Abstract—Cloud computing is envisioned a dominant role in the future. Extensive amount of data are stored, applications running in the cloud, and globally accessible. However, users are not interested in observing and processing that amount of information. Thus, a mentalistic model that represents the user’s goals could be integrated with the cloud to present processed extracts in a cognitively accessible way. Such an approach is presented with deliberative BDI agents both in the general and in a case study for an agent-based personal trainer for COPD patients.

Keywords: BDI agents, cloud computing, integration, PHRs

I. INTRODUCTION

Personal/Electronic Health Records (PHR/EHR) is a perfect example for the use of cloud computing, where the multi-user/multi-role perspective, privacy, security, and accessibility issues are addressed, as both health-care professionals and you personally are involved. Clouds spawned from service-oriented architectures and semantic web services, which has approaches trying to abstract and increase flexibility of services, such as WSDL and OWL ontology. However, the composition of services must still rise from a set of basic action by the user [1]. For PHRs the heterogeneous set of users and the complexity requires medical information to be presented in a cognitively accessible way [2]. We propose a deliberative agent model based on the BDI architecture to bridge cloud-based services (SaaS) and pervasive services to the user. The model is applied in a case study for a home training of COPD patients.

II. AGENTS TO THE CLOUD

A. Limitations of a service based model

Traditionally, web services were defined as software systems designed to support interoperable machine-to-machine interaction over a network [3]. Even with semantic descriptions of the services (OWL-S), a service based model does not overcome the limitations in how users naturally will express the goals they want to achieve rather than the actions they wish to be performed [1]. Thus, several key aspects are important if user-centered cloud apps should provide intelligent services.

- **Locus of control** – design of applications must be user-centered and reflect the user’s assessment of goals to be achieved.
- **Cognition** – pervasive applications should not rely on the user interaction in respect to current goals.
- **Adaptation** – information resources often reside in many systems (clouds) and needs to be combined either to be relevant or make sense for users.
- **Context** – environments are highly dynamic due to users’ mobility and global accessibility.

B. Capabilities of deliberative agents

Semantic web services is built on the basis of synchronous remote procedure calls and has been preferred by industry over more abstract definitions and less strict approaches for agent technologies, which comes from asynchronous message passing architectures [1]. However, the goal-oriented agents have a lot more to offer than services founded in basic actions. From a modeling perspective the autonomous characteristic of agents and the architecture for deliberative agents, e.g. the BDI model, has a more natural mapping to a user-centered design. The BDI model has a very “mentalistic’ notion for capturing user’s preferences and goals [4], whereas services mostly are designed as information providers that needs further (mental) processing.

Goal-directed behaviors are the nature of deliberative agents, and goals can be abstractly described. Reasoning on percepts and other inputs is required, if user acceptance should be improved. Interoperability is central to web services, but despite profile specifications and dynamic service discoveries, web services are still relying on common standards. The agent community builds on knowledge representation and ontologies to abstractly describe content of messages, which improves the possibilities of adaptation across different systems.

III. THE AGENT MODEL

Deliberative agents extend the basic agents model given by Jennings and Woolridge [5] with knowledge representation and symbolic reasoning capabilities [6]. The locus of control is captured in terms of the autonomous characteristic of agents. A reasoning engine covers the need for cognition. Adaptation and context-awareness is well aligned with reactive and proactive behaviors of agents and their responsiveness in general. The BDI model by Rao and Georgeff [7] is the most applied architecture for deliberative agents. The scope of the demo and the presented model is to cover use of cloud computing as an information source. The operational logic of BDI agents was formalized by Rao with the AgentSpeak(L) language [8]. The BDI agent is given the tuple \( \langle B, D, J, \Pi \rangle \). Where \( B \) is the belief base, \( D \) is the desire base, \( J \) the intention base, and \( \Pi \) is the set of selection functions and plans, which are defined as practical rules in the form \( \phi \leftarrow \varepsilon \pi, \phi \) is the goal, \( \pi \) the concrete plan of action that should lead to the goal, and \( \varepsilon \) the event that triggers the selection function. The agent-cloud communication is covered by the social capabilities. Agents would either reactively observe changes in the cloud or proactively request or query the cloud. It corresponds to subscribe, request, and query FIPA protocols. The triggering events for a state change will
come from inform messages, that will trigger the selection function on the belief base, which formally is given by

$$S_b((B,D,J,I)) = \langle \text{inform, id, at} \rangle$$

$$\langle B,D,J \rightarrow (B_u(at),D,I) \rangle$$

(1)

Where id is the identifier of the agent and at is the predicates expressed in first order logic, as explained in [8]. In the deliberation engine of the agent it will consider the desire base if there are relevant plans that should be added to the intention base, and such a plan would be considered applicable if a unifier \( \theta \) exists for the plan, so the plan is a logical consequence of the current belief base with respect to the event. Formally, we can describe it as an update to the intention base of the agent.

$$\langle \varphi,C \rangle \in D, \text{impact}(\beta, \varphi, \text{start}), B = C, \theta \models \varphi \theta$$

$$\langle B,D,J \rightarrow (B_u(\theta),D,I(\{ \varphi \theta, C, \pi \})) \rangle$$

(2)

where \( C \) is the commitment of the belief base, and \( \text{impact}(\beta, \varphi, \text{start}) \) is evaluation of a change in belief base, \( \beta \), that will lead to the desire of the plan \( \varphi \) being followed.

IV. A CASE STUDY

Healthcare systems are quite different around the world, especially between Europe and the US, but the need to store health related information and PHRs are universal. An overview of the system for the case study is presented in Fig. 1.

![Figure 1: Overview of healthcare system with PHRs in the clouds](image)

It is commonly known that the share of elders will double due to demographics changes and costs of healthcare services will explode. In particular expenses to chronic diseases, such as chronic obstructive pulmonary disease (COPD/COLD), diabetes, cardiovascular disorder and Alzheimer’s. There were 726,000 hospitalizations for COPD in the US in 2000, and the cost of COPD is $32.1 billion [9]. Especially, for COPD patients can benefit from training. Due to breathing trouble they do not only get anxious while exercising, but also fear walking the neighbor (even if capable), which lead to social exclusion. Ideally, exercise training would be individual, customized, assisted, and supervised by physiotherapists. Unfortunately, such training sessions are only provided to a very few patient. Recent year of advancement in sensor technologies enables opportunities for monitoring training at home.

A. Our approach

COPD patients are no different than the rest of us – it is very hard to keep up the motivation for physical exercising, unless someone constantly motives you or the results/effects are very visual. Thus, we need a responsive and proactive feedback that can motivate to keep up the training. Not all COPD patients are capable of walking outside, so exercises at home are required for many patients. Exercise programs are provided by physiotherapists, and we are developing a prototype based on the Kinect camera that can verify exercises and stream data to a PHR Google Health account. Integration with Google Health is rather simple, as it is part of the Google Data Protocol. The API for the Kinect camera allows you to analyze the joint angles of the body so it can be compared to an exercise program. Fig. 4 shows the Kinect’s view of joints in the body.

![Figure 2: Kinect view of a body](image)

From the professional healthcare system the medical records and diagnose data of COPD is registered in the personal health records. However, as training programs are not directly supported in the Google Health the agent must reason on the extracted information and compare it to exercise plans in the desire base of the agent. The agent will update the belief base based on inputs that are received from the cloud according to (1). If the evaluation of the change in the belief base, enables a new plan to be followed it will be added to the intention base of the agent according to (2). The applicable plan will contain tasks to update the UI and feedback to the user. The prototype uses text-to-speech for an audio feedback, and we experiment with mimic software to create an avatar video. A snapshot of the avatar is shown in Fig. 5.

![Figure 3: Avatar](image)

V. CONCLUSION

We have presented a BDI-based agent model to close the bridge between cloud computing and user-centered applications that aim to present rich and complex information from clouds in a cognitively accessibly visualization to the end-users. A prototype system is built for home training of COPD patients using extracts of information from the cloud to give motivational user feedback, so they continue training.

REFERENCES


