Doctoral Dissertation Abstract

Major: System Design Engineering

Course: Intelligent Information Systems

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1. Dissertation Title (If in English, add the Japanese translation.)

Bio-Inspired Active Robot Vision Toward Understanding of the Cortical Mechanism

(生物的アクティブプロットビジョンと脳機能の理解)

2. Abstract (Roughly 2,000 Japanese characters or 800 English words)

In our work we set up to achieve two main goals, first is to discover operating principles of the cortex, second is to build systems based on these principles, we start with anatomy and physiology, which are constraints on how the theoretical principles could work, then we developed some principles, and model them in software. Our models can only perform using specific type of robots.

With each passing year, autonomous robots that can interact with the environment in natural manner are becoming more and more real. One of the most essential sensory information of these robots is vision. Numerous studies have been devoted to robot's perception of human intentions and/or emotions. The problem that the researchers face in designing such system concerns the parallel and the hierarchical way of our brain that processes the input stimuli from our eyes. Moreover, the technology used for robotic system is still developing. Even though we have good cameras that can capture images at high frame rate, the hardware that supports the processing of these data are designed for specific functions. Due to recent progress in electronics and computing power, in control and agent technology, and in computer vision and machine learning, the realization of an autonomous robots platform capable of solving high-level deliberate tasks in natural environments can be achieved.

We implemented our vision system in two robot platforms: First in our Humanoid
Robot (RoboVie-R2), which has two cameras with 2 degree of freedom. Second we used iPhone 5 technologies with Arduino microprocessor to build our iRov Robot. iRov is a desk-top size robot the can perform image processing onboard utilizing the A6 which is a System-on-a-Chip (SoC). With the CPU and the GPU processors working in parallel, we design our robot to be able to move in the environment and to change its focus and interact with the objects. Our robot has two cameras: one is front camera to locate and trace the objects and the other one is mounted in the top of the robot for navigation and avoid obstacle. In addition, we are using parallel processing power of graphics processing unit (GPU), which enables us to implement our 3D object recognition in realtime.

3D robotic vision could be realized using a neural network model that forms sparse distributed memory traces of spatiotemporal episodes of an object. These episodes are generated by the robot’s interaction with the environment or by robot’s movement around 3D object. The traces are distributed in each cell and synapse that participates in many traces. This sharing of representational substrate enables the model for similarity based generalization and thus semantic memory. The results are provided showing that spatiotemporal patterns map to similar traces, as a first step for robot 3D vision system. The model achieves this property by measuring the degree of similarity between the current input pattern on each frame and the expected input given the preceding frame and then adding an amount of noise, inversely proportional to the degree of similarity, to the process of choosing the internal representation for the current frame and the predictable input given the preceding frame.

The significance of our study is not just to design intelligent vision system for robots but also to understand how our brain works. And that by analyzing the functionality of each of our vision system layers that works in top-down and bottom-up fashion to achieve specific behavior, And by applying this system in real experiment, we contributed in the knowledge of how our brain performs tasks such as learning and memory, attention, and 3D perception.