Perception, Action and Effective Representation in Multi-Layered Systems

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1. Abstract

Many robot control architectures possess several layers which view the activity of the agent from different perspectives. The lowest layer typically contains the sensor and effector sub-systems. We will discuss information flow in an agent architecture with an emphasis on structures which facilitate effective perception and action. We start by defining necessary properties of the information flow mechanism. We then describe how information flow in our agent meets the specified criteria. Finally, we describe an implementation of an architecture using these information flow structures on our autonomous agent, Bruce.

2. Introduction

Autonomous mobile agents must perceive and act in the real world. We are interested in vision-based agents, so to understand what agents must do, we need definitions of vision and action. According to Marr, *vision* is "to know what is where by looking" [10]. We define *action* as altering the world in a perceptible fashion. Mobile robots need both vision and action to be closely interrelated if they are to be effective. We will refer to the parts of the control architecture that compose these interrelated functions as the perception/action (PA) layer.

Robots intended to operate in dynamic environments are typically designed with (mostly) stateless sensor and effector sub-systems [5][11]. However, the limitations of such systems in complex domains are well known [18]. We contend that, in order to be feasible, perception needs to take into account the actions which an agent can perform. Similarly, actions need to know about the sorts of results available from perception. Further, the way in which perception and action are bound together heavily depends on the current task of the agent. This close connection necessitates some form of state. We propose a different perception/action layer which uses task dependent structures called markers [4][1].

Any perception/action layer is necessarily limited in its view of the world and the amount of state it can create and maintain effectively. In order to accomplish more complex tasks, many researchers have developed heterogeneous architectures which interface higher-level planning and sequencing capabilities to PA systems [3][6][8]. The question is then, if such higher levels maintain a more complete world model, what information should be passed to the PA system in order for it to perceive/act effectively?

We will argue that any such information flow should be highly structured and minimalist (not provably minimal, but the PA system should not be overburdened). We first discuss the properties that any information flow mechanism between a PA system and the rest of an agent architecture must have to be effective. We then present our PA system and describe how the information flow into and out of it meets these requirements. Finally, we describe a task for which our PA system performs as the lowest layer of a three-level architecture (TLA).

3. Information Flow

We seek to characterize the flow of information within, as well as, into and out of a perception/action layer. The perception/action layer of an architecture is the layer closest to the hardware. Information flows into the PA layer from the higher layers of the architecture and from the environment via sensors. Information from the higher layers configures the PA system for various tasks, while information from the sensors guides the PA system's actions. Many PA layers [7][8][20][21] contain concurrent behaviors whose interaction is an important part of the agent's information flow. Data derived from the PA system's sensors flows out of the PA system to the higher layers of the architecture. This is similar to "supervenience" [14].

The flow of information in a PA system is heavily tied to the internal representation used by that system. All information coming from higher layers of an agent architecture must be converted to structures which the PA layer can use, while all out-going information must be synthesized from