

# A User Profile-Based Approach for Adaptable Belief-Desire-Intention Software Agents

Gerd Schneider, Fraunhofer Institute for Information and Data Processing, Fraunhoferstr. 1, 76131 Karlsruhe, Germany; E-mail: gerd.schneider@iitb.fraunhofer.de

## ABSTRACT

An approach is proposed for the development of user profile-based, adaptable Belief-Desire-Intention (BDI) software agents. This proposed approach focuses on the integration of a user profile into the BDI software agent's beliefs and the adaptation of these additional beliefs either by a human user or the BDI software agent. The outcome of this user profile integration and adaptation is a more personalized and user-oriented reasoning process carried out by the BDI software agent and leading to a wider acceptance of software agent technology especially in human-centric fields of application. The realization of this approach is illustrated by applying it to a basic scenario based upon the open source agent framework JADEX (Java Agent DEvelopment eXtension).

## 1. INTRODUCTION

A Belief-Desire-Intention (BDI) software agent has the capability to adapt its desires, intentions and related plans to changing environmental conditions (beliefs), but it lacks the ability to adjust itself to the preferences and needs of an assigned human user. Especially in the case of interaction with a user and execution of tasks on behalf of a user the missing feature for personalization and adaptation states a significant disadvantage as the user cannot individually optimize his software agent. A user may have personal desires, intentions and preferences which he wants to be fulfilled by a BDI software agent under specific environmental conditions. The same is true for plans which are executed while pursuing a specific intention.

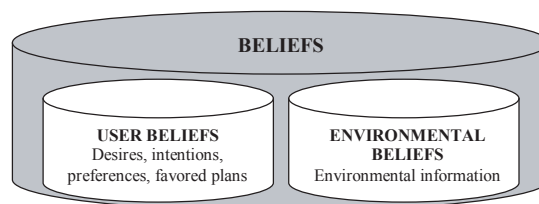
In the following, an approach is proposed to overcome the above-mentioned lack of individual adaptability and personalization of BDI software agents. Section 2 describes the conception of a user profile-based, adaptable BDI software agent and is structured in three subsections describing the basic idea (Section 2.1), the adaptation possibilities (Section 2.2), and the emerging agent architecture (Section 2.3). Section 3 outlines the realization of the proposed approach based upon the open source agent framework JADEX (Java Agent DEvelopment eXtension), while Section 4 presents some conclusions and discusses further work. Finally, in Section 5, the references are listed.

## 2. CONCEPTION OF A USER PROFILE-BASED, ADAPTABLE BELIEF-DESIRE-INTENTION SOFTWARE AGENT

### 2.1. Basic Idea

The integration of a user profile into the BDI software agent's beliefs should fix the above-mentioned lack of individual adaptability and personalization and represents the base for the development of an adaptable BDI software agent. Through the involvement of such user information about desires, intentions, preferences, and favored plans the usual BDI software agent's beliefs get separated into two parts: Environmental information (also called *environmental beliefs*) and user information (also called *user beliefs*), shown in Figure 1. These two components form the entire set of beliefs which – due to the integrated user information – allow an individual influence on the reasoning process of the BDI software agent. Especially the BDI functions *generate options*, *filter*, and *planning* are concerned.

Figure 1. Extended set of beliefs



### 2.2. Adaptation Possibilities

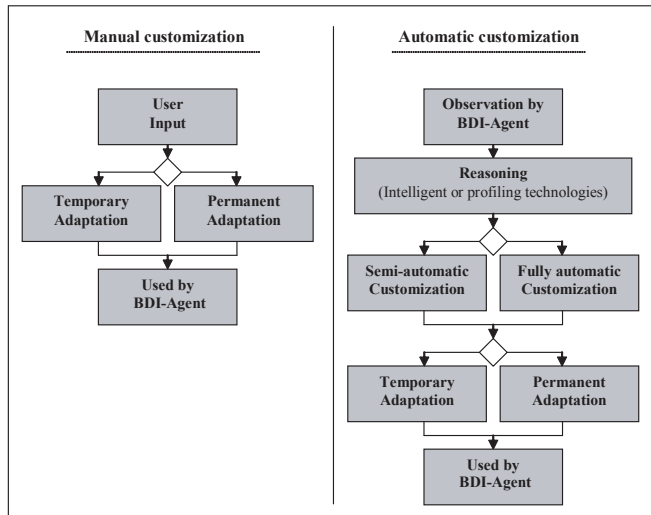
In addition to the integration of a user profile into the beliefs, a second important step towards an adaptable BDI software agent is the customization of this integrated user information. For this purpose, two different ways of user profile adjustment are intended. The first and easiest one is the *manual customization* accomplished by the human user. In contrast to this, the second way to adjust the user profile is an *automatic customization* which will be performed by the BDI software agent. Therefore, the software agent will observe the user's behavior and in case of need it will adjust the user profile, whereas two options of automatic customization should be possible: Either a *semi-automatic customization* at which the human user of the software agent has to confirm the adjustment or a *fully automatic customization* which will be performed autonomously by the software agent (the desired option should be manually adjustable by the human user). To achieve this automatic customization, either additional intelligent technologies (like neural networks or genetic algorithms) or profiling technologies will come into play. Finally, the time limit of a performed customization has to be considered. Either the performed customization refers only to the agent's runtime or beyond it. The first alternative is called *temporary adaptation* and enables the adjustment of the so-called *runtime user profile* located within the BDI software agent's beliefs (see the above introduced user beliefs). The second alternative, called *permanent adaptation*, adjusts the runtime user profile as well as a so-called *persistent user profile* located within a database. The human user gets the possibility to adjust its BDI software agent to one of these alternatives. Figure 2 depicts the sequences of the described adaptation possibilities en bloc.

### 2.3. Agent Architecture

Based upon the basic idea (Section 2.1) and the adaptation possibilities (Section 2.2) the architecture of a user profile-based, adaptable BDI software agent can be introduced. This architecture is subdivided into three layers, whereas the lowest layer represents the *database layer*, the middle layer represents the *application/agent layer*, and the highest layer represents the *presentation layer*. Figure 3 shows this layered architecture.

The presentation layer contains a user interface whereby a human user can interact with the underlying BDI software agent to perform custom-designed tasks relevant for a specific field of application. Additionally, the user interface provides the

Figure 2. Sequences of the adaptation possibilities



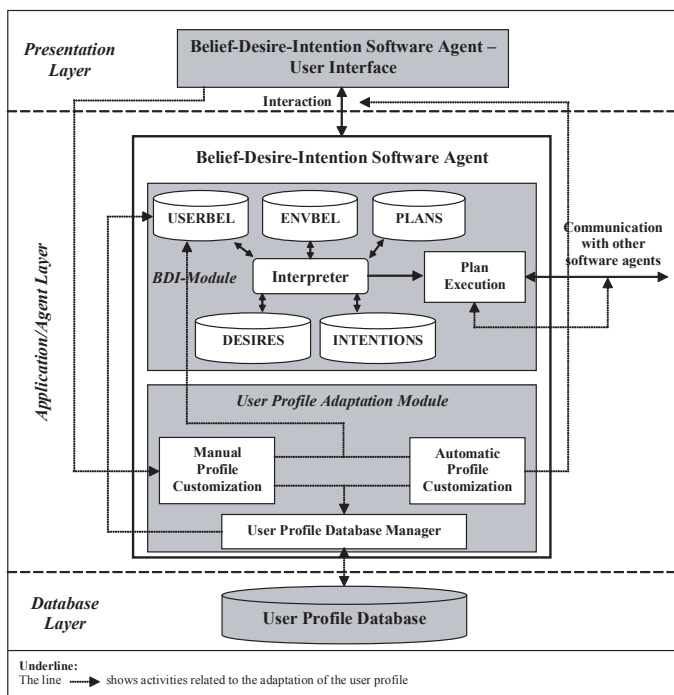
functionality to adjust the user profile (located within the BDI software agent's beliefs) manually. In the middle layer, also called application/agent layer, resides the adaptable BDI software agent composed of a *BDI-Module* and a *User Profile Adaptation Module*. In contrast to the classical BDI architecture, the BDI-Module gains two extensions: First, beliefs get separated into the introduced user profile/user beliefs (*USERBEL*), also known as the runtime user profile (see Section 2.2), and the environmental information/environmental beliefs (*ENVBEL*). Second, the component plan execution gets integrated, representing the execution of plans selected by the interpreter and providing the functionality to communicate with

other software agents. The User Profile Adaptation Module realizes the above-mentioned adaptation possibilities (see Section 2.2) and is separated into two components: The first component is the *Manual Profile Customization*, processing the manual adjustment of the user profile performed by the human user via the user interface. The second component is the *Automatic Profile Customization*, responsible for the automatic adjustment of the user profile and therefore observing the interaction between human user and software agent as well as the plan execution and communication with other agents. The reason for the additional observation of plan execution and communication is that these activities could fail several times, thus requiring the adaptation of the user profile. E.g. a human user prefers a specific plan (specified in the user profile) to be executed by the software agent but the execution fails five times. The software agent observes these failures and provides an alternative plan which leads to an automatic adjustment of the user profile. This additional capability is the reason for the above-mentioned second extension of the BDI-Module concerning the component plan execution. Finally, both described adaptation components provide the functionality to adjust the runtime user profile (*USERBEL*) as well as the persistent user profile which is stored in the User Profile Database located within the database layer. The access to this User Profile Database is controlled by the User Profile Database Manager, responsible for all database operations.

### 3. REALIZATION OF A USER PROFILE-BASED, ADAPTABLE BELIEF-DESIRE-INTENTION SOFTWARE AGENT

Based upon the open source framework JADEX (Java Agent Development eXtension) the basic characteristics of an adaptable BDI software agent are already implemented within the scope of the ongoing research. This includes the integration of a user profile into the agent's beliefs, an incorporation of this additional information into the reasoning process, and a manual and semi-automatic customization of the user profile. Additionally, an exemplary scenario is realized to demonstrate the operability of the adaptable BDI software agent. In this scenario two human users can get in touch with each other by means of assigned adaptable BDI software agents. On the basis of user information the contacted software agent identifies how an approach should be handled to satisfy the desires of its user and may come to an autonomous decision. In case of changed user interests the software agent can get informed and will adjust to this new situation. If changes in the user's behavior are detected autonomously by the software agent and a customization of the user profile appears necessary the software agent may perform this customization by itself which also leads to an adjustment of the agent's reasoning process. E.g. if a callee refuses an approach of a caller several times even though the callee's user profile specifies that an approach of this caller is allowed and welcome, the callee's software agent may adapt the user profile after precise observation. In consequence of this adjustment the next approach of this specific caller may end up in a refusal performed by the callee's software agent without the intervention of the human user.

Figure 3. Architecture of a user profile-based, adaptable BDI software agent



### 4. CONCLUSIONS AND FURTHER WORK

The current development status shows, that the integration of a user profile affects the BDI software agent's reasoning process and enables user-oriented decisions. Thus, this extended BDI software agent can be used to serve a human user in an unobtrusive and personalized way by what this user can be relieved of secondary tasks and gains additional time to concentrate on more relevant topics. However, there are three key aspects defining further research and development. The first one is the realization of a more complex scenario which requires an extensive reasoning process by the adaptable BDI software agent based upon the introduced user profile. This is necessary to demonstrate the robustness of the elaborated approach. Second, the automatic customization of the user profile has to be improved. The idea is to develop a plug-in framework that allows several so called observation modules to plug in, to observe the user's behavior, and to adjust the user profile if necessary. This ought to result in multiple observation modules, interested in different and independent user behavior and able to modify various pieces of information of the integrated user profile. The last key aspect of further research and development is related to the above-mentioned observation modules. Each of these modules should work using either intelligent technologies or specific profiling technologies. For this purpose, an evaluation and integration of adequate intelligent techniques (like neural networks or genetic algorithms) or profiling mechanisms has to be accomplished with particular attention to the kind

of information required by specific observation modules, the user information which can be modified by specific observation modules, and the over-all context of the entire observation modules.

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