Evolution of Artificial Soundscape in a Natural Environment

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Introduction

Research on artificial life involves attempts to produce life-like phenomena through simulations using computer models, robotics, and biochemistry. In this paper, we propose a new approach to artificial life experimentation in an open environment, with an autonomous sensor network (ASN) we have developed (Maruyama et al., 2013). It takes a form of an experimental sound generative art installation (Ikegami et al., 2012), aiming to explore behavior over a longer term in an open environment including living systems, e.g., song birds.

Our main study principle for installing autonomy in a system or an environment, a concept that has been fostered in the field of artificial life. Autonomy in a system creates a pleasant distance between object and observer but also arouses emotions which, like those we have for our pets, can give rise to long-lasting relationships.

Based on this concept, we have created a sound installation using an ASN. The system obtains sensor information from the environment, maintains a basic (artificial) metabolism, and changes its behavior after a certain amount of information processing has occurred (e.g., light and humidity sensor data). Those information will be used to control the pattern and amplitude of the parametric speakers. By coupling the ASN driven soundscape with a natural soundscape, we are also proposing a new idea of how an artificial system can resonate with a particular environmental pattern including real living systems. We believe such interaction between artificial and real systems will provide a new experimental platform for studying and understanding open natural systems.

ASN system

We propose an ASN system that is spatially distributed in the real world (Maruyama et al., 2013; Ikegami et al., 2012). One node is composed of sensors (e.g. light and humidity sensors), that senses the corresponding environment information with an adaptive sensing cycle. The sensor information obtained by each node will be sent to other nodes (we set the number of nodes at two) via wireless connections. In other words, each sensor is attached to a buffer of each node that accumulates sensor information from its own sensor. Two kinds of buffers (one associated with light, and the other with humidity) are associated with each node.

This system is unique in that we use a metaphor of spatially extended chemical reaction schema. A modified Gray-Scott reaction-diffusion model is used as a design for this sensor network. This model is a translation of a spatially extended chemical reaction into an active sensing and wireless network system. The comparison is summarized in Table 1.

Table 1: Comparison between Chemical and Sensor Networks

Chemical network	Sensor network
chemical species	sensor type
chemical sensors	digital sensors
chemical reaction tank	digital sensor buffer
diffusion	packet switching

Sensory data in each unit are put onto the buffer, and an assumed reaction will take place in that buffer. Suppose that sensor values A and B are received by the corresponding sensor. For example, we use the reaction $A + B^2 \rightarrow C$ to change the sensing cycle of the sensor, whose reaction speed is proportional to $[A][B]^2$. The sensing cycle length is defined as how often a sensor receives the sensory value from the environment. Namely, the sensing cycle will be increased or decreased, proportional to the reaction rate. It should be noted that the sensor values will not be affected by the reaction but, only the cycle length will be updated. After computing the reaction rates, those sensor values will be sent to the other wirelessly connected sensor nodes. As a result, the sensing data will be circulating in the network through a wireless connection.

Fig.1 illustrates the rough circuit of Arduino, XBee, and the main processor that implements the virtual chemical network in one unit, which has four inputs from and four outputs to other sensor nodes connected by a wireless connection. They are controlled by two XBees and two Arduinos. 1) The XBee is used to receive sensor data from other nodes and to send the data to the main processor. 2) The Arduino is used to send sensor data obtained from the sensor itself to the main processor when requested. 3) All of the data is eventually received at the input controller, a module implemented in the main processor. The main thread in the system emulates the chemical reaction thread. The buffers store sensor values in this thread, and the sensor data sent from the input controller are saved in these buffers. If a buffer becomes full, the input data are not received and are lost. The reaction thread is periodically executed by using the sensor data saved in the buffers for every 1,000 msec. As a result, the sensing cycle will be updated.

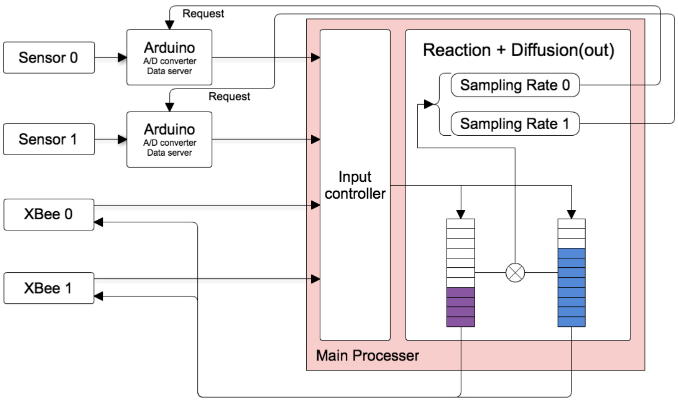

Figure 1: Overview of a sensor unit mechanism in the autonomous sensor network. The two buffers accumulate sensor information (IR and ambient sensors in this experiment Ikegami et al. (2012)) from the sensors and other data sent from other nodes connected wirelessly in the space. The reaction-diffusion module uses values in these buffers to changes the length of sensing cycle. A pair of sound file is associated with the sensing cycle of each sensor unit. When a sensing cycle bifurcates, it automatically switches from one sound file to the other.

Results and Discussions

Using the ASN simulator, we tested how the sensing cycle changes by increasing the value and complexity of various sensory inputs. Even by increasing a single ambient light inputs from a lower to a higher value, the sensing cycle shows a complex bifurcation from a periodic to chaotic behaviors. Bringing the ASN network to the open environment and using the parametric speakers to generate artificial sounds from it, we studied how behavior of ASN will be developed over time. A pair of sound file is associated with the sensing cycle of each sensor unit. When the length of a sensing cycle bifurcates, sound will automatically switch from one pattern to the other. A preliminary experiment showed that i) ASN certainly responds to the light changes and ii) parametric speakers are much more effective in the open environment. In the talk, we will report the further experiment of this artificial soundscape and the analysis of ASN state changes over a longer period of time.

The significance of this work is twofold. First, artificial life is shown as an autonomous chemical network that is translated into a digital sensor network system. Second, this work shows how an artificial life system behaves in an open environment as opposed to a closed, simulated environment for relatively longer periods of time. A most interesting finding here is that the network spontaneously generates a resonating state (and a resting state) to a particular set of parameters or to the space and time context, without having predefined conditions or functions.

The research is likely to be transformational in several ways. First, it will change ecology/behavior entirely if it establishes complexity of soundscape over a longer period of time and that it can be understand. Second, it will be transformational to computational "network" linguistics if the natural world beyond humans were to have echo-ecology. Similarly, it will radically expand the range of engineering with sound generation and recording in the spatially and temporally extended system.

The project has a strong outreach component with artists that will greatly aid appreciation of those transformations and furthering public understanding of the science involved. The principal thematic contribution; understanding complexity in natural systems, will come from building an artificial sensory network and let it interact with a natural open environment. Built on new contributions from engineering, this will permit the project to characterize and understand the complexity of acoustic environments, in particular of bird songs (Arriaga et al., 2013). By combining acoustic and behavioral observations it will be possible to model, simulate and predict complex systems of spatially and temporally extended.

References

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