CONTEXT-AWARE AGENTS
The 6Ws Architecture

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Abstract: Software agents have been designed and implemented to function within limited context-aware capabilities. For an agent to function correctly and efficiently it should contain sufficient knowledge and reasoning resources enabling them to process large quantities of implicit information conveyed through an explicit description. Presented in this position paper is an introduction of the 6Ws agent-based architecture which encompasses key reasoning capabilities which are not adequately supported by existing BDI frameworks but have been recognized as highly relevant for the development of Ambient Intelligent systems.

1 INTRODUCTION

Ambient Intelligence, AmI, refers to '*a digital environment that proactively, but sensibly, supports people in their daily lives'* (Augusto 2007). Other terms such as Ubiquitous Computing (Weiser, 1991) or Smart Environments (Cook and Das, 2005) are used with similar connotations. Supporting people in their daily lives means, for example, making an environment safer, more comfortable and more energy efficient.

What all these areas have in common is that they are intended to operate in a specific environment. Examples of such environments are homes, classrooms, cars, offices. For these systems to be truly 'smart' they need to perceive the interaction with the end users and need to know as much as possible about the environment itself (objects, user preferences, latest changes, etc).

Software agents are well established as one of the key enablers in delivering intelligent systems. These agent based architectures have been successful in delivering general purpose intelligent systems, however the complexity of the environments in AmI requires a more precise focus, such as the capability to naturally specify context-awareness features. Different concepts have gained recognized relevance in building AmI systems:

Who: the identification of a user and the role that user plays within the system.

Where: the tracking of the location where a user or an object is geographically located at each moment during the system operation.

When: the association of activities with time is fundamental to build a realistic picture of a system's dynamic.

What: the recognition of activities and tasks users are performing is fundamental in order to provide appropriate help if required. The multiplicity of possible scenarios that can follow an action makes this very difficult. Spatial and temporal awareness help to achieve task awareness.

Why: the capability to infer and understand intentions and goals behind activities is one of the hardest challenges in the area but with no doubt a fundamental one which allows the system to anticipate needs and serve users in a sensible way.

hoW: the alternative ways to achieve things in the given environment. An architecture which supports the previous five concepts will in turn provide the hoW with sufficient supporting information to make the correct decisions in a timely manner.

Some of the required features as outlined above may ultimately at present be obtained through complicated, ad-hoc programming or through a

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collection of technologies but developers in the area, and ultimately users through higher quality products, will benefit of having a specialized context-aware developing framework.

The purpose of this paper is to propose an architecture which relates to the current state of the art and highlights the importance of concepts which are fundamental for the facilitation of Ambient Intelligence in Smart Environments.

2 AGENTS: CURRENT STATE OF THE ART

The software agent-based paradigm is considered highly suitable for constructing modular software systems capable of operating in dynamic, unpredictable environments (Koch, 2004). They provide an established framework for analysing, specifying, and implementing complex software systems and can act as intelligent aids to users in delivering advanced pervasive services. Agents possess adept decision-making capabilities which make them ideal for operating within dynamic distributed networks.

In the context of software engineering, an agent can be defined as: “An entity within a computer system environment that is capable of flexible, autonomous actions with the aim of complying with its design objectives”.

Within a context-aware environment the dynamic interaction between objects need to be fully supported by intelligent software architectures. Such environments generate vast arrays of implicit and explicit information. An effective software architecture will maximize this data source to deliver the required services in a timely manner. In essence the agent paradigm may be seen to anticipate the needs of user and act on their behalf.

The agent paradigm has been applied to a number of rich context-aware environments including: as part of a real-time healthcare decision support system in the deployment of an ambulance services, (O’Donoghue, 2005) in the collection, correlation and dissemination of real-time body area network (BAN) sensor readings.

The agent paradigm has promised a great deal and has delivered in certain aspects. A large selection of software agent architectures have been developed with a number of inherent design philosophies with BDI (Beliefs, Desires and Intentions) asserting itself and morphing as the de facto approach.

With the BDI model Beliefs represent the informational state of the agent, Desires represent it’s motivational state i.e. it’s overall objective and Intentions represent the deliberative state of the agent, what the agent has chosen to execute.

In comparison AgentSpeak(L) (Rao, 1996) is based on a strong theoretical foundation of logic programming enabling it to explicitly define the role of a particular agent in a declarative way. One of the best recognised implementations of an AgentSpeak(L) related agent architecture is a Java interpreter called *Jason.* The interpreter was developed to help integrate it within a variety of applications. From a developers perspective the AgentSpeack(L) provides an advantage over JadeX in that it enables the designers to pay greater attention to the overall AmI aspects without having to sacrifice overall flow of reasoning in allowing for the amalgamation of external components.

The Belief Desire Intention (BDI) software model is an abstract designed primarily for software agents. It is capable of separating the activity of selecting a plan from the execution of a selected plan. The BDI model has its limitations and is not ideally suited for certain types of behaviour. *“There is a need for agent systems that can scale to real world applications, yet retain the clean semantic underpinning of more formal agent frameworks”* (Morley et al., 2004). In relation to ambient intelligence and spatial and temporal reasoning BDI models do have their limitations, for example with BDI one can equate “Desires”-to-“What” and “Intentions”-to-“Why” (c.f. figure 1).

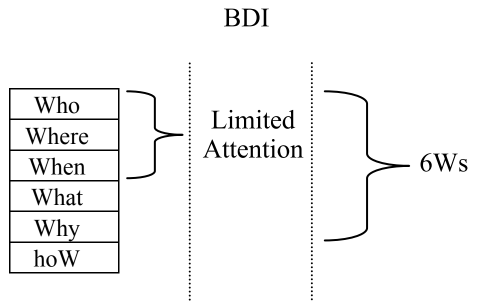

Figure 1: BDI vis-a-vis 6Ws Scope.

Although the “hoW” element is not highlighted in the BDI philosophy, it is usually present in the way of a plan base available to the agent. However the “Who”, “Where” and “When” elements are not so faithfully represented in a BDI based architecture, still they are essential elements in ambient intelligent systems.

For any software agent architecture to fulfil its true potential it needs to have the capability to relate or understand its real world environment. One such approach is known as the Semantic Web. The semantic web may be viewed as a web of information which is structured and linked up in such a way enabling other applications view and understand that data i.e. providing a foundation for agents to communicate and understand one another.

3 ENVIRONMENTS WHICH DEMAND CONTEXT-AWARENESS

Probably the most well known of such an environment is a "Smart Home". By Smart Home here, we understand a house equipped to bring advanced services to its users. There is a plethora of sensing/acting technology, ranging from those that stand alone (e.g., smoke or movement detectors), to those fitted within other objects (e.g., a microwave or a bed), to those that can be worn (e.g., shirts that monitor heart beat). For example, in the case of people at early stages of senile dementia (the most frequent case being elderly people suffering from Alzheimer's disease) the system can be tailored to minimize risks and ensure appropriate care at critical times by monitoring activities, diagnosing interesting situations and advising the carer. There are already many ongoing academic research projects with well established Smart Homes research labs in this area, for example Domus (Pigot et al., 2002), iDorm (Callaghan et al., 2001) MavHome (Cook, 2006), and Gator Tech Smart Home (Helal , 2005).

4 THE 6WS CONCEPT

This section focuses on the initial work to design and develop a 6W agent based architecture to help recognise and integrate all 6 aspects (Who, Where, What, When, Why and hoW) which are relevant for the implementation of AmI. At a logical level, a representation of the 6Ws architecture is compared against the BDI model c.f. figure 2.

Whilst "context" has been defined in many ways several years of research in Ambient Intelligence have highlighted the importance of certain elements in the success of building systems within this area. A consensus in this area is that systems with Ambient Intelligence should be built as human-centric, systems should serve humans and not vice-versa. Systems should be able to learn about the *needs* and *preferences* (compare "the user need to increase insulin intake to keep glucose at the right level" with "I prefer to minimize the number of insulin intakes") of the users they are supposed to serve and, if necessary and feasible, hold updated profiles of them to ensure they can accomplish their service in the best possible way.

1	Who	Profile (including Needs/Preferences)	**B**eliefs
2	Where	Spatial conditions	
3	When	Temporal conditions	
4	Why	General aims	**D**esires
5	What	Specific goals	**I**ntentions
6	hoW	Selection of plans	

Figure 2: The 6Ws attention to key ambient intelligent elements i.e. profile, situation and temporal. c.f. figure 3 in relation to the AgentSpeak(L) semantic model.

The rationale for the inclusion of the *Who* component is that an important part of the meaningful context the agent should know is the needs and preferences of the potential users. Fig. 3 provides a depiction on our modified AgentSpeak(L) architecture. [1] highlights the *Who* component (which emphasise the user-centred characted of the system) as an important component of the Belief Base, [2] and [3] embeds the *Where* (spatial conditions) and *When* (temporal conditions) elements within the meaningful events which can describe triggering situations, [4] includes the *Why* dimension which highlights the desires of the agent (this includes paying attention to the needs and preferences related to users as specified in the Who dimension), [5] highlighting the *What* component through the specification of intentions, and [6] refers to the *hoW* component as the plans represent the ways the agent can achieve the goals.

5 CONCLUSIONS

Presented is the concept of developing an agent based context-aware architecture with 6 elements which are key to the development of Ambient Intelligence system with a rational for the *Who, Where, When, What, Why and hoW* elements. As an initial step the 6Ws approach was compared against the well established BDI model. We have highlighted that the BDI model still contains a number of weaknesses as a framework for AmI e.g. user-centeredness, spatial and temporal reasoning which are within Ambient Intelligence systems.

Our proposed framework although following a route closer to AgentSpeak for the implementation

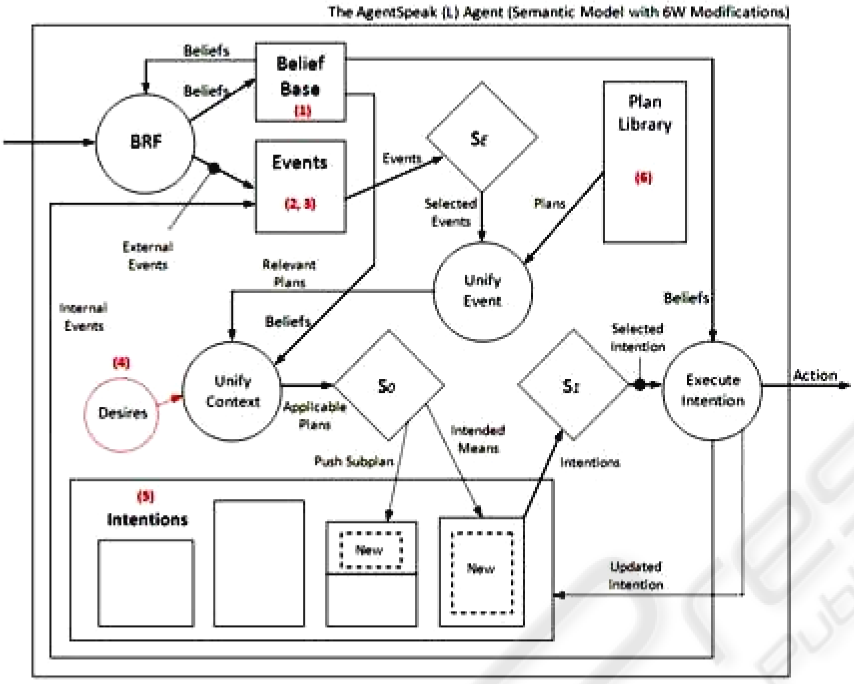

Figure 3: The AgentSpeak(L) semantic model with the 6Ws modifications to include key AmI elements.

of this architecture the idea is actually independent of the final implementation of choice currently under development. We are currently given further steps directed to have an implemented framework which supports the 6Ws extended BDI architecture.

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