Towards Symbiotic Interaction in/with Artificial Ecosystems

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Premise

This paper develops a comparative discussion of responsive and interactive art. By way of example, we discuss the conceptual ground and implementation of a recent interactive audiovisual installation called Crickets. Our system interfaces an artificial agency with the grounded world through computer vision. Truly interactive systems are characterized as affording a life-like, unpredictable though coherent audiovisual experience. We take inspiration form the science of complex dynamical systems, the process of biological reproduction and the theory of enactment. The notion of emergence is key; the agency develops complex spatiotemporal patterns from simple interactions amongst constituent components. The human participant is actively engaged in an anticipatory process; a rewarding experience issues from the appreciation of relative uncertainty and unpredictability in system behavior.

1. Introduction

Natural ecosystems like rainforest are intrinsically complex in terms of morphology and behavior because innumerable active components are engaged in continuous processes of interaction. Living species coexist and co-evolve in a sustained common biotope generating perpetual novelty. Complex spatiotemporal patterns materialize spontaneously from interlocking processes; for example, the sound of the forest emerges as an articulate dynamical pattern blending anticipation and surprise in a human participant. In addition, ecosystems exist as complex hierarchical structures themselves spawning behavior at a higher level. A forest is thus seen as a complex adaptive system sustaining the development of hierarchies of signals and boundaries still holding many mysteries [3, p11]. According to Holland, four categories are relevant to all signal/boundary systems: diversity, recirculation, niche and co-evolution. Diversity follows from internal constraints and the interaction of species in a struggle for survival. Recirculation of resources from organism to organism creates complex patterns in morphology and behavior. Our implementation loosely follows the adaptive signal/boundary systems framework in the construction

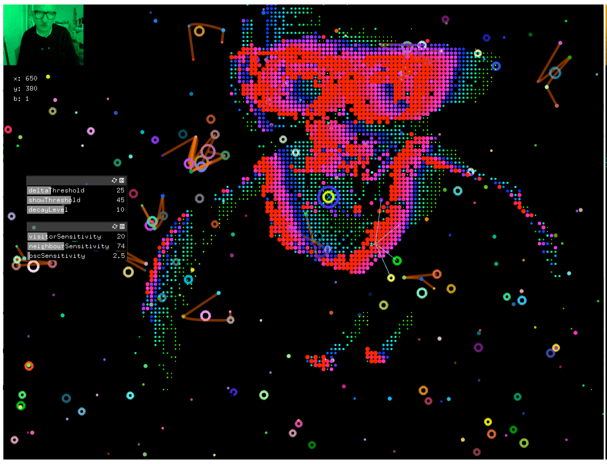

Fig. 1. Snapshot showing camera image, processed image, particle agency, and parameter editor.

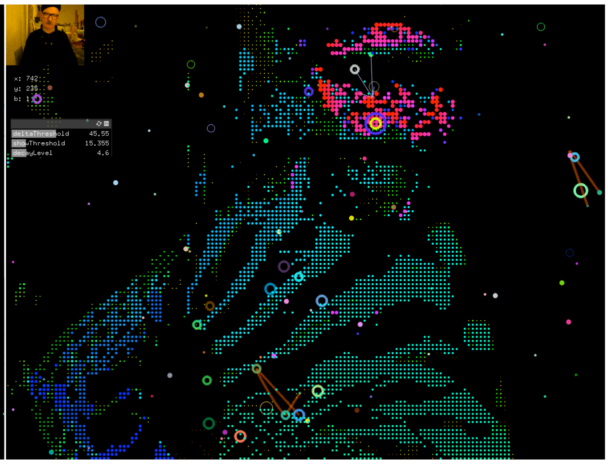

Fig. 2. Snapshot showing camera image, processed image, particle agency, and parameter editor.

of a hybrid reality system; the artificial world and human participant(s) coexist in a shared higher-level compound environment. Also, Crickets builds on earlier work, including *Living Gestures* [1], and *Rainforest* [2] - a large-scale interactive installation where the notions of coexistence, mutual influence, emergence and autonomy underpin systems design. However, Crickets suggest a more private, complex single user experience. Unpredictable waves of audiovisual patterns emerge – nevertheless the impression of coherent behavior subsists: balancing anticipation and surprise contribute to a strong engaging experience.

In this light, let us briefly compare the creation process of (1) artificial structures and (2) living structures as found in nature. In general, explicitly engineered artificial structures are designed top-down, exploiting unambiguous knowledge through symbolic representations. Such structures are brittle facing unpredictable impact. Most often, explicit engineering implies a predefined goal. When turning to natural artifacts, things are very different: nature creates complex hierarchical structures bottom-up, life emerges spontaneously from the enactment of simple components. According to the theory of enactment, first advocated by biologists Maturana and Varela, living systems continuously recreate the required components and their hierarchical organization in order to remain alive [4]. Therefore, natural systems behave autonomously by adapting gracefully to unpredictable challenges.

What can we learn from examples of adaptive interaction in biological workspaces? Symbiotic interaction amongst living species implies mutual benefit in terms of chances for reproduction and survival. Some creatures in nature develop deeply cooperative behavior: consider the symbiosis between the sea anemone and the clownfish as an exceptional example of interconnectivity between different plants and animals in their common environment. The fish seeks to hide in the plant as to find protection from predators, in addition, the fish eats the algae in the plant while the sea anemone needs protection from competition with algae. So both anemone and fish develop an intimate relationship based on the principle of rewarding coexistence. We suggest to turn to such inspiring instances of complex biological behaviour to design augmented forms of human machine interaction.

In conclusion, predictable engineering structures are created through explicit instructions. In contrast, natural living structures emerge through construction – the constructive effect of many contributing forces. In addition, in terms of its design, Crickets is not engineered from unequivocal instructions but adapts a strategy of speculative computing; the focus is mobile and a functional system gradually emerges from active experimental programming. Inspired by the theory of enactment we may rethink interactive art systems. Let us first address the global nature of interactive systems according to a collection of underpinning keywords.

2. Implementation

Crickets is implemented as three concurrent processes (1) a distributed artificial agency and (2) a computer-vision component, both written in C++ (OpenFrameworks [6]) and (3) an audio component implemented in SuperCollider [5]. Processes communicate via Open Sound Control.

The agency holds a variable collection of agents, particle-like objects, characterized by 2D position, energy level, angle of movement, angle delta, status (awake or asleep), gender (4 options), neighbor sensitivity, level of attraction to human activity, survival chance and reproduction chance. Agents locally interact and dissipate energy by configuring themselves into temporal clusters. In addition, the centroid of the intensity of human activity in the analog word is relayed to the agency; agents, when awake, move toward this temporal zone of influence. Given a critical mass of agents in a particular area, they will create offspring according to a variable reproduction table accommodating non-binary gender. Agents gradually disappear depending on the history of their interactions and the energy they spent. Dynamic visualization documents global systems behavior and signals the moments in time when individual agents interact. In addition, the moment when any two agents connect, a sound is heard reflecting features of the agents in question – a Frequency Modulation synth object is instantiated in SuperCollider; agent energy, velocity and angle of movement are mapped to FM parameters.

A small camera captures outside activity in a low resolution, maps intensity of activity in a color scale and stores the result in a self-fading memory structure. The rationale is to capture movement in time (in a time frame from one to several seconds) rather than stationary snapshots. We are interested in the quality/ complexity of spontaneous body language and its dynamic visualization.

3. Discussion

Crickets suggests an interactive experience rather than a responsive structure, there is no clear-cut relationship between internal and external behavior. Humans interact as participants in a non-transparent interface since we avoid trivial mappings in favor of expression of influence over otherwise autonomous system behavior. From simple local interactions between agents we get global emergent functionality: variable hierarchies of emergent spatiotemporal patterns.

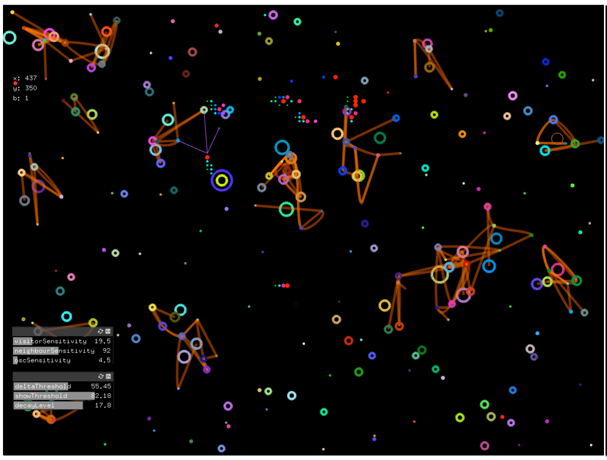

Fig 3 Snapshot documenting particle clustering and parameter editor.

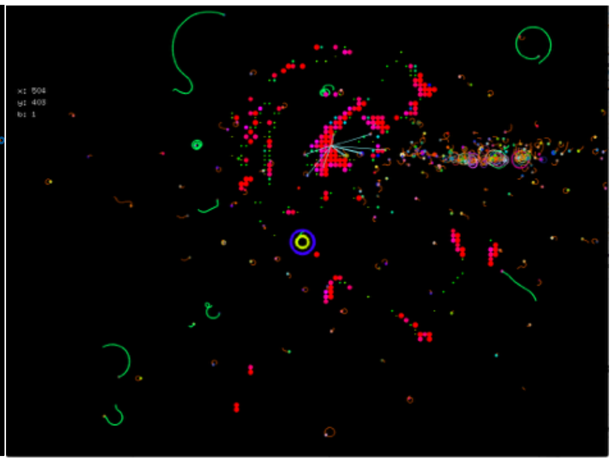

Fig 4 Snapshot documenting user/particle attraction and particle interaction.

Figures 1 to 4 display snapshots of the running system. Fig 1 and 2 provide an impression of the picture-processing algorithm: a low-resolution grayscale version of the live camera image is captured in a rectangular array; gray values are mapped to a HSI (hue, saturation, intensity) color model using the complete color spectrum. Three parameters condition the behavior of the vision procedure: (1) deltaThreshold, showThreshold and decayLevel. In case the absolute difference in image intensity between the current and previously captured frame is higher than the DeltaThreshold, the image memory array is incremented – if not, values in the memory array are decremented in proportion to the decayLevel parameter. When the memory array is shows on top of the particle world, array values below the showThreshold parameter are not displayed. Note the GUI sliders are only used to explore the system's behavioral scope and they are not displayed under normal operation. Parameters self-adapt within a particular range of values as to accommodate external under- or overstimulation.

Life-like qualities are reflected in the emergence of spatiotemporal patterns. Agents contain a simple form of parametric self-representation and exchange information with their neighbors and the environment i.e. the human interactor. Actors' functionality follows from the integrity and relationships between their instance variables. Long-term complexity follows form the multi-gender reproduction process. This procedure is self-sustaining and self-critical since both the number of offspings and their diversity (the quality of the breeding process) influences the fitness of the reproduction process. Somehow metaphorically, we introduced the concept of enactment to view the notion of (1) autonomy as a system that regenerates its components and their organization and (2) structural coupling as a way to explain emergent patterns as byproducts of the systems' interaction history. We shall further develop this orientation in future work.

Merging dynamic visualization of emergent structures and real-time sonification contributes to an engaging experience of a life-like artificial world. In contrast to virtual worlds conceived as computer games, the work reported here excludes explicit goals. It aims to connect abstract scripted virtual life forms with grounded individual and social life forms 'on the other side of the screen'. Also, Crickets is adaptive and gracefully accommodates from vigorous to extremely subtle human activity. The interaction paradigm explored here leaves the human participant with a variable degree of understanding; global behavior cannot be explained from the observation of local events. A particular mix of meaning and mystery acts as a source of rewarding human-machine interaction; the idea of interaction itself is extended into a profound, machine mediated aesthetic experience.

Future research will address the full potential of symbiotic interaction in cultural rather than biological workspaces. A first step is the development of the notion of aesthetic survival - how machine and human performers subsist in a common habitat while sharing life through mutual creative decision making.

References

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