Towards a new Role of Agent Technology in User Modelling

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Abstract

This paper discusses resent attempts to employ multi-agent technologies for user modelling purposes. Based on the analysis of recent implemented systems, this contribution provides a general agent definition representing a flexible implementation to employ highly specialized entities for user modelling tasks, and illustrates communication and cooperation approaches. In the overall solution, agent teams cooperate to fulfil the requirements of user modelling in a more appropriate way.

1 Introduction

A growing number of application fields, such as intelligent information acquisition, eLearning applications, and exhibition guides, need to adapt to the user's behaviour, preferences, technical capabilities, and so forth in order to be accepted by users. In the development of user-adaptive systems, several problems need to be solved. Recent projects and research work at the Fraunhofer Institute have revealed two major aspects to be addressed: How do we implement adaptivity in an efficient way that is compatible with several domains, and how can we bridge the lack of standards.

Common generic user modelling systems, as described in [Kobsa, 2001], adapt the system behaviour starting from the definition of the user's context, which is composed of four dimensions as introduced by Gross and Specht [2001]: *Identity*, *Location*, *Time*, and *Environment*. In addition, users establish relationships to several entities within the domain they are acting in. For example, they communicate with other people, they form groups of users trying to attain a certain goal, they provide data to computer systems, and so forth. Strictly speaking, an adequate representation of a human being as the user of a computer system has to take the human's *activity* (in different *roles*) into consideration.

This contribution discusses the role of agent technology [Jennings and Wooldridge, 1998] for representing users of computer systems. The discussion addresses three major aspects: Firstly, the paper motivates the use of agent technology in this field, and secondly it describes the role of agent systems in recent implementing approaches for the above-mentioned application fields. In the main part, this contribution then provides a general agent definition and discusses benefits and possible applications.

2 Users and Agents compared

In the research field of user modelling many systems have been implemented based on one of the classic development approaches, even though the terms 'Agent' and 'User' were often used equally. This chapter illustrates why agents seem to be worth considering to represent users.

At the current stage, the state-of-the-art system development and programming approach is the object-oriented approach [Odell, 2002]. Applying this approach for user modelling purposes allows defining users as single entities. One of the drawbacks is that objects are considered passive since their methods need to be invoked by any other entity, therefore the agent approach for representing users sounds more likely:

> "Software agents have their own thread of control, localizing not only code and state but their invocation as well. Such agents can also have individual rules and goals, making them appear like 'active objects with initiative'. In other words, when and how an agent acts is determined by the agent."[Odell, 2002]

As active entities, users do wilfully behave following their own decisions in order to fulfil desires. They plan their decisions based on their knowledge, goals, believes, memories, or emotions. The freedom of users with regard to behaviour is often limited by internal (like time, credibility) and/or external (e.g. laws, contracts) restrictions. The desires to be fulfilled emerge from their interests, intentions, goals, and preferences. All of these attributes are part of the above-mentioned *Identity* dimension. Analysing the variety of agent modelling approaches (intension-based, rule-based, role-based, to mention just a few) shows that behaviour and identity are central issues in modelling agents. Although modelling emotions (like modelling emotional agents with personality as described in Padgham and Taylor [1997]) or cognitive states (for example, Boella and van der Torre [2003] proposes a cognitive agent model based on a symbolic representation of mental attitudes) are non-trivial tasks, the agent approach reflects the individuality of each user more appropriate than classic approaches.

In addition, users cooperate with other users (including being deliberately unwilling to cooperate). For this purpose, they build (and release) communities, for instance to share information, or to get the help of an expert. In translation to multi-agent terminology, cooperating agents need the support of organization and communication, whereby the latter includes transferring/receiving information as well as negotiation, teaching, and even deliberately hiding information or attempting misinforming others.

Depending on context, users act in real life in different roles. In the role of a curator of an exhibition, for example, the user will concentrate on aspects like how to order the exhibits, how to illuminate them, or whether to play a sound and what kind of sound, if any. In the role of the visitor of an exhibition, the same user will be more relaxed, feels the atmosphere of the lights and lets the underlying music sink in. Without much doubt, such a user will deliberately alternate between these roles at daily work. For each of these roles would exist one highly specialized agent in order to implement real individual behaviour. Based on a concept of cooperation between the agents, the most appropriate agent will act depending on the current context. For example, the agents representing the different roles could compete with each other for several control tasks; if the user's context changed, then other agents could come to the fore. To resolve possible conflicts between the agents, conflict management mechanisms can be implemented [Tessier *et al.*, 2000].

Furthermore, users improve their own behaviour by learning directly from external entities (teachers) or by observing their environment and its entities. Additionally, both learn by analysing the outcome of their past (re-) actions in similar situations. In Wooldridge [1996a] is shown that agents can also learn and improve routine interactions.

3 Recent Approaches to apply Agent Technology

In recent work, the term 'User-Agent' was often used without any connection to the research field of multi-agent systems. Furthermore, there exist a variety of agent definitions, modelling techniques, and architectures in this field (to get an overview, refer to [Wooldridge, 1996b]). In this section we describe recent attempts of combining user modelling and agent technologies for the application fields mentioned in the Introduction to this paper.

Driven by the boom of web-applications in the late 1990s, the value of personalization was increasingly recognized in the field of intelligent information access on the WWW. Pazzani and Billsus [2002] have introduced adaptive web site agents that recommend relevant documents to the user in an Amazon.com-like manner. They argued that the information is best used to change the behaviour of an animated agent (avatar) to assist the user. In Billsus and Pazzani [2000] an intelligent information agent is considered to be a personal assistant that gradually learns about users' interests. Like the adaptive web agents presented in Menczer and Belew [2000], agent technology is either used for personalized information acquisition or for individual information presentation.

In the domain of eLearning, Vassileva *et al.* [1999] base the adaptation within the I-Help system on models of human users maintained by personal agents:

> "Each personal agent manages a user model containing information about the *user's goals* (help requests, current goal), about *knowledge resources / competencies* on certain topics or tasks, and about the *relationships* existing between the user and other users."

The Baghera project [Webber *et al.*, 2001] has implemented personal interface agents for students and teachers, and tutor agents that base whose didactical decisions on a student model. In order to integrate human-like intelligent tutors into collaborative learning environments, Goodman *et al.* [2003] have also proposed to integrate tutoring agents. These approaches have in common that student and tutor agents are connected with external user models; the representation of the individual learner is not part of the agents' definition.

Furthermore, agent technologies have been applied for personalizing location-based services like city- and tourism-guides. The Deep Map Agents introduced in Fink and Kobsa [2002] provide tour recommendations, analyse spoken text, generate speech output etc. These agents, which loosely adhere to the FIPA agent specification [FIPA,], communicate to a User Modelling Server (UMS) about the user's interaction with the system and query the UMS for user characteristics. In the EU-founded CRUMPET-project [Poslad *et al.*, 2001], FIPA compliant user agents are hosted on the end user terminal devices and provide the user with the service GUI. These agents adapt the information presentation to the platform evaluating the usage profile of the user. Once again, the user modelling task is not subject of the agents' work.

In summary of these approaches, the agents usually query an external user model. In terms of the general scheme of an adaptive system [Jameson, 2003], teamworking agents improve user model acquisition resp. user model application. Referring to Figure 1, the agent systems fulfil the requirements of the information acquisition layer and/or of the domain-affecting layer.

4 An User Modelling Agent

In order to define a new role of agents systems, this chapter provides a general agent definition. As the central issue of Figure 1 this definition focuses on the user representation layer. In terms of a general definition of an agent:

An Agent is a triple {*Dat*, *Act*, *Sit*}, whereby *Dat* represents the internal knowledge base of the agent, *Act* is the set of possible actions, and *Sit* consists of the situations the agent acts in,

our approach maps the internal knowledge base of the agent to the user model. The possible user actions within the domain determine the set *Act* of agent actions, and *Sit* consists of the user's contexts.

In contrast to recent approaches an agent here represents *the user*. For different roles a user might take on, highly specialised agents should compete for selection. If the role changes, another agent comes to the fore regarding to changed attributes and behaviour. Therefore, the assignment between the user and the representing agent is not static. In Figure 1, inactive agents appear within grey boxes; white boxes illustrate active agents representing different users.

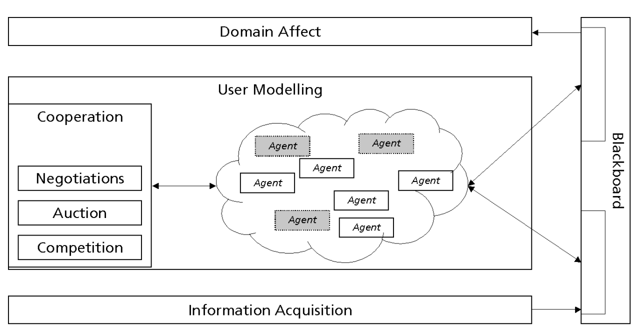

Figure 1: A Set of User Modelling Agents

4.1 Communication between the Agents

To enable the several agents to share information with each other, a blackboard approach [Ash and Hayes-Roth, 1990] for sharing information could be applied. Basically, the blackboard represents a common platform where agents write information down and read the results written by others. In contrary to the message sending approach, sender and receiver do not need to explicitly address each other, agents can join and leave the communication platform effortless, and the system can be connected with external information delivering agents effectively.

In the message sending approach, the sender agents deliver information to the receiver explicitly or broadcast messages to a set of receivers. Due to the direct connection, the information transferring process is more effective, because the other agents do not have to observe the complete blackboard for relevant information. In order to enable information transfer from/to external components, communication agents need to be defined sending messages/events to external addresses. In the way around, these external components need to address internal receivers for delivering. The flexibility in changing the set of agents on demand and the connection to applications will be reduced.

4.2 Cooperation approaches

Like users cooperate with other users, agents work together in multi-agent systems. Common cooperating approaches are negotiation, auction, and competition, to mention just a few. On the one hand, a number of agents cooperate for representing one and the same user. Lorenz and Denzinger [2003] have also introduced an approach to separate several agent systems by their functionality. For example, sensoring agents cooperate for observing the environment and for fulfilling the information demand of the overall system. On the other hand, several user modelling agents cooperate in the overall system, for instance to transfer information between users.

4.3 Discussion

On the one hand, this approach provides a number of benefits: regarding to some currently underrepresented attributes of human beings (such as individual behaviour) the approach provides a more adequate representation of active users. Users who behave individually can be modelled by different configurations of the agent systems. By implementing several roles, and several ways of thinking, differences between individuals can be represented more appropriate.

Additionally, the user modelling component becomes more able to react to changes (for example if the user's interest decreases over time), and we have the possibility to apply several artificial intelligence methodologies (cf. Section 4.4). Furthermore, conflicts inside users themselves can be explicitly recognized. Regarding for example the limited credibility of a person, taking one decision can interfere with the possibilities of taking another one. In this case, such conflicts in the decision making process can be solved by negotiations between the agents, for instance.

The implemented agent systems in recent applications (as discussed in Section 3) are strongly connected with one certain application. The implemented individual behaviour of each user is defined by the system developer and cannot be changed at runtime. As the result, the user models cannot be applied to any other domain without totally replacing the modelling component. For employing the user representation in another domain, domain-independent agents were retained unchanged. In our approach the system would switch effortless between user agents, which are still domain-dependent since the agent's set of actions usually is, if such agents for the new domain already have been implemented.

In comparison with the object-approach, a general drawback of our approach is the need of a well-defined architecture for a multi-agent environment. This environment has to provide background facilities for the organization of agents, interaction channels, cooperation schemes, communication protocols, etc.

4.4 User Modelling Agent in Practice

Sets of agents representing several users can be used for varying purposes. In the above-mentioned example, agents representing different roles of a user are selected based on the user's context. A similar solution can be applied to define stereotypes and to categorize the current user at runtime. The attributes that characterise several stereotypes are part of the knowledge base of several agents. To find the most similar stereotype to the current user, each of the agents could offer the value of its similarity measure in an auction, for instance.

Continuing this idea, a similar approach can be applied in recommender systems: the agent's knowledge base consists of the user's interests and the agents compete for the opportunity to recommend to the user. In order to find out recommendations, e.g. Case-Based Reasoning methodologies [Aamodt and Plaza, 1994] can be employed to analyse past user behaviour. In the manner like Denzinger and Fuchs [1996] have improved a game-strategy by optimising a set of agents, Genetic Algorithms [Goldberg, 1989] can be used to optimise the quality of the recommendations.

In the field of human computer interaction, Avatars are the current state of the art approach in multi-modal interaction with regard to the user's emotions. In the attempt of Goodman *et al.* [2003], the system integrates an intelligent tutoring agent into the collaborative learning system in the same manner like human students appear in the chat room. By associating graphical interfaces to the agent as described in this paper, a mix of real users and intelligent active system components can represent the next step towards human-like interaction. Although the user can clearly recognize the computer partner in the pictures of the discussants in Goodman *et al.*, the behaviour of the component behind is similar to the behaviour of a human teacher.

4.5 Challenges ahead

Regarding to the general definition of an agent in Section 4, a variety of approaches can be applied to implement user modelling agents. Due to the lack of standards, a clear definition in multi-agent terminology will provide the background for implementing such systems. To provide the opportunity of domain-independent reuse, this definition must not be task-driven by a certain application. As mentioned in Section 4.3, a multi-agent system additionally needs a well-defined environment. Based on the definition of the agents, such architecture needs to be designed and implemented providing cooperation and communication background facilities.

In the next step, the implemented system needs to be connected with domain-dependant external applications. On the one hand, interfaces have to be designed and implemented for gaining data from the application. On the other hand, the agent system needs to have influence on the application in order to adapt its behaviour based on the agents' knowledge. Between the acquisition of data, and the affect to the domain, the data is semantically enriched in several steps, and the gained information is used to control the system behaviour.

To improve the behaviour of each single agent, Case-Based Reasoning technologies could serve as an intelligent approach of an agent's memory. In order to optimise the overall solution, evolutionary algorithms could be implemented for the "survival of the fittest". Based on the examination of (implicit or explicit expressed) user feedback, the representation of the application's users could be optimised.

5 Conclusion

In this paper, we have presented an overview of use of multi-agent methodologies in the fields of information acquisition, eLearning applications, and exhibition guides. Based on the analysis of recent work, we have introduced a general agent definition, and communication and cooperation approaches. After a discussion of advantages and drawback of this approach, fields of practical use and the challenges ahead have been described.

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