User-Control of Personalised Intelligent Environments which Support Health

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Abstract—**This research project aims at supporting workers in the mining and construction industries and older adults at home, in monitoring the risks of their daily work or living situation. A goal is to create awareness in the individual about risks and how to decrease risks. Methods and knowledge-based applications are developed, which synthesise knowledge about the user, the user's activities, the environment and generic domain knowledge for the purpose of providing tailored support and advice to individuals. This knowledge is also what the user can relate to, interact with and control through different methods. In this paper we investigate different approaches to user control of intelligent environments and propose a dialogue-based method for user control.**

Keywords- Knowledge representation, user model, human computer interaction, multi-agent system, argumentation, ubiquitous computing, ambient assisted living

I. Introduction

The following categories of knowledge are needed for an intelligent environment to provide personalised support for activities: knowledge about I) *the user*, II) *the user's activities*, III) *environment*, and IV) *generic domain knowledge*. The knowledge about the user consists of the individual's preferences [11], ability, interests, habits, needs, wishes and social network, etc. The knowledge about the user's current and previous activities deals with *what* is being done, its *purpose* and *how* a particular activity is performed. The third category is environmental knowledge that concerns physical, social and virtual components. To a certain extent all types of knowledge, which the user possesses, can be obtained by a system through *information-seeking dialogues* between the user and the system agent [18]. This method can be supplemented with observations of the user performing activities. The user may describe explicitly their environment and what activity is being done and, while the environment knowledge is obtained by observation of both environment and activity, e.g. by the use of sensors as part of a ubiquitous computing environment [16, 17, 13]. Knowledge about the user, activity and environment is specific to an individual whereas the last category, domain knowledge, is generic, regardless of the user, and is obtained from domain experts such as a health care professional [7].

There is a need for methods for software agents to reason about risks and risky situations, based on combined information obtained from different sources of information in a ubiquitous environment [5, 14]. This is for the purpose of making decisions about what advice to provide the user, or in which ways to adapt the environment to the user's needs. These decisions should be based on the obtained information specific to the user, combined with generic knowledge about hazardous factors in the environment. Moreover, in order to use the intelligent environment for empowering the user, there is also a need for methods to allow the user to maintain the power over the intelligent environment [15], which is the main topic of this paper.

II. Purpose

The main purpose of our work is to develop methods and software tools for the purpose of providing personalised computer-based support for monitoring and maintaining health in home or work situations involving risks. Central to this work is how the user can control their intelligent environment in a satisfactory way in order to maintain autonomy, locus of control, and improve health in work and home environments.

III. Related work

Several attempts have been made to develop adaptive systems [11, 12]. There is a lot of information obtained from an environment from heterogeneous sources; which poses challenges like maintaining privacy, trust, handling conflicts and uncertainty [3, 4]. A flexible system should give the user greater freedom; improve the correspondence between user, task and system characteristics; and increase the user's efficiency and safety [11]. Adaptivity in the form of an adaptive system is based on the assumption that the system is able to adapt itself to the wishes and needs of the user by an evaluation of the user's behaviour [12]. Therefore, adaptivity is implemented by referring actions to action patterns and finally to action plans on which the actions of the person are based. The interpretation of user actions serves to identify user intentions [11]. Thus it is also necessary to identify the activities perceived as purposeful, important and desired by the individual among all activities that can be performed in a home environment [15, 6]. Deducing user intentions from user actions may be done in several ways. For example, having deduced an action plan, the system may initiate a dialogue to identify the user's real intentions. The system presents alternative interpretations, and the user selects the appropriate one. In this way, the current action is checked for specific regularities agreeing with previous action sequences. Where agreements are detected, appropriate subsequent actions will be assumed.

Moreover, this adaptivity should be provided on the basis of conditions defined and regulated by the individual [3].

IV. Methods

A literature study was conducted to investigate previous research related to users' control of intelligent environments.

Domain knowledge is modelled by domain experts using ACKTUS (Activity Centred Modelling of Knowledge and Interaction Tailored to Users), a prototype application for knowledge and interaction modelling in the health domain [10]. The domain experts apply user scenarios where they adapt knowledge to different characteristics by using simple rules. A participatory action design approach has been followed in the modelling of knowledge repositories and interaction design of knowledge-based support applications.

For representing the necessary knowledge to be used in reasoning about tailored support in an intelligent environment, we build upon the ACKTUS ontology, which contains a basic model of the user and activity [8]. ACKTUS is based on models of human occupation [6], the International Classification of Disability, Functioning and Health (ICF) provided by the World Health Organization [19], and other medical terminologies. We take a *persona* and a *case scenario* as starting point for the development of supportive knowledge-based environment for an individual [7]. It is then used to extend the ACKTUS user model, to create the environment ontology and the activity ontology. Activity theory has been used to categorise and interpret activities in order to represent knowledge about recognisable activities [6].

For accomplishing reasoning and dialogue-based support we developed a multi-agent dialogue system (Fig. 1). The design essentially follows the outline in [7] including the following software agents: a Domain Agent (DA), which uses a domain knowledge repository as belief base, and a Coach Agent (CA), which manages the user model by reasoning with other agents about conflicting interpretations of the human activities, and preferences obtained from different sources [9]. It is also the CA's task to protect the user's interests in dialogues with other agents. The multi-agent system uses an implementation of an argumentation inquiry dialogue system [1] for reasoning between agents without the user's participation in the dialogue. These dialogues are then mediated to the user through different tailored applications. However, for the purpose of this work, human-agent dialogues are viewed as a means to provide the user with the control over the system, which is a goal for this work. Therefore, we design and implement a human-agent dialogue system for the purpose.

V. Results and On-going Work

The results includes extension of ACKTUS ontology with environmental and activity information, a prototype system for assessment of environments involving risks due to dust (module in *ArbetsVis*, Fig. 1), an initial design of a multi-agent dialogue system (MAS) and an activity recognition system based on 3D sensors (MUDRA, Fig. 1). A summary of the results will be given in the following sub-sections.

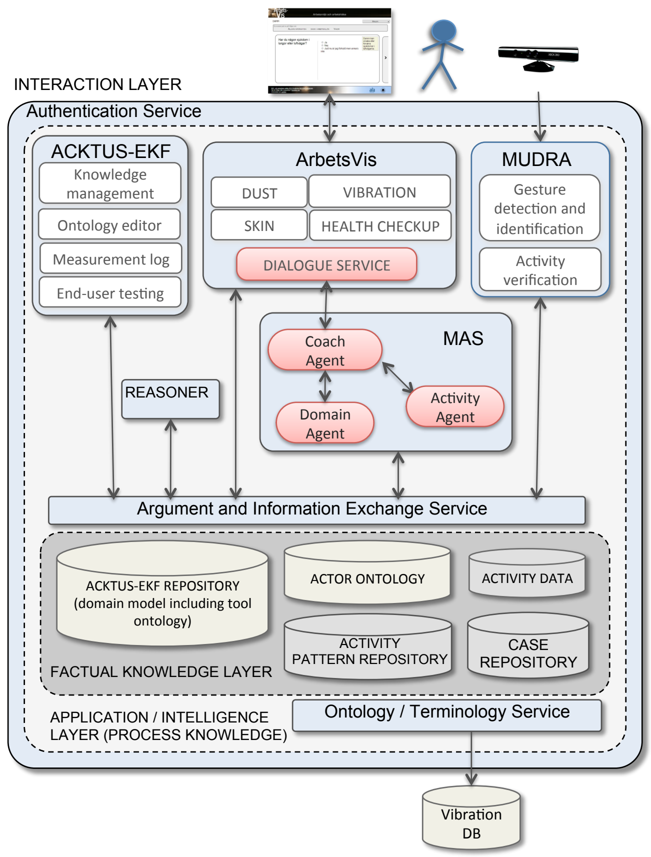

Figure1: Architecture of the intelligent environment including applications.

A. *Extended ontology for structuring knowledge*

The existing ACKTUS ontology has been extended from the ubiquitous computing perspective. Features that relate to a physical home environment (e.g. in terms of *space*) can be captured by the ACKTUS ontology at a generic level using the *building* class. Furthermore, smart objects can be considered as being examples of an *object*, in an activity, fulfilling the property *has_tool* (e.g., *Breakfast* (activity class) has_tool (property) *Cup* (object class)).

B. *Integration of activity and environmental information*

A prototype system for monitoring health in work environments involving hazards due to dust has been developed by experts from the medical domain using ACKTUS as modelling tool. For the system to take into account measures of dust in the environments, ACKTUS was extended with a measurement module, as an additional editor to be used by initially the physicians (Fig. 1). The purpose is to make this module accessible also for environmental health engineers through the ArbetsVis

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application, such that they could use the application for adding and editing dust values. They have the responsibility to control the work environments in the mining and construction industries. This module is the initial step towards automated data collection embedded in work environments. The measurement data, which the module currently contains, are measures not specific to any particular individual, but collected in research studies. However, the data is integrated into algorithms, which generate personalised advice, when synthesised with person-specific data.

The next step in our work is to integrate sensor data from the mining work environment of a particular worker into the system. By feeding more person-specific information into the algorithms we expect that the accuracy of the calculations will increase and, consequently, the system may become even more useful. Moreover, since we take as a starting point selected activities, which the user prioritises as important and which the user wants to have support with, we also need to identify these activities during the course of the user's work and leisure activities. For this purpose, an activity recognition system is being developed, based on 3D sensors.

In the case of monitoring the wellbeing of, for example, an older adult, important activities that the older adult wants to be able to perform in a satisfactory way can be identified and selected in an initial assessment and added into their user profiles. This is accomplished through the dialogue systems, described in the next section. This selection will be used in a training phase of the activity recognition system. In this phase an Activity Agent (AA) collaborates with a 3D camera and sensors to observe and mediate information between the human actor and the system.

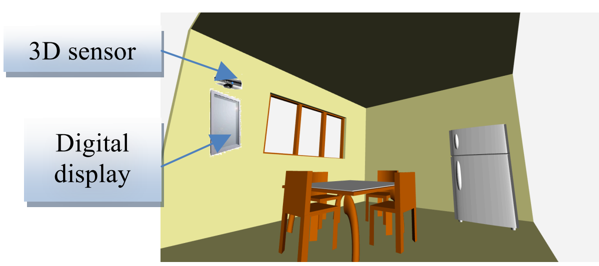

Figure 2: 3D sensor in home environment

A pilot study was conducted to find out if gesture based interaction could be used for social activities such as keeping up with what is happening in society by reading the news, and at the same time having a conversation with a friend about the news through a social network application. Suitable tasks were identified and selected, and an empirical study of subjects was conducted for the purpose of exploring which gestures are most natural for each task. The identified tasks were *select* person to communicate with, *start* and *end* a dialogue. The results of this pilot study form the basis for development of a prototype for our Machine Understandable Decision about Recognisable Activity (MUDRA) system (Fig. 1). The MUDRA system allows an older adult to interact with a digital portrait superimposed on the wall (Fig. 2), using natural hand gestures. MUDRA forms the base for activity recognition and evaluation both in home and work environments.

C. *User control through multi-agent dialogue systems*

The user may control the system by explicitly expressing e.g. preferences, priorities, interests, and adjust these over time. Currently, the user may interact with the system in two ways. The base for interaction is implemented as a set of *information seeking dialogues* as defined in [18], through which the user can inform the system about preferences, priorities, interests, etc. Based on this and environmental information the system provides feedback to the user in the form of: 1) well-founded suggestions about decisions to make, 2) advice (e.g. wearing a mask if the air contains dust including harmful components such as lead), and 3) suggestions of actions to take in order to obtain more knowledge about a situation. The information capture, inferences and responses are built upon knowledge and interaction flows modelled by the domain professionals.

The second way of user interaction is through a multi-agent prototype system, which has been implemented for simulating *inquiry dialogues* as defined in [18] between a user and a system agent [9]. Each agent participating in the dialogue has its own individual belief base consisting of facts and rules. The purpose of this dialogue implementation is to allow the user to propose a claim about a topic and receive an elaborated discussion about the topic, with well-founded arguments in favour and against the claim. For instance, a physician may propose a hypothetical diagnosis, a mining worker may claim that a particular machine is hazardous, or an elderly adult may claim that he or she is at risk for falling in their home environment. The arguments are built and shared using an implementation of the Argument Interchange Format (AIF) [2] combined with an extension of the inquiry dialogue systems introduced in [1]. This dialogue system is being extended to a similar dialogue system, but where the user can also interact with the system agents, proposing supportive and contradictory arguments claim. The initial design of this extension has been created, and the implementation will be finalised shortly. The dialogues between human and software agents aim at providing a natural dialogue with the system. Therefore, the interaction design of the dialogues will be an important issue to explore in future work.

VI. CONCLUSIONS AND FUTURE WORK

The results obtained so far include:

i) Extended ACKTUS ontology with environment and activity information,

ii) A prototype system for assessment of risky environments due to dust,

iii) Initial design of a multi-agent dialogue system, and

iv) Initial design of an activity recognition system based on 3D sensors.

In future work, the ubiquitous environments will be developed, both for the mining industry and home environments of older adults. We will implement and apply the human-agent dialogue system for managing the intelligent environments such that the user is given means to control the intelligent environment. As an integral part of the development, end-users will be involved in the design process and in evaluation studies.

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