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An Ontology-Based Mobile Application for Task Managing in Collaborative Groups

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Abstract

This paper presents an ontology-based application for mobile devices which is responsible for supporting groups of people with the management of their shared tasks. The ontology stores the domain knowledge about collaborative tasks, which is used to support task recognition and relocation. Such knowledge is used by a multi-agent system that consists of a group of agents representing each person in the group. The agents use plan recognition techniques to monitor the execution of tasks according to the schedules and negotiate task allocation when needed. Our techniques have been applied in a healthcare scenario which consists of a family group that takes care of an elderly person.

Introduction

Collaborative groups usually share and distribute a series of tasks that must be executed to achieve a common goal. These characteristics are commonly found in multi-agent systems based on the organisation-centred paradigm (Hubner, Sichman, and Boissier 2007). Sometimes a member of a group may face a particular problem which might lead his/her goal to fail. In that case, it is desirable to foresee such situations and prevent that failure from happening. Hence, we propose a framework/application to help a collaborative group to coordinate their shared tasks by monitoring their plans, predicting plan failures, and support them in task reallocation.

In accordance with our goal, we propose an ontology-based multi-agent system that supports users in the real-time execution of their planned tasks. Our application is developed in a multi-agent platform extended with the AI techniques described in this paper. User observations are combined with the knowledge about tasks encoded in an ontology to perform task negotiation and reallocation in failure situations predicted by the system. These services are performed by agents on users' behalf in a transparent manner. The features of our application are illustrated through a healthcare scenario.

The contribution of this work is twofold. First, we introduce a general framework for the development of multi-agent applications that support task management for collaborative groups. Second, we demonstrate the use of our framework in a practical healthcare scenario by describing an application developed using our framework.

Related Work

This section describes previous work that use ontologies for activity representation and recognition. Activity modelling in ontologies consists in defining formal semantics for human tasks by means of the operators in ontological languages. Then, ontological reasoning can be used to recognise that the user is performing a certain activity starting from some facts (e.g., sensor data, location of people and objects, properties of actors involved) (Riboni and Bettini 2011b).

Riboni and Bettini (2011) propose an ontology of activities that combines ontological reasoning with statistical inference to enable activity recognition. Their solution uses statistical inference on raw data retrieved from body-worn sensors (e.g., accelerometers) to predict the most probable activities. Then, symbolic reasoning refines the results of statistical inference by selecting the set of possible activities performed by a user based on the context.

Chen, Nugent and Wang (2012) introduce a knowledge-driven approach to activity recognition and inference based on multi-sensor data streams in smart homes. The ontology represents the correlated domains of smart homes contexts and Activities of Daily Living (ADL). Contextual information is obtained by sensors that are linked to physical and conceptual entities such as objects, locations, and states.

Garcia *et al.* (2013) propose one approach based on ontologies to solve problems related to resource sharing in pervasive environments. The ontological model is composed by a set of ontologies that represent the elements involved in a collaborative environment. Ontologies refer to types of managed resources (human, physical, and virtual) and other characteristics such as environment and organisational aspects. This set of ontologies is part of the RAMS architecture (Resource Availability Management Service).

Bae (2014) presents an approach to ADL recognition called RADL (Recognizing Activities of Daily Living). RADL is a system that detects and monitors ADL's standards for smart homes equipped with sensors. RADL is exemplified in a smart home scenario where one elderly person lives alone. The ontology proposed by the author is able to reason about ADL's standards and provide semantic discovery of locations, devices, activities, and other relevant information. The ontology is divided into three parts. The first represents concepts about daily life services such as the air conditioner being on or off and window being open or closed, for instance. The second represents safety services such as “fire alarm activated”. The third part represents message services such as sleeping messages, wake up messages, and so on.

Our work differs from the above because the focus is in collaborative groups working together to achieve the daily tasks. In this direction, we combine AI techniques such as multi-agent systems, negotiation and reallocation of tasks, as well as ontologies to represent the relevant knowledge.

Task Ontology and Plan Library

The task ontology allows queries and inferences about collaborative tasks, providing the necessary information to the multi-agent system. The ontology can be seen as the core of the system, where the multi-agent system has access to that information using a CArtAgO artifact (Ricci, Viroli, and Omicini 2006).

Task is the main concept in the ontology; it represents an activity that is executed by one or more people. We can also say that the execution of a *Task* may happen in a particular location and time, and normally involves agents and objects. Therefore, the main and most generic concepts of the proposed task ontology are: *Task*, *Person*, *Location*, *Object*, *TimeInterval*, and *TaskPurpose* (see Figure 1).

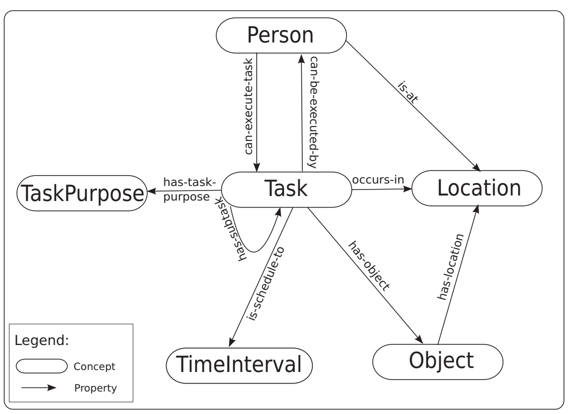

Figure 1: Task ontology – main concepts and properties.

Collaborative tasks may have restrictions as to who can execute them and when and where they occur. Then, to address these issues our ontology specialises the task concept as in Figure 2. In our ontology, the concepts were defined based on restrictions and other logical characteristics related to collaborative tasks.

The *CompositeTask* concept is equivalent to a task that has at least one sub-task. The *RestrictedTask* concept is subdivided into three kinds of restrictions: *(i) RestrictedAgent_Task* can be used to define features that agents or people must have to perform certain tasks; *(ii) RestrictedLocation_Task* can be used to classify a task according to the location where it occurs; *(iii) RestrictedTime_Task* can be used

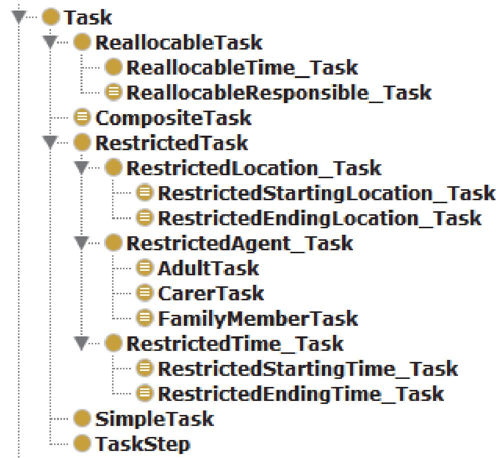

Figure 2: Taxonomy of task concepts.

to classify a task that has restrictions about the starting or ending time that it occurs.

In addition, our task ontology allows agents to negotiate about reallocation of tasks. To provide this information, the concept *Task* has the sub-concept *ReallocableTask* whose function is to indicate the possibility of reallocation in terms of time and person responsible for the execution of a task. It is divided into two sub-concepts called *ReallocableResponsible_Task* and *ReallocableTime_Task*. *ReallocableResponsible_Task* refers to a task instance that has the property *can-be-reallocated-to*. The temporal reallocation can occur when one task instance is not *RestrictedTime_Task*. Besides, we created SWRL rules to define who is able to perform each task. For instance, some tasks such as driving can be executed only by adults. Below we define the *ReallocableResponsible* concept and the rules in SWRL that allow us to infer instances of suitable people for conducting a task reallocation.

$$Task(?x) \wedge Person(?y) \Rightarrow \textit{can-be-reallocated-to}(?x, ?y)$$
$$AdultTask(?x) \wedge Adult(?y) \Rightarrow \textit{can-be-reallocated-to}(?x, ?y)$$

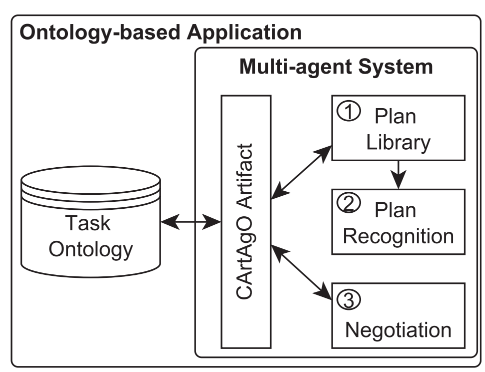

Figure 3: Components of our ontology-based application.

The ontology development in this project was divided into two phases. The first one corresponds to the definition of the most general concepts and relationships that can be used in various collaborative groups. The second phase corresponds to the instantiation of the ontology in the specific case of a healthcare scenario. The ontology consists of 34 concepts, 31 object properties, 4 data properties and 73 instances. Further details can be found in (Schmidt et al. 2015).

In our approach, the also ontology provides information for modelling a plan library structure. A plan recognition module uses the plan library for recognising, monitoring, and predicting failures in agent plans. When a problem is detected, the negotiation and reallocation of tasks among agents automatically starts. Figure 3 shows the main components of our proposal.

The *Plan Library (1)* can be created by instances and restrictions of tasks modelled in the ontology. Consider a plan called *prepare-meal*. In the ontology, there is an instance of *CompositeTask* called *prepare-meal*. This instance is classified as a top-level plan in the plan library and is decomposed with sub-task instances such as prepare-breakfast, prepare-lunch, and so on. The hierarchy between the top-level plan and the sub-tasks occurs through the has-subtask property, which allows us to differentiate between sequence or decomposition plan-library relations.

Plan Recognition and Task Negotiation

Our application is composed of other components such as plan recognition and task negotiation. The *Plan Recognition (2)* module is responsible for recognising agent plans. For this, we used an implementation of a symbolic plan recognition algorithm (Avrahami-Zilberbrand and Kaminka 2005). The plans are based on the structure specified in the plan library that was generated from the ontology. In this context, the ontology's role is to provide information for the construction of plans and a set of features that help the plan recogniser to identify what task is being executed, whether it will fail or a task negotiation process should be started.

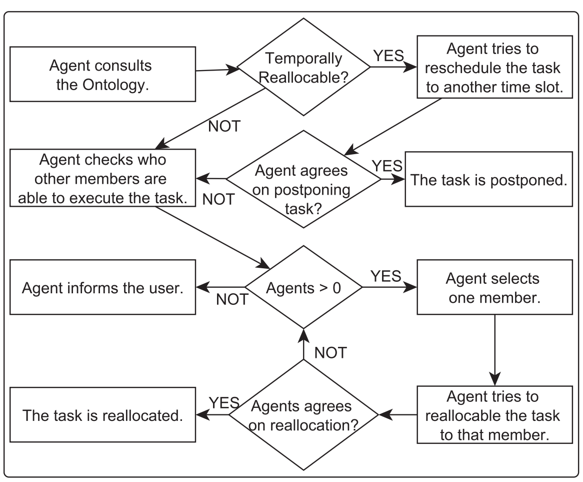

Figure 4: Decision-making for task negotiation.

The *Negotiation (3)* module performs queries in the ontology[1] when agents need to know, for example: *(i)* if a task is temporally reallocable; and *(ii)* if a task can be reallocated to another member of the group. In the first case, it is checked first if the task instance belongs to the concept *ReallocableTime_Task*; if the answer is positive, then the agent can negotiate to postpone the task. Otherwise, the agent queries the ontology to know if that particular task instance can be reallocated to other group members who might be able to execute it[2]. In this case, the application proceeds to negotiate with the members related to the task.

This process is succinctly represented in Figure 4 (more details can be found in (Panisson et al. 2015; 2015)).

Application in Healthcare

Recognition and monitoring of daily activities are important opportunities for applications focusing on caring for the elderly (Bae 2014). The use of concepts and information modelled in ontologies is a suitable way to represent knowledge and behavioral rule systems about household facts(Bae 2014). Ontologies provide readable and understandable knowledge for both humans and machines, and have an important role in knowledge representation and sharing, data management, information retrieval, among others. In addition, computational agent-based systems can be used to support distributed computing, dynamic information retrieval, automated discovery of services, pervasive computing, etc. Ontologies and agent-based systems are two different but complementary technologies where the ontology is responsible for providing knowledge to the system while the agents provide the dynamism and autonomy that the system needs (Hadzic et al. 2009). Our research integrates such technologies to explore collaborative task management applications, as in the healthcare application we describe in this section.

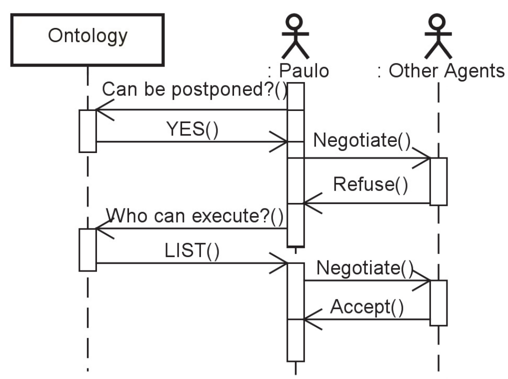

Figure 5: Negotiation example.

Our application is inspired by a particular scenario of

[1]The infrastructure between the multi-agent system and the ontology is described in (Freitas et al. 2015).

[2]This information is related to the property *can-be-reallocated-to* which takes into account constraints such as tasks that can be performed only by adults, for example.

a family group with an elderly person living alone called *Joao*. He has health conditions requiring constant monitoring of his daily tasks. *Joao* has two children called *Paulo* and *Stefano*. *Paulo* lives next door with his wife *Jane* and their two children (*Pedro* who is 12 years old and *Maria*, 14 years old). *Stefano* lives in the same city, but about 10 km away from *Joao*'s house. To help with daily tasks, *Joao* has two professional carers that help him (one during the day and another for the nights). *Joao* has a routine of activities that includes walks in the park, physiotherapy, mental stimulation activities (memory games, for instance), as well as feeding and taking medicine at specific times. The group's tasks are related to the care of the elderly. As *Joao* needs full-time monitoring, the group established routine tasks that start when he wakes up and extend across the rest of the day. Thus, the ontology is designed to represent all aspects of the tasks of daily living (ADL) for debilitated people and their relationship with other members of the caring group. As mentioned, the application is supposed to help reallocate tasks related to *Joao*. For example, suppose that *Paulo* has a specific task assignment, and in a given moment something hinders the task execution (this is identified by the plan recognition module in a non-intrusive manner). In this case, following the process described in Figure 4, *Paulo*'s agent starts a negotiation to resolve the identified problem. A possible negotiation is represented in Figure 5, where, initially, the agents involved disagree about postponing the task, and after this, in a second dialogue, they agree about another agent executing *Paulo*'s task. In this paper, we illustrate our approach with an application to support an eldercare group; different applications will require, first, a different domain-specific ontology that will support the whole development and execution of the application.

Final Remarks

This paper applies various AI techniques such as multi-agent systems, ontologies, plan recognition, and argumentation-based negotiation to build applications for collaborative groups. An example of application in the area of healthcare was discussed. More generally, we address situations of collaborative groups in which the members can share and negotiate tasks. As group members may face problems that may lead to task failure, the framework supports the development of application capable of predicting and preventing such situations on behalf of the users. Our approach to support collaborative groups coordinating their shared tasks is implemented by monitoring their plans, predicting plan failures, and helping them in the reallocation of tasks. Also, our techniques can be applied to other contexts by modifying the ontology instantiation and reusing the software components discussed in this paper. Applications based on ontology and agent technologies provide reasoning and distributed/mobile computing, and this work presents several technological components that are combined together for building such intelligent applications. In future work we aim to extend the ontology to support other healthcare scenarios and simplify the application set up by the end users.

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