

An Ontology-Based Approach for Mobile Agents' Context Awareness

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INTRODUCTION

Mobile agents are software agents that can travel among computers under their own control. They can be applied with significant advantages in many domains like network management, information filtering, and electronic commerce. They are especially attractive for performing complex, tedious, or repetitive tasks in open and dynamic systems (Fugetta, Picco, & Vigna, 1998).

Nowadays, mobile agents' applications have to operate within environments having continuously changing execution conditions that are not easily predictable. They have to dynamically adapt to changes in their environment resulting from others' activities and resources variation. To survive, mobile agents have to be aware of their execution context and to have flexible architecture enabling them to envisage an adaptation easily. To do so, it is necessary to have an architecture with two clearly decoupled parts: the mobile agent functional compounds and those ensuring the context handling.

In a previous work (Amara-Hachmi & El Fallah-Seghrouchni, 2004), we proposed a component-based generic adaptive mobile agent (GAMA) architecture that exhibits a minimal mobile agent behavior. In this article, we will focus on GAMAs' awareness of their execution context. Thus, we propose a formal model of context to be used in a semantic approach for checking agents' compatibility with new execution contexts.

The remainder of this article starts with definitions of context and context-awareness for GAMA mobile agents. We then introduce our context model and detail the proposed approach, before concluding the article.

MOBILE AGENTS: CONTEXT AND CONTEXT-AWARENESS

Definitions

As stated in Dey (2001), context consists of "any information that can be used to characterize the situation of an entity" where an entity is "is a person, place, or object that is considered relevant to the interaction between a user and

an application, including the user and applications themselves." This definition stresses the relation between the system, the context, and the user. In our work, by context we mean information about the current execution environment of the mobile agent, and we focus rather on how the context influences the agent behavior when executing its assigned tasks. This can be illustrated by a failure of the agent execution process if it moves to a host where the context attributes do not fit the agent's requirements. According to these considerations, we propose a definition of the GAMA agents' context-awareness as follows:

Definition 1. A mobile agent GAMA can be context-aware if it is able to detect contextual situations that affect its behavior aiming to achieve its tasks.

According to these definitions, developing context-aware mobile agents requires facilities for recognizing and representing context in order to enable agents to reason on it and make decisions about their execution process (adapt, inform the user, etc.). For GAMA agents, sensing and structuring context information is performed at the hosting platforms. Every interaction between agents and the operating systems (of computers and the network) as well as those between agents and their owners (human users) are achieved by the platform.

The Context Elements

To describe the agents' context, we identify three specific context levels: physical context, social context, and user context. Physical context refers to physical devices the mobile agent is running on, for example, the host's processing power and the network bandwidth. This information is sensed using different probes installed on each operating system. Social context refers to the local multi-agent system (deployed on the platform) with whom the incoming agent has to interact. For instance, information about this context includes the local interaction and coordination protocols. User context refers to the agent's owner preferences, such as restrictions about the exchanged files' size or type, the display quality, and so forth. The user expresses his or her preferences through the platform graphical user interface.

How To Achieve Context-Awareness

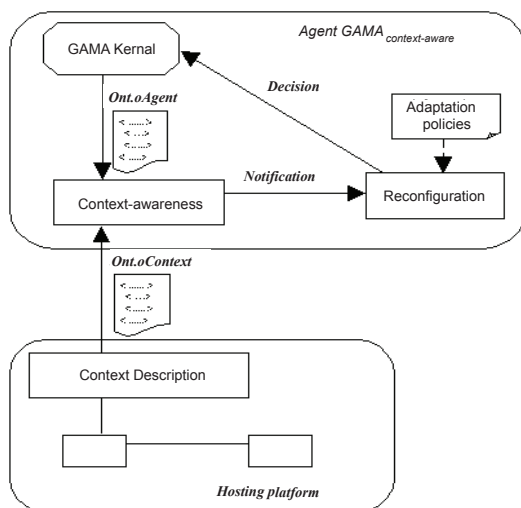
Developing context-aware mobile agents needs capacities to:

1. Capture of the contextual parameters by the means of some physical sensors, graphic interfaces, and the deployment platform. Currently, this step is outside the focus of our work.
2. Model the context by providing formal models of the rough contextual parameters in order to be available for use by the agents.
3. Reason on the context model in order to be aware of it. The reasoning will enable the mobile agent to check if it is able, using its current configuration, to achieve its goals in the new contextual situation to which it moves.

The result of this process is a notification that enables the agent to make a decision about the behavior to adopt in the new context: adapt itself to continue its execution, or alert the user if the adaptation is not possible. Thus, the agent needs not only a model of its context entities, but also a comparable model of its own components. Mapping these models onto one another allows checking their compatibility degrees.

Assuming these requirements, we propose to extend the GAMA architecture with a new component called 'context-awareness'. This component processes the context model provided by the component 'context description' of the platform, and the agent model provided by the component agent profile of the agent. The GAMA architecture is baptized from now up to GAMA_{context-aware} (see Figure 1).

Figure 1. From GAMA to GAMA_{context-aware}



ONTOLOGY-BASED CONTEXT MODEL

To model context, a number of formal and informal approaches exist. We quote specially attribute-value tuples (Dey, Salber, & Abowd, 2001), entity-relationship models (Henricksen, Indulska, & Rakotonirainy, 2002), and first-order predicates (Ranganathan & Campbell, 2003). These representations have the advantage of addressing a certain level of context reasoning, but they offer a weak support for knowledge sharing and are deprived of semantic.

In our work, we need a context representation that: (1) can define common vocabularies to be shared by different agents, and (2) provides a context description at a semantic level in order to enable agents to reason on it. Ontologies seem to be a reasonable solution that meets these requirements. Thus, we propose to develop two distinct ontologies: the first models the context entities *OntoContext*, the second represents the agent components *OntoAgent*. These application ontologies are built using the Web Ontology Language OWL, the latest standard of the Web-Ontology Working Group.

A Uniform Frame for Ontologies

If we consider the scenario of a coordinating GAMA mobile agent, an example of contextual attributes that influence its execution process is the type of the negotiation protocol used by the multi-agent system hosted at the visited platforms. The agent must be able to check if it uses the same type of protocol by comparing the parts of two ontologies, *OntoAgent* and *OntoContext*, describing the used protocols.

Thus, in these ontologies, the components providing the negotiation features (of the agent and the hosting platform) must be modeled in a uniform way in order to be able to test their compatibility. Indeed, we consider that compatibility between the agent and its context is ensured whenever the agent's required services (respectively, provided) are provided (respectively, required) by its context. That is why we need a generic and uniform representation of the different agent components and the context entities. Genericity is motivated by the need to model all the entities whatever their origin, and the uniformity aims at facilitating the process of mapping the ontologies.

Representing Entities

Within our working ontologies, we propose to model each component of the agent and each entity of its context by a concept (class, in OWL). These concepts have properties (in OWL, *DatatypeProperty*) that represent their general characteristics such as the identifier and whether the entity is replaceable or not (in the case of the agent components). Thus, we propose to define a generic concept, *#ENTITY*, having common properties of the agent components and

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