Active Vision for Neural Development and Landmark Navigation

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Introduction

Brains and sensory systems are characterized by limited bandwidth and computational resources. At any point in time, we can focus our attention only to a limited set of features or objects. One of the most remarkable –and often neglected– differences between machine vision and biological vision is that computers are often asked to process an entire image in one shot and produce an immediate answer whereas animals are free to explore the image over time searching for features and dynamically integrating information over time.

Coevolution of Active Vision and Feature Selection[1]

We show that the co-evolution of active vision and feature selection can greatly reduce the computational complexity required to produce a given visual performance. *Active vision* is the sequential and interactive process of selecting and analyzing parts of a visual scene. *Feature selection* instead is the development of sensitivity to relevant features in the visual scene to which the system selectively responds. Each of these processes has been investigated and adopted in machine vision. However, the combination of active vision and feature selection is still largely unexplored.

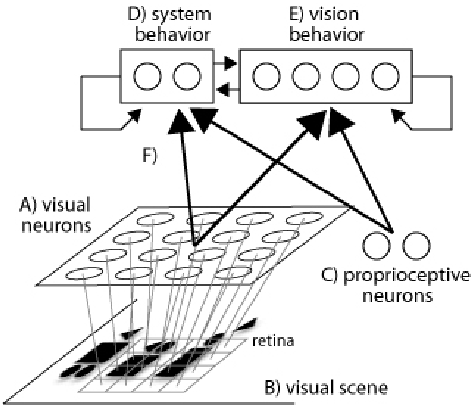

Fig. 1. The architecture for active vision and feature selection.

In our experiments behavioral machines equipped with primitive vision systems and direct pathways between visual and motor neurons (Fig. 1) are evolved while they freely interact with their environments. We describe the application of this methodology in three sets of experiments, namely, shape discrimination, car driving, and robot navigation. We show that these systems develop sensitivity to a number of oriented, retinotopic, visual-feature-oriented edges, corners, height, and a behavioral repertoire. This sensitivity is used to locate, bring, and keep these features in particular regions of the vision system, resembling strategies observed in simple insects.

Active Vision and Visual Development[2,3]

In a further set of experiments we investigate the *ontogenetic development* of receptive fields in an evolutionary mobile robot with active vision. In contrast to the previous work where synaptic weights for both receptive field and behavior were genetically encoded and evolved on the same time scale, here the synaptic weights for receptive fields develop during the life of the individual. In these experiments, behavioral abilities and receptive fields develop on two different temporal scales, phylogenetic and ontogenetic respectively. The evolutionary experiments are carried out in physics-based simulation and the evolved controllers are tested on the physical robot in an outdoor environment (Fig. 2).

Such a neural architecture with visual plasticity coupled with a freely moving behavioral system allows us to explore the role of active body movement in the formation of the visual system. More specifically we study the development of visual receptive fields and behavior of robots under active and passive movement conditions. We show that the receptive fields and behavior of robots developed under active condition significantly differ from those developed under passive condition. A set of analyses suggest that the coherence of receptive fields developed in active condition plays an important role in the performance of the robot.

Fig. 2. The Koala mobile robot by K-Team S.A. with a pan/tilt camera in an outdoor environment.

Active Vision and Sequential Landmark Detection[4]

Lastly, active vision may also be useful to perform landmark-based navigation where landmark relationship requires active scanning of the environment. Here we explore this hypothesis by evolving the neural system that controls the vision and behavior of a mobile robot equipped with a pan/tilt camera so that it can discriminate visual patterns and arrive at a predefined goal zone. The experimental setup employed here requires the robot to actively move its gaze direction and integrate information over time in order to accomplish the task.

We show that the evolved robot can detect two separate features in a sequential manner and discriminate the spatial relationships. Since the system can perform active vision and sequentially store the events of visual feature detection, we do not need expensive computational power nor large memory storage capacity which would be required to resort to image memorization and matching. Although there is evidence that insects may indeed adopt such an image memorization and matching strategy, it is tempting to speculate that their tiny brain with restricted memory capacity may favor a more economical strategy such as shown here.

References

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