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

<table>
<thead>
<tr>
<th>Chemical network</th>
<th>Sensor network</th>
</tr>
</thead>
<tbody>
<tr>
<td>chemical species</td>
<td>sensor type</td>
</tr>
<tr>
<td>chemical sensors</td>
<td>digital sensors</td>
</tr>
<tr>
<td>chemical reaction tank</td>
<td>digital sensor buffer</td>
</tr>
<tr>
<td>diffusion</td>
<td>packet switching</td>
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</tbody>
</table>

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 connec-
tion. 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 eventu-
ally received at the input controller, a module implemented 
in the main processor. The main thread in the system emu-
lates the chemical reaction thread. The buffers store sensor 
values in this thread, and the sensor data sent from the in-
put controller are saved in these buffers. If a buffer becomes 
full, the input data are not received and are lost. The reac-
tion 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 au-
tonomous sensor network. The two buffers accumulate sen-
sor 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 in-
puts 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 sens-
ing cycle of each sensor unit. When 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) para-
netric speakers are much more effective in the open envi-
ronment. 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 find-
ing here is that the network spontaneously generates a res-
onating state (and a resting state) to a particular set of pa-
rameters 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 es-
tablishes complexity of soundscape over a longer period of 
time and that it can be understand. Second, it will be trans-
formational to computational “network” linguistics if the 
natural world beyond humans were to have echo-ecology. 
Similarly, it will radically expand the range of engineer-
ning 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 com-
plexity in natural systems, will come from building an arti-
ficial 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, simu-
late and predict complex systems of spatially and temporally 
extended.

References

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