MAGPIE: An Agent Platform for the Development of Mobile Applications for Pervasive Healthcare

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Abstract. In this paper we present the Mobile computing with AGents and Publish subscribe for Intelligent pervasive hEalthcare (MAGPIE) platform. MAGPIE is an agent platform designed for the Android OS. The aim of the platform is to simplify the definition of Personal Health Systems (PHSs) to monitor chronic diseases. The agents running in the platform use a symbolic reasoning approach to formalize the events happening to the patient. We show the formalization of this reasoning for the particular case of monitoring Gestational Diabetes Mellitus (GDM).

1 INTRODUCTION

The new advances in medicine are contributing to an increase of life expectancy, which in turn increases the healthcare costs due to a major prevalence of age-related chronic diseases. Pervasive Healthcare [1] is a scientific discipline that tries to mitigate these issues by defining Personal Health Systems (PHSs). These systems shift the paradigm of healthcare services, by moving them from a centralized approach focused on doctors to a decentralized one focused on patients; that is a pro-active and preventive delivery model where people are active participants in their own well-being.

In the context of PHSs the use of mobile devices with sensors deployed on the body gives the vision of *healthcare to anyone, anytime and anywhere* [5]. In the recent years the market of smartphones and tablets has been well established. Nowadays the smartphones hardware components offer powerful computation capabilities that allow to perform the same tasks we do with a desktop computer. Another factor that contributed to the establishment of this new scenario for mobile computing is the apparition of operating systems specially designed for handheld devices, like Android [2]. Android as it is offered as an open source solution, can be used by different vendors in their products without adding additional costs. Moreover, application developers can create and publish applications for this operating system and target a wide range of devices. In the

particular case of PHSs there is a key fact in the new generation of mobile devices that are the integrated sensors like accelerometers, GPS receiver, ambient light, etc. that can provide information that complements the one provided by the sensors deployed on the body.

In this work we present the implementation directions of MAGPIE, an agent platform for simplifying the development of mobile applications in Android with the aim of monitoring chronic diseases. The platform is based on the concept of agent environment as a first class abstraction [6], and it is designed with the aim of tackle some of the technological challenges arising from the development of PHSs like modeling the domain knowledge, their scalability and their personalization.

The agent environment concept, is becoming increasingly more important to simplify the definition and deployment of multiagent applications, by mediating the interaction between the agents and resources deployed in the system, by hiding to the agents the complexity of dealing with the state of resources external to the agent, and by providing standard interfaces and standard descriptions to resources so that the agents can utilize them for their own goals.

2 THE MAGPIE AGENT PLATFORM

The aim of the MAGPIE agent platform is to help on the development of mobile applications that can be used in a PHS for monitoring chronic diseases. In a PHS patients with one or more chronic diseases are monitored by means of sensors deployed on their body. In MAGPIE we link such sensors with the abstraction of agent environment in multiagent systems [6]. The agents deployed in the agent environment can perceive the events happening in the patient's environment, perform reasoning on these events and produce alerts of interest for the particular disease being monitored.

As shown in Figure 1 the MAGPIE agent platform consists on different components. The central element of the platform is the *environment* where we can deploy two main entities: *agents* and *context entities*. Agents are cognitive entities deployed on the agent environment and are composed by a declarative mind called agent mind, which is the component in charge of the agent's reasoning abilities. The mind of an agent is situated in the environment through another component called agent body. The agent body is the part of the agent that receives and produces events from/to the agent environment, so it acts as an interface between the agent mind and the agent environment.

Context entities are connectors linking the real environment with the agent environment. They encapsulate the communication with a source of information from the real world. The goal of a context entity is to throw to the agent environment events related with physical measurements from the real world, so that the agents can perceive them. There are different kinds of context entities for the three different sources of the information we have. First, measurements can come from Bluetooth sensors deployed on the body of the patient, which can measure physiological values like the heart rate. Second, measurements can

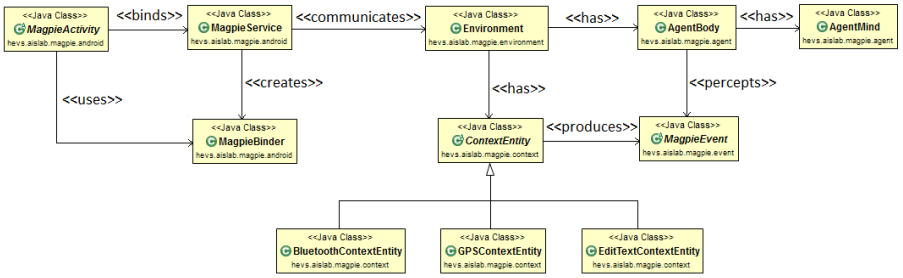

Fig. 1. MAGPIE class diagram

come from the sensors of the smartphone, which can provide for example the GPS position of the patient. Last, measurements can be provided by the patient itself through the user interface of a mobile application to report values that are difficult to measure with sensors, like the amount of carbohydrates of a meal.

The environment acts as a mediator for the interactions between the agents and the context entities. The events produced by the context entities are identified by the kind of measurement they represent, and the agent environment notifies the events to those agents interested on that particular measurement.

The agents and the environment have a lifecycle that takes into consideration the limited energy resources of smartphones. This limitation implies that in Android it is not possible to consider a full multithreading approach for agents as if multiple threads were to be run, then the battery life would decrease. The environment lifecycle takes care of mainly two things after the initialization of the Android application. Firstly, the environment dispatches events to the entities deployed in it. Secondly, the environment works also as a scheduler for the agents. For the sake of this contribution, the implementation of the environment entity has a sequential scheduler to execute the existing agents. The agent lifecycle is more complex. In a lifecycle an agent has to perceive the environment, to update its internal state and then, if no modification of the model is necessary, to perform actions in the environment, such as submitting alerts to the patient. When the agent perceives an event of model modification, then the current agent mind is discarded and modified with the new model, and the agent starts its cycle again from perceiving the environment. Contrary to the environment and the agents, the context entities are not active, so they are activated only when triggered by an event, performing a purely reactive behavior.

An important characteristic of the MAGPIE agent platform is its integration with the Android OS. We use two of the Android main components for that purpose: activities and services. An activity represents a graphical interface that the user can see on the screen, in MAGPIE activities are used as a communication channel between a mobile application and the patient. A service runs in the background to perform long-running operations that do not interact with

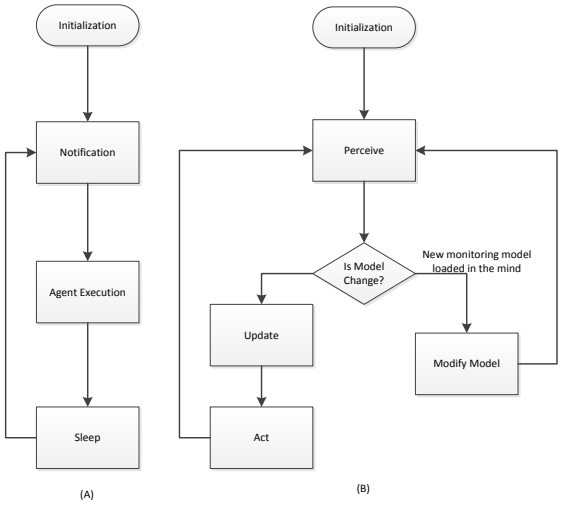

Fig. 2. Lifecycles of the (a) environment, and the (b) agents

the user, in MAGPIE the environment, the agents and the context entities run autonomously in a background service.

3 KNOWLEDGE REPRESENTATION

The knowledge used by the agents is based on the Event Calculus (EC) [4]. The EC is a formalism defined in Prolog for representing actions and their effects, so EC is suitable to model expert systems representing the evolution in time of an entity, by means of the production of events. In this case, our EC reasoner is embedded inside an agent, and models alerting rules applied by medical doctors through a web interface. More specifically, the events produced in the agent environment that are `LogicTuples` are automatically translated to a first order logic representation that can be interpreted by the reasoner residing the agent mind of MAGPIE agents.

In this paper we are motivated by the use case of monitoring Gestational Diabetes Mellitus (GDM); a condition affecting 3-4% of pregnant women due to increased resistance to insulin caused by the growth of the baby. Such a condition disappears just after delivery, but it is an indicator of the insurgence of diabetes type 2 (DT2) later in life: about 40% of the women affected by GDM also develop DT2 [3].

We give an example on how we define rules to handle the detection of repeated events such as hyperglycaemia events. The rule below is expressed in terms of the domain independent predicate `initiates_at/2`, which defines the conditions holding in the context of GDM

```
initiates_at(alert(postprandial_hyperglycaemia)=active, T) ←
    happens_at(glucose(V1,P),T),
    last_week(Time7days,T),
    (P=after_breakfast;
    P=after_lunch;
    P=after_dinner),
```

```
V1>=7,
count((happens_at(glucose(V2,P),T2),
    T2>Time7days,
    T2<T, V2>=7),C),
C>3.
```

The predicate `count/2` specifies the amount of times that the condition taken in consideration holds. The rule states that an alert of hyperglycaemia after a meal is triggered when in the last week more than three times the value of glucose for postprandial periods was above 7 mmol/l.

4 CONCLUSIONS

In this paper we presented a prototype of MAGPIE, an agent platform to develop mobile Android applications in the context of chronic illnesses monitoring. MAGPIE allows the deployment of agents and context entities in an agent environment. Furthermore, MAGPIE allows to personalize for each patient the behaviour of their agents by means of alerting rules. These rules are deployed in the agent cognitive model in terms of an Event Calculus theory.

As future work we plan: to develop a web interface for the doctors so that they can define the monitoring rules for their patients remotely; study different strategies to minimize the energy consumption of the mobile application using MAGPIE; use a distributed event based system approach to notify the events generated by the platform to doctors and relatives of the patient.

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