Building Object-Agents from a Software Meta-Architecture

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Abstract. Multi-agent systems can be viewed as object-oriented systems in which their entities show an autonomous behavior. If objects could acquire such skill in a flexible way, agents could be built exploiting object-oriented techniques and tools. There are several ways for building agents from objects: defining common interfaces and behavior in abstract superclasses, wrapping objects with agent behavior using composition techniques, etc. However these ways present problems for becoming objects in agents and for adapting the behavior assigned to agents, especially whether it is required in a dynamic way. This article presents one alternative in which agent characteristics (such as perception, communication, reaction, deliberation and learning) can be dynamically added, deleted, and adapted to objects using a particular computational reflection form achieved by meta-objects.

1 Introduction

Agent-oriented and object-oriented programming work on cooperative entities. These entities have limited competence, which is defined by a set of actions that are able to execute. However, the following definitions show an important difference between the entities that each one of the paradigms work on.

An agent is an autonomous entity that has action capabilities, which are used in a non-deterministic behavioral way and internal knowledge for supporting their decisions and the execution of its behavioral capabilities. An object is an entity that has action capabilities defined in a deterministic way and internal knowledge for supporting the execution of its behavioral capabilities.

Objects and agents define a well-bounded behavior but there is one difference: objects use it in given ways and agents can decide the way they take. Thus, additional characteristics must be designed for achieving object-agents: communication among agents, perception of changes in the environment, and decision processes related to what to do next.

Communication capabilities determine how agents of different types can communicate among them. Examples of communication performatives: achieve (aGoal), askIf (aQuery), askAll (aQuery), etc.
Perception capabilities allow an agent to know facts without receiving any information from communications. Perception capabilities allow an agent to observe activities performed by other agents (a conversation among agents, transference of information between agents, destruction of agents, agents changing of communities, etc.) and environment changes (i.e. external sensors becoming enabled, locking of internal structures, etc.).

Decision capabilities determine the course of action that an agent takes in a given point of time. Such course of action can be characterized as reactive or deliberative [5]. Reactive behavior allows agents to act without thinking before act. Deliberative behavior shows a meditative selection of a particular set of actions. We can recognize three behavioral levels in agents (see Figure 1). The lower level shows us what an agent can do in terms of actions. An agent robot, for example, could execute the following actions: go, turnLeft, turnRight, etc. This level represents the characteristic behavior of objects. The next level represents social capabilities inherent to agents. Objects only can receive known messages, they don’t manage a common protocol of communication as agent can do. Agents communicates with other agents requesting help to achieve a given goal, giving notice of a trouble, advising about a problem, giving information, etc. In addition, agents can observe events happened in their environment. The third level represents the set of decision capabilities that are used for agents to determine actions to execute. To do this, the observed events and the received communications are considered basic information for such decision processes.

![Decision capabilities: reaction and deliberation
Social capabilities: perception and communication
Actions showing what the agent can do](image)

**Fig. 1. Agent behavioral levels**

A multi-agent system can in summary be considered as an object-oriented system in which object-agents has associated extra capabilities. This idea is not new, [8, 16] have shown the potential characteristics of the object-oriented paradigm for building agents. However, there are several alternative ways in which these extra capabilities are associated to simple objects.

This paper presents a software architecture named Brainstorm. This architecture allows objects to be the main support of agents and meta-objects to be the way for flexible adding the mentioned agent-specific capabilities.

The breakdown of the paper is as follows. Section 2 identifies the advantages of the usage of meta-objects. Section 3 presents an architecture based on the meta-object concept. Section 4 relates results and experiences with the architecture. Sections 5 and 6 expose related works and conclusions.