INTELLIGENT MONITORING OF ELDERLY PEOPLE

A. Tablado, A. Illarramendi, J. Bermúdez, A. Goñi
Department of LSI. University of the Basque Country. Donostia, Spain

Abstract-**The aim of this article is to present our proposal for an intelligent monitoring of elderly people based on: the agent technology, a decision support system implemented using a description logic based system and Personal Digital Assistants (PDAs). Agents technology allows us to customize the monitoring service and to distribute the global functionality of the system among several agents. We use the DAML+OIL description logic based system to describe an ontology that categorizes different anomalous situations. The reasoning mechanism provided by that system permits the detection of anomalous situations for many different user conditions. Finally, the use of PDAs allows us to offer an anywhere and anytime monitoring.**
***Keywords* - Agents, Description Logics, PDAs**

I. INTRODUCTION

Many recent surveys agree with the following statement: "the population of the first world is getting older". This situation is similar on both sides of the Atlantic and the fate of these countries is conditioned by their ability to deal with this increasing number of elderly people. Traditional Social Services in these countries could well be overwhelmed within 30 years. Another important issue is that elderly people are becoming more independent. As medical science advances, people can live with better health and alone up to a very advanced age. Therefore, to let elderly people live in their own homes leading their normal life, while, at the same time taking care of them requires new kinds of systems.
Concerning related works, we would classify them in two major groups. In the first group we include those systems that provide limited coverage, such as existing tele-alarms. The main features of those systems are the following: they use wired phone communications to contact Social Services, their coverage is restricted usually to the user's home and their activation is triggered by the user, generally using a button. Therefore, they do not support *anywhere* and *anytime* assistance.
In the second group we include more advanced systems. The coverage provided by these systems is broader, they use PDAs and take advantage of wireless communications. They provide *anywhere* and *anytime* assistance, but they are not *reactive*. PDAs are used as intermediary elements and their goal is merely reduced to transmit data to a central computer where data analysis is made. They do not take advantage of the power of the PDAs to carry out some computation before sending data to the central computer. Notice that wireless communications are slow, expensive and weak so, analysis made in the PDA can save costs and can detect anomalies earlier. Examples in this group are Sensatex [1], SILC [2], TeleMediCare [3] or doc@HOME [4].

Our proposal goes one step further by providing not only *anywhere* and *anytime* assistance using wireless communications, but also a high quality assistance, mainly due to the use of agents located at the PDAs. Agents that take part of our system are specialized in different tasks (e.g. vital constants check) and their behavior can be *reactive* when necessary. So, in our system, agents called Conditions Checkers reside, that take decisions according to the users conditions. To accomplish their goal, those agents make use of an ontology that categorize different alerts. This ontology is represented using DAML+OIL [5], a conceptual modeling language founded on Description Logics [6]. The main advantage underlying Description Logic based systems is that there is a benefit to be gained when languages for talking about classes and properties resources[1] yield structured objects that can be reasoned with. There are other systems that also promote applying agents in Health Care [7,8,9,10]. However, as far as we know, they are still in their initial development and they do not put a special emphasis in combining the agent technology with the use of PDAs.
In the rest of this paper we present a general description of our system by introducing a motivating example that illustrates the behavior of the system.

II. OPERATIONAL BEHAVIOR OF THE SYSTEM

A motivating example: suppose that the user is a 76 years old man with a Parkinson's disease, who also suffers from convulsions. His doctor has prescribed him the use of our system to monitor his shakes in order to detect hard convulsions, differentiating them from shakes usually associated to the Parkinson disease. To achieve a correct monitoring, the user wears an accelerometer in a wrist. This sensor checks every movement done by the user and transmits the data to the PDA using Bluetooth.

A. Agents: which and where

Here we explain which agents are related to this example and where they live. But, first of all we want to clarify that we assume a distributed architecture which main components are: the PDA of the user, the Care Centers whose goal is providing swift attention to the users, and, the Health Centers that take care of the health of the users and provide medical assistance to them. We also assume that there are more Care

[1] A resource may be any real object or entity imaginable, which is perfectly identified, and which is described by asserting specific properties about it.

0-7803-7667-6/03/ $17.00

Centers than Health Centers. Figure 1 depicts the distribution.

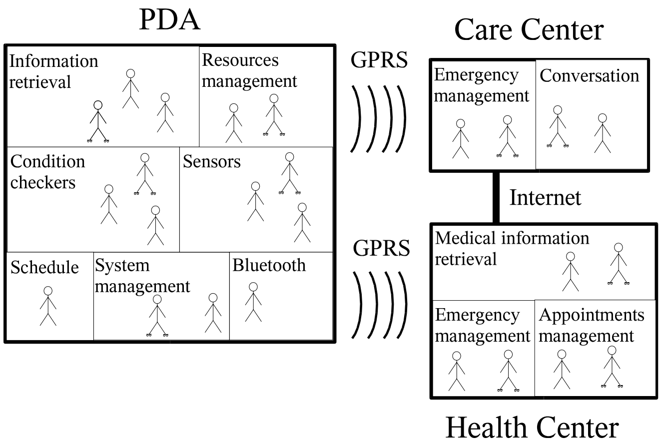

Figure 1: Agents and agencies in our system.

In each component, there are not only agents but also there are agencies: contexts that allow the execution of agents and that provide them with some system resources. In figure 2 the distribution of agents and agencies appears.

In the user agency, located at the PDA of the user, the Bluetooth agent, the Shakes Sensor agent and the Conditions Checker agent reside. The Bluetooth agent can retrieve data from the accelerometer sensor using wireless communications. These data are requested by the Shakes Sensor agent, which presents the information to other agents. One of these agents is the Conditions Checker agent, which has requested to Shakes Sensor agent to be informed when the measured values exceed a predefined threshold. This agency also houses the Localization agent (which informs about where the user is), the Majordomo agent (responsible for interacting with the user) and the Information agent (which registers some info about the user, i.e. his contact information, and about the system, i.e. the associated Health Center and Care Center). The Alerts Receptor agent resides in the Care Center Agency, which is responsible for receiving alerts from other agents and dispatching them accordingly to its configuration. Finally, the Health Center agency houses the Emergency management agent, which responses to emergencies requested by other agents.

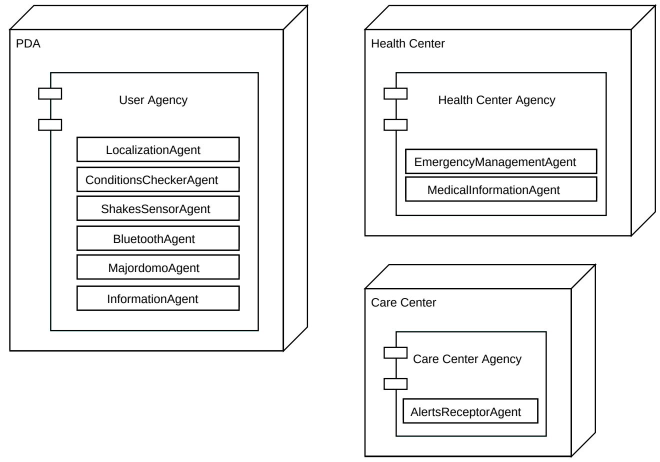

Figure 2: Distribution of agents and agencies.

B. Configuration

Before the user leaves the Health Center, the user agency is configured. A customized Conditions Checker agent is installed in the user agency with instructions for monitoring user shakes. The specialist has customized the agent to check for shakes greater than 30 m/s^2 and has annotated that the user suffers a Parkinson's disease, so he does frequent mild shakes[2].

The Conditions Checker agent interrogates the Information agent to find out from the specialist agent that sources the data regarding shakes. It retrieves the ID of that agent, the Shakes Sensor agent, located at Sensors place, and subscribes to it by sending a message. This message contains the threshold that the Conditions Checker agent is interested in. The Shakes Sensor agent sends back an agree message, telling that the subscription has been accepted. The Conditions Checker agent also requests to the Shakes Sensor agent that reads data from the accelerometer every ten seconds. The Shakes Sensor agent also has to contact with the sensor that provides data about shakes. It knows that the sensor transmits data using Bluetooth, so it carries out a search in the agency to locate the Bluetooth agent. When the Shakes Sensor agent knows the Bluetooth agent's ID, it is ready to request data.

C. Operation

One day, the user is walking down the street and suffers a severe shake and falls. In its continuous monitoring, the Shakes Sensor agent queries the sensor about shakes suffered, finding a shake of 43 m/s^2. When this value is read, the Shakes Sensor agent goes through its list of subscriber, searching for an agent interested in this episode.

In our example, the Conditions Checker is suitable to be notified of the episode, so the Shakes Sensor agent sends a

[2] This configuration is for testing purposes only. In real life, the threshold values would be selected according to well-proven values.

message to it according to the FIPA Subscribe Interaction Protocol [11].

The message from Shakes Sensor agent alerts Conditions Checker agent, which in the presence of this anomalous situation, requests an intensive monitoring: the shakes must be examined every second over the next minute. To accomplish this task, the Condition Checker agent requests to Shakes Sensor agent to do the monitoring every second and to be informed about every datum measured. If a datum received from the Shakes Sensor agent is below the threshold, the Conditions Checker agent returns to its normal status, requesting to the Shakes Sensor agent to do the monitoring interval every ten seconds again and canceling the every second notification. In the case of all measurements being greater than the limit (30 m/s^2), an ontology event is triggered. This event forces Conditions Checker agent to assert one statement (all values greater than 30) -representing those measures-underlying the ontology[3] and to check if an alert must be propagated. The reasoning system infers that the alert must be fired.

D. Reasoning

Let us present an example of the reasoning power provided by a Description Logic system. Assume a conceptualization as shown in Figures 3 and 4, describing different kind of illnesses and their relationships. Assume there are also two symptoms -Symptom1 and Symptom2- whose conceptualization -accorded by the ontology designers- classify them as subsumes of IllnessB and IllnessA2, respectively (i.e., it is admitted by ontology designers that if Symptom1 is recognized about a person, then that person suffers from IllnessB, and analogously for Symptom2 and IllnessA2). In addition, it is described as an Alert when a person suffers from IllnessB1 and Symptom1. Now, we assume the Conditions Checker agent recognizes that a person suffers from Symptom1 and Symptom2. Then, the reasoning mechanism will infer that it is an Alert. The reasoning process works this way: Symptom1 implies that the person suffers from IllnessB, although it is uncertain the specific subclass -IllnessB1 or IllnessB2-; On the other hand, Symptom2 implies IllnessA2. Moreover, IllnessA1 is discarded due to the specification of the concept IllnessA as the pairwise disjoint union of the concepts IllnessA1, IllnessA2 and IllnessA3. Then, IllnessB2 -being subclass of IllnessA1- must be also discarded; and finally it is inferred that such IllnessB must specifically be an IllnessB1 and, consequently, there is an Alert.

```
class-def IllnessA
class-def IllnessA1
   subclass-of IllnessA
class-def IllnessA2
   subclass-of IllnessA
class-def IllnessA3
   subclass-of IllnessA
disjoint-covered IllnessA
   by IllnessA1 IllnessA2 IllnessA3
class-def IllnessB
class-def IllnessB1
   subclass-of IllnessB
class-def IllnessB2
   subclass-of IllnessB IllnessA1
disjoint-covered B
   by IllnessB1 IllnessB2
class-def Symptom1
   subclass-of IllnessB
class-def Symptom2
   subclass-of IllnessA2
class-def Alert
   subclass-of Symptom1 IllnessB1
```

Figure 3: Ontology showing the inference capabilities.

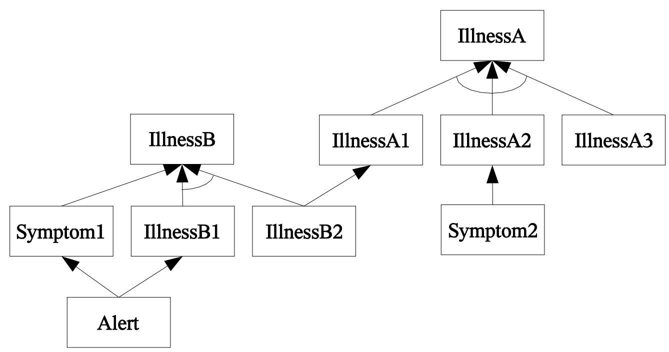

Figure 4: Graphical representation of the ontology.

E. Notification

Now that the Conditions Checker agent knows that an alert must be notified, it sends a message to the Alerts Receptor agent of the Care Center assigned to the user. To find out the ID of the agent, the Conditions Checker agent contacts the Information agent and gets the desired ID. The message sent to Alerts Receptor agent is a request to manage the alert, and the Alerts Receptor agent replies with an agree message if it can or with a refuse message if cannot. In our case, the Alerts Receptor agent can deal with the alert. It examines the alert, retrieve where the user is located contacting with the Localization agent of the user agency, and pass this information to other agents. At the same time, the Conditions Checker agent sends a report of the incident to the Health Center, to be archived in the user's medical records. As the Medical information agent located at the Health Center agency understands HL7, the Conditions Checker agent

[3] There is an ontology in each PDA, called alert ontology, built up by a specialist, that describes the alerts that must be checked for each user.

sends the report formatted in this language[4]. Figure 5 shows an example of a Patient Problem HL7 message, which is composed of various segments.
The Message Header segment (MSH) describes the message, including the sender, the receiver, the subject and a message ID. The Patient Identification segment (PID) identifies the user whose data is being transferred and the Problem Detail segment (PRB) explains, in greater detail, the problem detected. Finally, the Observation/Result segment (OBX) carries some data; in this message, the acceleration of the several shakes that have triggered the alert being transmitted.

```
MSH|^~\&|AG_CONST_VIT|
SHAKES_SENSOR|AG_EMERGENCY|
200229091030|
|ORU^R01|CVP001|P|2.3.1<cr>
PID|1||11234234-N|
|RODRIGUEZ^JUAN|JIMENEZ|
|M|||||943565656
<cr>
PRB|AD|200229091028|SEVERE CONVULSION|
Conv00001|||200229091028
<cr>
OBX|1|ST|8462-4^SHAKE
ACCELERATION:^LN||43|m/s2|0-
30|HH|||F<cr>
OBX|2|ST|8462-4^SHAKE
ACCELERATION:^LN||45|m/s2|0-
30|HH|||F<cr>
OBX|3|ST|8462-4^SHAKE
ACCELERATION:^LN||42|m/s2|0-
30|HH|||F<cr>
...
OBX|60|ST|8462-4^SHAKE
ACCELERATION:^LN||44|m/s2|0-
30|HH|||F<cr>
```

Figure 5: HL7 message.

When all steps of the notification are performed, the Conditions Checker agent waits for the stabilization of the user (i.e. returning to normal shakes). When this normal situation is reached, the life cycle of the Conditions Checker agent starts again.

III. CONCLUSIONS

We have shown in this paper, by means of an example, our proposal for an intelligent monitoring of elderly people. The main features of this proposal are:

- Detection of anomalies in many different situations. The use of a Description Logic based system to describe the ontology of alerts permits the reasoning with the objects described in the ontology.
- Immediate detection of anomalies. Exploiting the execution power of PDAs we can detect the anomalies locally and as soon as they are generated.
- Anywhere and anytime monitoring. Portable devices like the PDAs favor freedom of movement to the users while being monitored at the same time
- Customized. The autonomy feature provided by agents permits that each agent be responsible for a specific task and control its reactions independently of others.
- Use of standards (RDF, HL7, FIPA). The proposal is compatible with other solutions described for the considered problem.

Our current prototype runs in an IPAQ 3870 PDA and is being implemented by using the JADE agent platform, based on the Java programming language.

REFERENCES

[1] Sensatex. http://www.sensatex.com/
[2] Supporting Independently Living Citizens. http://www.fortec.tuwien.ac.at/silcweb/SILC.htm/
[3] Telemedicare. http://www.telemedicare.net/
[4] doc@HOME. http://www.docobo.com/
[5] DAML website. http://www.daml.org/
[6] Description Logics Homepage. http://dl.kr.org/
[7] Antonio Moreno and David Isern. Offering agent-based medical services within the AgentCities project. In 15th European Conference on Artificial Intelligence, 22 July 2002.
[8] Haralambos Mouratidis, Gordon Manson, Paolo Giorgini and Ian Philp. Modelling an agent-based integrated health and social care information system for older people. In 15th European Conference on Artificial Intelligence, 22 July 2002.
[9] Luis M. Camarinha-Matos and Hamideh Afsarmanesh. Virtual Communities and Elderly Support. Advances in Automation, Multimedia and Video Systems, and Modern Computer Science, pages 279-284, September 2001.
[10] Susan L. Mabry, Steven J. Kollmansberger, Timothy Etters, and Kent L. Jones. IM-Agents for patient monitoring and diagnostics. . In 15th European Conference on Artificial Intelligence, 22 July 2002.
[11] Foundation for Intelligent Physical Agents. http://www.fipa.org/
[12] Health Level Seven. http://www.hl7.org/
[13] Resource Description Framework (RDF) Model and Syntax Specification. http://www.w3c.org/TR/REC-rdf-syntax

[4] For content specification, we use RDF [12], a recommendation for knowledge exchange, and, for the clinical data transmission, we adopt the HL7 standard [13].