behaviour through a period doubling route. Chaotic behaviour starts at around r=3.5699456 and when r=4, the attractor covers the whole unitary range [12].

2.2 Visual Generator

The outputs from the Director are used to control three groups elements, each containing a few hundred copies of a geometric primitive. The groups are controlled by adjusting the distance of each element from the original position, scale of each element, and the distance among elements of the same group. Figure 4 shows the three primitives used. The leftmost and rightmost models are actually space-state trajectories of Sprott and Aizawa attractors.

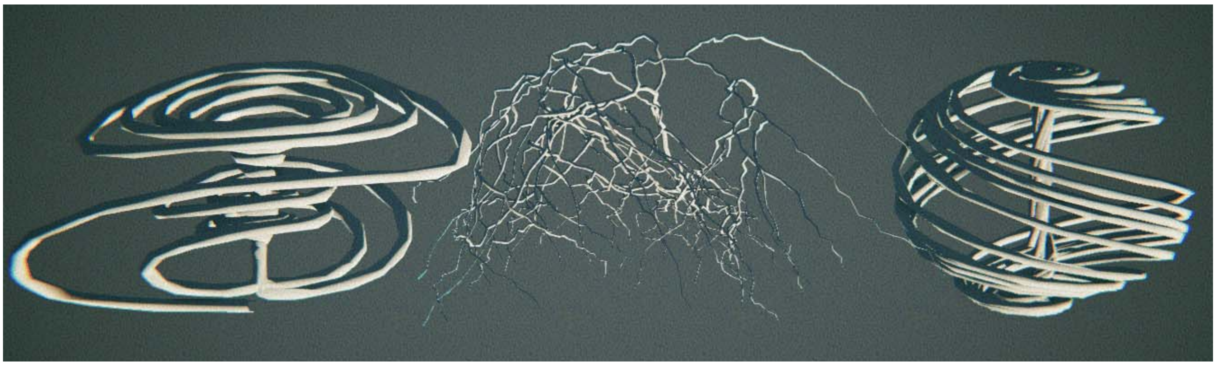

Figure 4 – Geometric primitives used in the artwork. Left: Galaxy; Middle Roots; Right: Intelligence

The artwork was inspired by cosmological theories of multiple universes, the origin of life, and consciousness as a way to navigate among realities. Figure 5 shows some generated visuals.

2.3 Audio Generator

The output from the Director is fed directly to the audio synthesis software SuperCollider using an Open Sound Control interface. The population value is used to choose a tone from the major scale. A script generates tones resembling a string synthesizer with chorus effects. Agents operating below the first bifurcation (r≈3.0) are muted to prevent distracting continuous sounds.

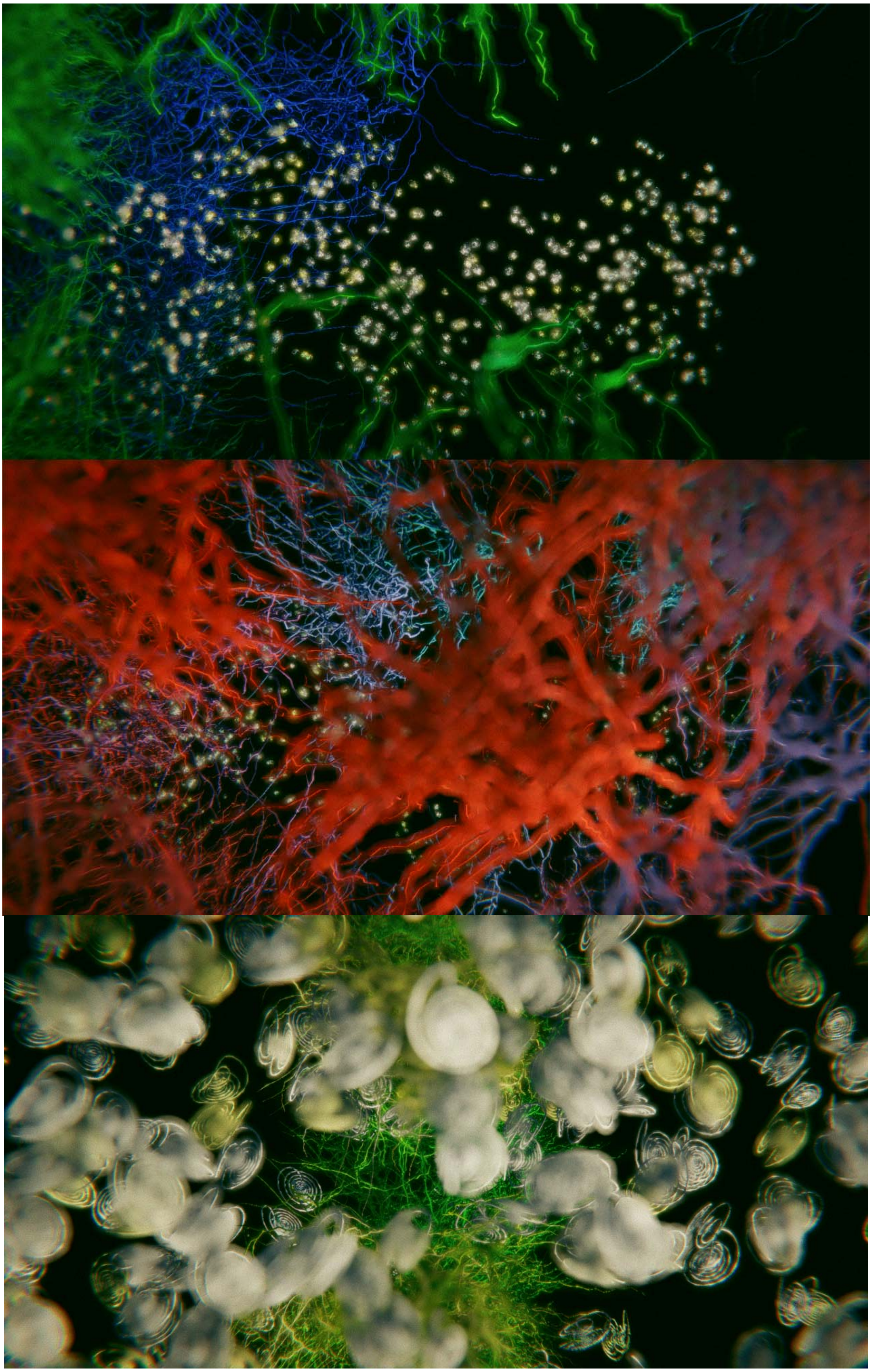

Figure 3 – Screenshots of the resulting animation

3. Conclusion and Future Work

The multi-agent model outlined in this paper was successful in creating patterns that could not be seen when the agents were isolated. The use of multiple agents also gave more freedom to select how each audio-visual element would behave, since each was tied to a single dynamical system. In a high dimensional system, all variables are coupled, effectively preventing this sort of individual adjustment.

When synchronization is desired, one possible strategy is to design separate agents with the same parameter but different initial conditions. As the system evolves they will converge in the same attractor (if outside the chaotic region). Another strategy is to use the interaction between agents to synchronize them (by matching the current state). However, if a more coherent behaviour is desired, it may be more convenient to use a single dynamical system to drive all elements simultaneously.

Finally, in this work we simply exchanged the parameter of the logistic map, while maintaining the same population. Future work may look into more complex interactions, such as duplicating, deleting, and generating new agents based on the parent's interactions. In addition, our movement strategy was very simple. More interesting behaviours may arise with more sophisticated movement patterns.

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