How Intelligent are Ambient Intelligence Systems?

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Abstract

Since the appearance of the Ambient Intelligence paradigm, as an evolution of the Ubiquitous Computing, great deal of the research efforts in this field have been mainly aimed at anticipating user actions and needs, out of a prefixed set. However, Ambient Intelligence is not just constrained to user behaviour pattern matching, but to wisely supervise the whole environment, satisfying those unforeseen requirements or needs, by means of rational decisions. This work points at the lack of commonsense reasoning, as the main reason underlying the existance of these *idiots savant systems*, capable of accomplishing very specific and complex tasks, but incapable of making decisions out of the prefixed behavioral patterns. This work advocates for the integration of the commonsense reasoning and understanding capabilities as the key elements in bridging the gap between idiot savant systems and real Ambient Intelligence systems.

1 Introduction

The Ubiquitous Computing concept was first defined by Mark Weiser in [1], referring to a new computing era where electronic devices merge with the background, becoming invisible, in such a way that people could make use of those devices in an unconsciously way, focusing just on their needs and not in the interaction.

One decade later, the IST Advisory Group first states the concept of Ambient Intelligence [2], which lying on the Ubiquitous Computing paradigm, refers to those environments where people are surrounded by all kind of intelligent intuitive devices, capable of recognizing and responding to their changing needs. In these contexts, people perceive the surrounding as a service provider that satisfies their needs or inquiries in a seamless, unobtrusive, and invisible way.

Therefore, these contexts have to be supported on a service-oriented architecture capable of dealing with the device heterogeneity and service dynamism, exhibited in these contexts. Nevertheless, the state of the art in Ambient Intelligence, demonstrates that these are well addressed issues, by any of the flavored service-oriented architectures, in the form of an OSGi framework, such in the case of the AMIGO project[3], web services such as in the Hydra project[4], middleware technology as in the approach proposed in [5], or a Multi-Agent System such as in the CHIL project[6].

However, there are some other aspects of the Ambient Intelligence that if not left behind, they have not been so effectively addressed as the previous ones. Aspects such as the ambiguity, uncertainty, or incompleteness of the context information, prevent Ambient Intelligence systems from being fully context-driven.

In words of Doug Lenat et al. [7], the bottleneck arises when trying to respond to unexpected situations, which by the way, are the most common situations found in Ambient Intelligence contexts. However, how do people react to these unexpected situations provides an idea about the direction where efforts are to be addressed. Generally, when facing novel situations we tend to establish some similarities with past experiences, or resort to the general knowledge about how things work –the so called commonsense knowledge–, or even look for advice in books, for instance. In any case, the authors of this article believe that only Ambient Intelligence systems will be flexible enough to support the scenarios envisioned in [2] when commonsense reasoning starts being considered an structural part of such systems.

Automating commonsense reasoning is a task that requires an expressive enough language, a knowledge base where to store such a large amount of knowledge, and a set of mechanisms capable of manipulating this knowledge, so as to infer new information. Regarding the knowledge base, Cyc[8] and WordNet[9] are by far the most evolved and sucessful approaches. However, Cyc is the most complete, in terms of the amount of comprising facts, the representation language used –CycL–, and the mechanisms provided to infer and reason upon the stated knowledge, based on planning, deduction, and rules.

Essentially, Ambient Intelligence challenges demand a high level of autonomy and self-sufficiency, and this work analyzes how an approach based on CYC could bridge the gap that prevent Ambient Intelligence systems from being intelligent. Therefore, the remainder of this article is committed to this justification. Section 2 revises the state of the art of Ambient Intelligence systems, so as to identifies the main shortcomings, and how these can be overcome by adopting a commonsense approach. Section 3 analyzes the benefits of an approach based on CYC. Finally, last section outlines the conclusions that can be derived from this work.

2 An Ontology for Ambient Intelligence

The previous section pointed out at the commonsense reasoning as the mean to support the system capability to react to unexpected situations. However, before getting into the details about how these tasks are performed, it is required to set the basis for the knowledge representation task, prior to tackling the reasoning one. This knowledge engineering task [10] can be summarized so as to identifying the relevant entities, their properties and their relationships one to each other, or in other words, providing an ontology for the application domain.

The importance of providing an ontology for Ambient Intelligence is twofold. On the one hand, it unifies the vocabulary used to describe the domain knowledge, by stating the type of objects that play an important role in the domain, their properties and relationships. Moreover, interoperability among the different architectural elements of an Ambient Intelligence system draws on this unified vocabulary. On the other hand, providing an ontology allows that information modelled by means of this ontology can be automatically plugged into large bodies of knowledge, and therefore logically related [11]. As it will be explained later on, this is one of the many strengths of Cyc, the possibility of plugging ontologies into the knowledge base, almost in an automatically fashion.

The work found in the literature related to ontologies for Ambient Intelligence, commonly assign a key role to the user concept. In [12] the ontology proposed clearly focuses on the role played by the user. This approach is founded on [13] where only context information that affects users is being considered. An extensive survey can be found at [14]. Based on these works, this is the author's belief that although being important, the user concept should not be part of the ontology. Basically, users tend to be either the agents of the actions that take place in the contexts, or the sink of the services provides by the Ambient Intelligence system. Moreover, due to the eminently service-oriented character of Ambient Intelligence systems, it is sensible to advocate for an ontology where the focus is on the service concept.

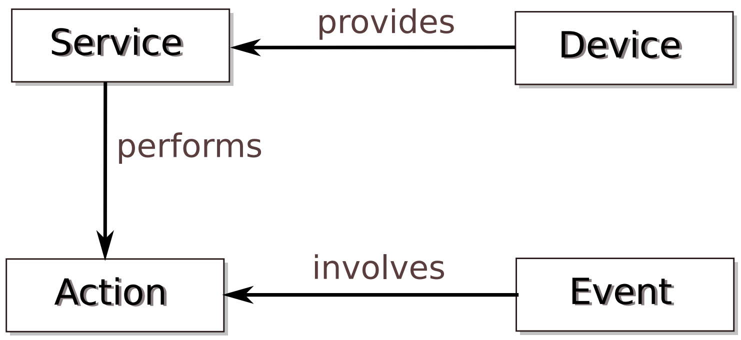

Figure 1: An ontology for Ambient Intelligence

Based on these premises, figure 1 depicts the proposed ontology for an Ambient Intelligence domain. The *device* concept represent the devices deployed in the domain. These devices provide a set of services, represented by the concept *service*. Furthermore, each service perform actions, represented by the *action* concept. Finally, the events taking place in the context are represented by the concept *event*. Although quite simple, this ontology suffices to reason about the actions that need to be performed in response to the events taking place in the context.

3 Automatic Service Composition

One of the main challenges that have to be faced by Ambient systems is how to provide the right services that meet the requirements emerging in the context. So far, this work has pointed out that an approach based on commonsense reasoning could provide these systems with the flexibility and dynamism required to support these sort of decisions. However, little has yet being said about how to capture the results of the reasoning task into services or actions to be performed, apart from the interoperability support provided by the ontology. Since the services provided by the Ambient system comprise the basic available tools to implement the solution, supporting service composition seems to be the best approach to answer to these context or user requirements and needs.

This solution has been addressed by means of a wide range of technologies, refer to [15] for an extensive survey of dynamic service composition approaches for Ambient Systems. However, the most popular and widely implemented approach is the Web Services technology. Nevertheless, independently of the selected approach, there are some commonalities regarding the information required to support the composition task. The service description provides information for the service identification, while the binding information refers to the requirements for the composition process, such as protocol-dependant details. For example, web services uses WSDL[16] (Web Services Description Language) for describing the service, exposing the messages that can be exchanged with the service, as well as the binding information that contains the protocol specific details. The composition process starts by locating the services that offer a required functionality, by matching the service descriptions. For example, web services can be discovered using UDDI[17] (Universal Description, Discovery and Integration). Once the appropriate services are identified, and the binding requirements are fullfilled, services can be bound.

Despite being considered automatic or dynamic, the approaches provided to date require some higher level entity addressing the requirements of the services taking part in the composition. Furthermore, only basic services are considered, ignoring the possibility of performing some modifications over the available services that provide extra functionalities. Therefore, it is more correct to refer to these approaches as service binding or combination, rather than composition.

Requirements for automatic service composition[18] lead us to conclude that only by an appropriate middleware architecture can services be automatically composed. Therefore, the work in [19] claims for an approach based on the combination of a Distributed Object-Based Service architecture[20] and a Multi-Agent System approach to support service composition. Adopting this solution seems to effectively meet the requirements to implement the services that respond to the user and context needs.

4 Cyc for Ambient Intelligence

It is evident that exhibiting an autonomous and self-sufficient behavior needs to be founded on the knowledge about how things work, and eventually, in the capability of making decisions based on that knowledge. In this regard, the dramatic advances achieved by Cyc, uphold it as the most promising approach to provide Ambient Systems with the *intelligence* and flexibility required when dealing with unforeseen scenarios.

This section goes through those aspects of the Cyc system that make it the most appropriate choice. To start with, one of these aspects refers to how events are handled in Cyc. If events are the basic elements that describe how contexts evolve, it is obvious that an appropriate theory is required in order to efficiently represent that knowledge.

Cyc implements a Davidsonian[21] interpretation of events and actions. In the knowledge base, events are asserted as individuals about which facts can be stated, so as to specify the moment in time when the event took place, the location, or the performer agent, for instance.

Theories of actions and events have been closely related to those of planning, so as to talk about *action planning*, supported on theoretical frameworks, as the one proposed in [22]. Moreover, goals play an essential role in achieving the autonomy and self-sufficiency, so many times referred here. On the basis of these goals, the system behavior is determined by those actions that work towards the achievement of these goals. How these actions are selected is the responsibility of the planner, based on the information held in the knowledge base.

The planning problem has been traditionally stated in terms of a description of the world, or initial state, the goal to be achieved and the possible actions that can be performed at that initial state. Needless to say, the action descriptions are specified in terms of prerequisites that are to be satisfied so as to perform the action, and the effects of executing the action. The Cyc planner is an extended version of the SHOP[23] system, that has been optimized to reason about actions and events.

It has to be remarked that both, events and planning are the most appealing features in advocating for an approach based on Cyc. Combining these features, with the proposed ontology and the middleware framework for Ambient Systems, it is possible to compose a plan, as a set of actions performed by services, that lead the system to satisfy, achieve, or maintain any of the goals that the Ambient System is commited to.

5 Conclusions

As an step towards real intelligent systems, this work advocates for an approach based on commonsense reasoning to drive the system behavior in response to the events taking place in the context. However, the commonsense reasoning capability cannot be considered, on its own, as the silver bullet for Ambient Systems, since without an extensive knowledge base that gather the knowledge about the everyday life, reasoning capabilities can be of a little help.

The Cyc knowledge base seems to overcome this drawback, providing a large knowledge base, with roughly 3.5 millions of assertions, at the moment of writing this article. Along with such as an extensive amount of knowledge, it also provides an exceptional way of managing the events that take place in Ambient Intelligence contexts, that combined with an event-optimized planner envisions the Cyc system as the backbone of the Ambient Systems that are to come.

Finally, the main contribution of this work is not only constrained to advocate the integration of Cyc, but it also proposes an ontology for modeling Ambient Systems and a middleware architecture, intended to support the service composition, considered an essential requirement to exhibiting an autonomous and intelligent behavior.

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