Integration of Intelligent Agents Supporting Automatic Service Composition in Ambient Intelligence *

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Abstract

Systems for Ambient Intelligence environments demand at some stage a service composition task, as a mean of adaptability to the context changes. However, in contrast to what ubiquitous and pervasive computing propose, users generally find themselves involved in the service composition task, by selecting or deciding what to compose and how. This paper proposes the use of Intelligent Agents for the automation of the composition task, providing transparency from the user point of view.

1. Introduction

The Ubiquitous Computing concept was first defined by Mark Weiser in [8], referring to a new computing era where electronic devices merge with the background. People make use of those electronic devices unconsciously, focusing just on their needs and not in how to accomplish them.

The concept of Ambient Intelligence [3], lying on the ubiquitous computing paradigm, refers to those environments where people are surrounded by all kind of intelligent intuitive devices, capable of recognising and responding to their changing needs. People perceive the surroundings as a service provider that satisfies their needs or inquiries in a seamless, unobtrusive and invisible way.

Last decade research efforts in distributed systems have been mainly addressed to find solutions that properly support this new era. Ambient Intelligence concept provides an innovative way of conceiving computing technology, rather focusing attention on actions being performed than in how to interact with devices, minimising in this way the user distractions.

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Due to the rapid improvements in mobile technology, devices are increasing their capabilities and popularity. Simultaneously, the wide range of heterogeneous devices and services come along with an extensive set of different frameworks that lead to incompatibility in the designs. Furthermore, these frameworks do not support the development of systems that dynamically adapt their services to the changing scenarios, which remains a mandatory requirement for Ambient Intelligent systems.

The Service-Oriented paradigm provides the foundations for overcoming the drawbacks derived from the existing heterogeneity and dynamism. This paradigm basically considers resources (e.g. distributed objects, agents, or basic web services) as services, in such a way that one service is created for each available resource. Moreover, this paradigm identifies two types of services, namely: basic and composite services. The former are the services directly offered by resources, while the later are composed of basic services, which result in more complex services. User needs are generally better fulfilled by composite services than by basic ones.

Nevertheless, service composition is not a trivial matter and it considerably increases the complexity of the system. Depending on the level of autonomy, service composition can be carried out in three different ways [1]: manual composition, semi-automated composition and automatic composition.

Manual and semi-automated composition expects the user to interact in the decision making task involved in composition, that is, the user knows the available services and how those can be composed to synthesise new services. Even in semi-automated composition, the user is involved in the composition task, by selecting the services to be composed from a shortlist.

Nonetheless, neither manual nor semi-automatic service composition make any further contributions on Ambient Intelligence since they are user-dependent. Therefore, automatic service composition stands out as an effective solution to achieve the self-management required for a system in Ambient Intelligence.

The role played by middleware architectures for Ambient Intelligent systems is essential in simplifying and abstracting the complexity and heterogeneity of both, network and device technologies. Furthermore, some of the requirements for service composition, such as the reasoning capability, are to be provided at the middleware level. Therefore, the proposal presented in this paper, introduces the use of a multi-agent system (MAS), as a constituent part of the middleware architecture, for the automation of the service composition task. The MAS relieves the user from having any expertise regarding the details involved in the composition. In this way a more intelligent ambient is achieved, since the agent system is in charge of knowing what, how, and when to compose the basic resource-oriented services.

The remainder of this paper is structured as follows. Firstly, the background section provides the basis of the contributions presented in this paper. The next section aims at drawing the outline of a composer agent system, from the process of service discovery to the automatic service composition. The following section is devoted to provide implementation details of the ideas here outlined. Finally, the last section presents the conclusions and provides suggestions for future works.

2. Background Information

2.1. Intelligent Agents

A common situation faced by people, takes place when in their way to accomplish a certain task, they found that the mechanism provided to this end is not available. People will then reason in order to obtain the same result by means of the available mechanisms. Therefore, what people will do in this type of situations is what so far in this paper has been referred as service composition.

Automatic service composition in a dynamic context entails a high degree of adaptability and reasoning in order to react to changes, new scenarios and events. Uncertainty arises due to unforeseen situations and people demands. Therefore, Ambient Intelligence systems have to decide the response to such situations, in the same way a person would do, by gaining knowledge of the context, establishing goals and employing reasoning in order to accomplish them.

It has to be remarked that the ability to replicate human reasoning remains one of the main objectives in the Artificial Intelligence field. In this regards, Intelligent agents have come to be a powerful solution to this issue, and therefore their use is investigated in this paper in the context of automatic service composition.

Different approaches to implement the intelligent agents are found in literature [9]: Logic based architectures (deductive agents), reactive architecture (reactive agents), layered architectures (hybrid agents), and practical reasoning architectures (Belief-Desire-Intention agents). Among these alternatives, the Belief-Desire-Intention model (BDI) has proved to be a powerful framework for building rational agents [9].

The BDI model of decision making is intended to reproduce the process carried out when people take decisions to achieve a certain goal. The main characteristic of the BDI model lies on the significance conceded to beliefs, desires, and intentions involved in rational actions.

The reasoning capability is highly dependent on the semantic model used to describe the agent context, and so, providing a good semantic model has long been an issue of concern. In [4] the lack of agreement on the knowledge properties is identified as one of the main shortages that need to be overcome. J. Hintikka in [6] provided a good approach to this matter with the *possible-worlds semantics*. This semantic describes the agent's possible worlds or states accessible from its current state of the world. Rao and Georgeff proposed in [2] an approach to model possible-worlds, by means of a temporal structure with a branching time future and a single past, called time tree. CTL, CTL*, and LORA, just to name a few, are some of the formalisms used for this purpose.

Jadex [7] is an agent-oriented reasoning engine supporting the development of rational agents. In spite of using formal logic descriptions, Jadex proposes the use of two commonly known languages, such as Java and XML. The BDI agent is modelled by mapping the concepts of beliefs into Java objects, while desires and intentions are mapped into procedural recipes coded in Java that the agent carries out in order to achieve a goal.

2.2. The DOBS Architecture

Distributed Object Based Services (DOBS) is a framework that comprises several research projects developed by the ARCO group[1]. DOBS aims at developing a full framework for home services, starting from an object-oriented distributed (OOD) platform.

DOBS is composed of a set of core component, such as the DOBS interfaces for modelling services, the audio and video services adopt the AVStream from the Object Management Group (OMG), a set of basic services for service discovery, security mechanism, bootstrap, or management facilities, just to name a few. Furthermore, DOBS also provide the required features for subsystem integration, therefore, UPnP, X10, or Bluetooth services are seamlessly integrated. Finally, DOBS has considered the impor-

[1] http://arco.esi.uclm.es/dobs

tance of providing a complete information model. A complete taxonomy of user services (with their attributes) has been developed so that the manufacturers can use a common nomenclature. This taxonomy is built up from UPnP templates and Bluetooth profiles and it has been completed with nomenclature and services from most relevant standards (Mobile Location Protocol, AVStreams, etc.). Together with the service type, the developer can consult the different service attributes. The idea behind this taxonomy is to create a basic set of home services that work as POSIX interfaces do for operating systems.

The Multi-Agent Service Composer System (MASCS) is

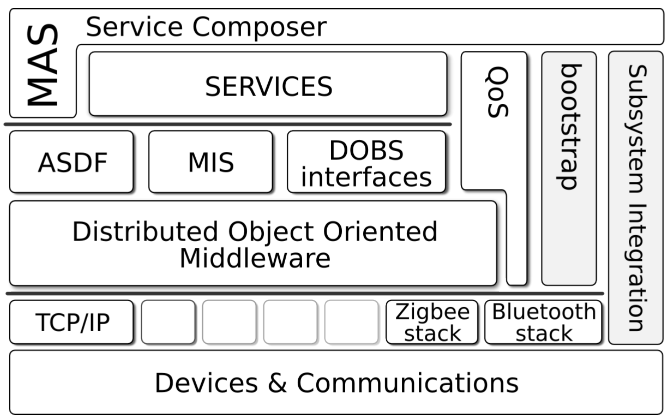

Figure 1. DOBS Architecture

being developed on top of the Jadex platform that provides the reasoning engine. This platform has been integrated in DOBS as one for automatic service composition of the service offered by the middleware.

2.3. Automatic Service Composition

Composability has become an appealing field, mainly because of its support to Ambient Intelligence environments that dynamically react to new situations, events, or user requirements. Most of these new emerging scenarios are not taken into account at implementation stage, due to the unmanageable number of combinations. This fact, along with the heterogeneity of device and network technologies, makes dynamic and automatic service composition a key requirement for any middleware aimed at supporting Ambient Intelligence environments.

Some of the most promising approaches towards automatic service composition are based on web services, ontologies or artificial intelligence planning techniques. Despite of the groundbreaking ideas provided by these approaches, none of them has so far successfully addressed the dynamism implicit in Ambient Intelligence environments.

Dynamism implies changes, that have to be captured in the knowledge the Ambient Intelligence system holds about its environment, in other words, the system needs to be context-aware. Nevertheless, capturing these changes is not enough when a self-sufficient behaviour is expected from the environment, intended to understand what is happening around, in order to wisely react. In this regard, this paper states the use of reasoning mechanisms as a way of dealing with these changes and the effects they cause on the environment. The reasoning capability is at the root of the automatic service composition support. Enriching the environment with the reasoning capability means that even unforeseen scenarios can be dealt with by the environment. In spite of the attempts made to provide some sort of dynamism into middleware architectures [10], none of them has succeeded in the task of responding to new or changing context requirements, mainly due to their lack of reasoning capabilities.

3. Supporting automatic service composition in DOBS

In above sections, the MASCS has been presented as the reasoning engine that leads the system in its way to wisely react to the events happening in the environment. Furthermore, the DOBS framework has also been presented as the middleware architecture that serves as the foundations for the MASCS. Therefore, this section describes the proposed architecture as a solution toward automatic service composition in Ambient Intelligence.

The key element of the proposed architecture, as stated above, is the **MASCS**. Its main responsibility consists in responding to incoming events, needs or requirements by means of service composition. The **Jadex platform** provides the Composer Agent System with all the mechanism to reason about the context and deliberate about the best plans to be accomplished in order to reach the defined goals. Moreover, the Jadex platform rests on top of the **middleware** layer, built using *The Internet Communications Engine* (Ice) [5], which is an object-oriented middleware platform, similar in concept to CORBA, on top of which services are deployed. Middleware features are also promoted upwards to the agent. Despite the fact that the Ice adapter for Jadex, has not been provided along with Jadex, the well documented API and its modular design has required little effort to develop the adapter.

Finally, it can be argued that there is no difference between what it has been exposed so far and a deep search or a planning. However, the use of an ontology introduces a reasoning mechanism providing a more efficient decision making process, far from what can be achieved by means of a deep search or planning. Moreover, human expertise can be incorporated in a better way by using reasoning.

So far, when a need for a service has been identified, the Composer Agent System finds a set of services that combined together behave as the required one. If the seek for these basic services consists in finding the list of services whose outputs match the next service inputs, then it falls on the planning or deep search category. However, this proposal expects the system to behave as a person would do in the same situation, by reasoning about the context, and trying to accomplish the best action at each moment.
The gap between the composer agent behaviour and the human behaviour is mainly due to the semantic knowledge humans extract from the environment, which is used as the base for their reasoning. Therefore, if the Composer Agent System manages itself to infer this semantic knowledge from the ontology, the agent will select the best plans or actions that will lead it to accomplishing its goals.
It has to be remarked that the same ontology is used by the agent platform and the middleware. Since the Jadex platform provides support for managing ontologies, the composer agent system appeals to the ontology, in order to understand what the available services are doing. Once the composer agents assign semantic meaning to these services, it just has to find out which is the intersection of services that supplies the desired functionality.

4. Conclusions and future works

Ambient Intelligence environments are characterised by their high dynamism. The set of devices present in the environment is constantly in change, and consequently, the set of services offered by these devices is varying as well. Due to such dynamism, a primary identification of needs can only be used as a starting point, since new needs will arise as new devices and user requirements change in time. This context requires mechanisms able to effectively manage an environment constantly in change. An appropriate design of an Ambient Intelligence middleware, combined with service composition turns out to be the more suitable solution to this issue.
The proposal presented in this paper, exposes the use of intelligent agents for automation of the service composition task. The composer agent system relieves the user from being aware of the details involved in the composition, achieving in this way a more intelligent ambient, since the agent is in charge of knowing what, how, and when to compose the basic resource-oriented services.
Intelligent agents have been modelled as BDI Agent, using for this purpose the Jadex platform. Jadex provides a set of tools supporting the BDI Agent construction, but it also provides the reasoning engine that leads the agent to accomplish its intentions.
The combination of the composer agent system along with the middleware layer results in a middleware architecture able to cope with the dynamism inherent to Ambient Intelligence environments.
Despite the fact that this proposal implies an important step forward to real Ambient Intelligence, there are still several issues that have to be dealt with in order to reach a high-performing Ambient Intelligent environment. Some of these issues are connected to the ontology, since it is the main resource from where all the semantic information is being extracted.
Moreover, the Directory Service could be implemented by means of another intelligent agent, in order to provide a list of services satisfying a list of constraints. The main idea for this service is to perform a semantic search, in order to return a list of services that satisfy the restrictions defined by the composer agent.

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