Implementation of Symbiotic Information Systems

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1 Introduction
The purpose of this theme is to develop an actual system based on the outcome of the 21st Century COE (Center of Excellence) Project. It is important for the program to spread its potentialities and symbiotic information systems. Therefore, we proposed an object selection system as an instance of an actual symbiotic information system. The system is based on a compound image capturing system and attractor selection. This report shows the basic theory and a prototype system developed under the research.

2 Object selection system based on attractor selection
In this research theme, the target of research is the object selection system based on attractor selection. In particular, a basic architecture, processing algorithm, and its hardware implementation are investigated. Then, TOMBO (Thin Observation Module by Bound Optics) is proposed as an actual system inspired by the information processing mechanism of a living organism [1]. The compound image is applied to the estimation of distance information in object space and color information of objects [2, 3]. According to the information, the system selects a target object.

2.1 Compound Imaging System TOMBO
Insects and arthropods have compound eyes consisting of multiple small eyes as their visual system. Various interesting features can be utilized in the application of the compound eye to information systems [2]. Figure 1(a) shows a sensor module of a compound camera, which is used for an object selection system. The camera captures the compound image in the form of Figure 1(b).

Figure 1: Compound imaging system. (a) Photograph of the sensor module (9.6mm(W) × 9.0mm(D) × 3.4mm(H)) and (b) Captured compound image.

2.2 Object selection algorithm
The object selection algorithm is constructed on the basis of attractor selection [4]. In the attraction selection, the evaluation value act can be calculated, and it represents the activity of the given system. Parameters of the system are changed according to the evaluation value. Figure 2 shows the conceptual scheme of the object selection algorithm. In the object selection problem, the attentive distance is defined as a parameter of the system. Dynamics of the given system is described by a temporal differential Equation(1), which determines the attentive distance. The principal part of the equation value in the temporal differential equation changes with the previous attentive distance and stochastically generated fluctuation.
$$\Delta r_i = \alpha \frac{\left( E_{i-2} - E_{i-1} \right) \left( r_{i-2} - r_{i-1} \right)}{\left| E_{i-2} - E_{i-1} \right|} \times r_{i-2} - r_{i-1} + \beta \eta, \quad (1)$$

where $i$ is the transition time. Evaluation value $E_i$ at time $i$ represents the tendency of hue given as the selecting condition. Variable $r_i$ and $\eta$ represent the attentive distance at time $i$ and random fluctuation ($-10 \leq \eta \leq 10$), respectively. Variables $\alpha$ and $\beta$ are weighting factors.

$E_i$ can be written in further detail with the following equation:

$$E_i = \sum_{j=1}^{m} \frac{\gamma C_j + (1 - \gamma) R_j \cdot R_j}{\sum_{j=1}^{m} R_j}, \quad (2)$$

where $C_j$ and $R_j$ are the evaluation values at pixel $j$ regarding the color and the attentive distance, respectively. Variable $m$ is the total number of pixels and $\gamma$ is a weighting factor. Detail $C_j$ and $R_j$ can be written as follows:

$$C_j = \exp \left( - (\phi_j - \theta)^2 \right), \quad (3)$$

$$R_j = \exp \left( - (r_j - r_i)^2 \right), \quad (4)$$

where $\phi_j$, $\theta$, $r_j$, and $r_i$ are the hue of pixel $j$, the attentive hue, the attentive distance of pixel $j$, and the attentive distance, respectively. Effectiveness of the algorithm is demonstrated by simulations.

2.3 High-speed processing board

Figure 3 shows an evaluation board for the object selection system. The specifications are shown in Table 1. The board executes estimation of the object distance and the object selection algorithm. The result of the object selection is output as an image in the monitor. In this system, high-speed processing is achieved by a parallel memory access and the effective utilization of downtime.

<table>
<thead>
<tr>
<th>Table 1: FPGA specifications.</th>
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<tbody>
<tr>
<td>FPGA Virtex-4</td>
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<tr>
<td>SDRAM (FPGA)</td>
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<tr>
<td>SDRAM (CPU)</td>
</tr>
<tr>
<td>Input and output</td>
</tr>
<tr>
<td>SH7709S 133 MHz</td>
</tr>
<tr>
<td>TOMBO, Analog RGB, DVI, USB, serial communication</td>
</tr>
</tbody>
</table>

3 Summary

As an instance of an actual symbiotic information system, a compound image capturing system is studied in this research theme. The system is based on the attractor selection, and correct operations for object selection are confirmed. A prototype system has been developed by FPGA technology, and its fundamental operations are demonstrated.

References


