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A semantic model for actions and events in ambient intelligence

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ABSTRACT

Event ma nagement and response generation are two essential aspects of systems for ambient intelligence. This work proposes handling these issues through the use of a semantic model for ambient intelligence which, under the umbrella of a philosophical and common-sense optic, describes what actions and events are, how they are connected, and how computational systems should think about their meaning. This model entails an approach with which to both reason about and model context events and generate behavioral responses to those events, when necessary. The model supports this ad hoc response generation by automatically composing services when those which are available do not meet the expected functionality (without requesting user intervention). An evaluation methodology is presented and illustrated with a case scenario, in which synthetic data has been generated to emulate events and analyze the system response. The evaluation of the system response is carried out on the basis of a vector of attributes.

1. Introduction

Self-management, pro-activeness, dynamism and goal-driven behavior are some of the most challenging requirements that have to be tackled when developing systems for ambient intelligence (Ramos et al., 2008). Despite the fact that devising a strategy with which to address these issues has been one of the main concerns for researchers in this field during the last decades, the majority of the solutions proposed to date remain far from the scenarios envisioned in Ducatel et al. (2001).

An additional difficulty in developing ambient intelligence systems is that of having to cope with the wide range of device technologies present in these contexts, and the lack of continuity in device availability. These drawbacks have been addressed, with different levels of success, through the use of a wide variety of techniques, such as web services (Kim and Choi, 2007), middleware (Gu et al., 2005; Campbell, 2003), dynamic reconfiguration (Cao et al., 2004), agents (Chen, 2004), context modeling and reasoning approaches (Reichle et al., 2008; Niu and Kay, 2010), etc.

Nevertheless, in the authors' opinion, the autonomy expected from ambient intelligence systems can only be achieved by leveraging both common-sense knowledge and reasoning capabilities, rather than by focusing on implementational issues or the available technology. This work therefore starts from the premise that before tackling the specific requirements for ambient intelligence, it is first necessary to understand and model the nature of human agency. To this end, the approach followed in this work consists in the adoption and implementation, in the form of a computational model, of the conclusions concerning actions and events drawn from philosophical doctrine. The notion of event, action or service should not vary among systems, nor should they respond to the approach convenience used, as is evidenced in the models surveyed in Roussaki et al. (2008). Contrary to current practices, systems for ambient intelligence should be grounded on a solid base of a semantic model for actions and events.

Based on the enacted semantic model, and from a common-sense point of view, the problem of developing systems for ambient intelligence has to be tackled from two different perspectives: cognitive and behavioral. From the cognitive perspective, the problem can be addressed as an understanding problem. Comprehending a situation that takes place in a context might involve, for example, the inference of implicit, nondeterministic or delayed effects. A delayed effect of turning on a tap in a kitchen sink whose plug is in, will be a water overflow. From a behavioral perspective, the problem can be addressed as a planning problem of deciding what action to take in certain given circumstances. A common-sense strategy for planning and understanding, such as that presented in Wilensky (1983) would, therefore, appear to be the most compelling approach towards emulating the human-like rationality and reasoning capability.

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In words of Lenat et al. (1990), the bottleneck of intelligent systems is reached when attempting to respond to unexpected situations, which, it should be noted, are the most common situations found in ambient intelligence contexts. The way in which people react to these unexpected situations provides an idea of the direction in which efforts should be addressed. Generally, when facing new situations, people tend to establish some similarities with past experiences, or resort to their general knowledge of how things work – the so-called common-sense knowledge – or even look for advice in books. Whatever the case may be, the authors of this paper believe that only ambient intelligence systems will be sufficiently flexible to support the scenarios envisioned in Ducatel et al. (2001) when common-sense reasoning starts being considered as a structural part of such systems.

Understanding and modeling common-sense reasoning, in such a way that it can be automatically performed, is considered here as the key challenge that, once achieved, would allow systems for ambient intelligence to indeed be intelligent. In this paper, an implementation of the key issues (Mueller, 2006) required for the automation of common-sense reasoning is also presented. Nevertheless, the main contribution of this work is founded on the proposition and formalization of a semantic model for actions and events in ambient intelligence, as a previous step towards common-sense reasoning and understanding. Section 2 provides a review of related and previous works. Section 3 describes the details of the proposed semantic model for actions and events. Section 4 provides the implementation details of the architectural approach adopted here. Section 5 presents a validation methodology to assess the goodness of the system response. Finally, Section 6 presents the conclusions drawn for this work.

2. Related works

The multidisciplinary nature of the ambient intelligence paradigm entails a state-of-the-art review task that must be addressed from the different areas of knowledge that play a role in the paradigm. The work in Cook et al. (2009) provides an excellent starting point from which to obtain an overall view of the technologies involved in ambient intelligence.

Due to the fact that this work is framed in a comprehensive approach to ambient intelligence, this section is intended to revise the fields of knowledge to which the proposed solution is making contributions to. Besides, the justification for those contributions to be presented along with the proposed semantic model is due to the fact that they are a direct consequence of the proposed semantic model strengths.

2.1. Planning strategies

From the acting point of view, the planning theory contributes not only towards providing articulated responses by means of service composition, but also towards supporting the decision making of agents that exhibit goal-oriented behavior. However, literature in the field of planning for ambient intelligence is scarce, principally owing to the nonlinearity of problems that involve the exploration of a huge number of states. Some other features also contribute to this shortage: the nondeterministic effects of events, for example, make it impossible to determine whether picking up a slippery object will culminate in the object being dropped; those delayed effects, that occur a while after an event has taken place, lead people to foresee that if the kitchen sink has its plug in, then turning on the tap will cause the water to overflow. These are just a few of the features that make planning in ambient intelligence a nontrivial issue. Nevertheless, the need for planning strategies in ambient intelligence has already been stated in Amigoni et al. (2005). This work pays special attention to the device heterogeneity so characteristic of ambient intelligence contexts, and advocates the use of a distributed-centralized HTN-like approach (hierarchical task network) (Erol et al., 1994). In spite of the agreement on having to address device dynamism and heterogeneity, here, it is believed that these aspects should be tackled from the middleware perspective, rather than from that of the planner. The device heterogeneity should therefore remain a transparent matter for the planner, as is justified in the following section. In this respect, the use of agent approaches is also commonly accepted for auxiliary tasks. The work in Gatti et al. (2008) highlights the role assigned to a multi-agent system (MAS) architecture, acting as the context observer and regulator. The MAS assumes the responsibility of providing the planner with the required information about the context and the mechanisms with which to respond to it.

Although not directly applied but easily extrapolated to ambient intelligence, the use of a probabilistic search techniques (Stroupe and Balch, 2005) is presented in Jolly et al. (2010). This work addresses the problem of task planning and action selection by means of a fuzzy-neural network approach combined with agent coordination and cooperation methods. Agents are trained to select the most appropriate action depending on the field configuration, changing their selections whenever the objects in the field adopt a different configuration. Another interesting approach, with applications in the ambient intelligence field, is that proposed in Kang and Choi (2008). This approach adopts an HTN planning strategy which has been enhanced to fill the gap between real world environments and planning scenarios. The script-based task planner (STP) resorts to a scrip structure to adapt the planning scenario to the real world environment. Finally, the work in Kaelbling et al. (1995) is also relevant. This work presents and discusses a planning strategy that seeks the optimal actions in partially observable stochastic domains, providing a firm foundation for planning in uncertainty conditions of actions and observations. An overall view of the planning strategies in distributed and cooperative circumstances is presented in Patkos et al. (2007). The conclusions and suggestions drawn from this study set the basis for identifying the shortcomings of traditional artificial intelligence planning strategies, along with the strengths that can be used in a combined solution to the proposed planning approach. As will be stated later, the planning strategy proposed here is based on an HTN approach.

2.2. Cognition

From the cognitive perspective, planning depends strongly on knowledge and understanding competences. This dependency is grounded on the tight coupling that exists between knowledge and decision making. As stated by the authors of Fagin et al. (1995), there are certain pragmatic concerns about this relationship that do not have a unanimous answer. What does an agent need to know in order to perform a concrete action? When does an agent have to stop gathering information and make a decision? Or at what point does an agent have to answer "I don't know what to do"? Answers to these questions imply the conviction that some degree of common-sense is required. Refer to Wilkins and desJardins (2001) for a thorough analysis of the most relevant knowledge-based planning techniques available in literature.

Automating common-sense reasoning has been one of the primary concerns for researchers in the artificial intelligence field. Mueller (2006) provides a brief history of common-sense reasoning, the first work in this field dates from 1956. The main contributions to this field come from authors such as Newell,