Towards on embedded agent model for Android mobiles

Jorge Agüero, Miguel Rebollo, Carlos Carrascosa, Vicente Julián.
Departamento de Sistemas Informáticos y Computación
Universidad Politécnica de Valencia
Camino de Vera S/N 46022 Valencia (Spain)
{jaguero, mrebollo, carrasco, vinglada}@dsic.upv.es

ABSTRACT
This paper presents, a new agent model “specially” designed for the new Android\(^1\) Google SDK, where the Android mobile phone can be considered as a software agent. This agent model has an approach more practical than theoretical because it uses abstractions which makes possible its implementation on different systems. The appearance of Android as an open system based on Linux has created new expectations for agent implementation. Agents may run in different hardware platforms, one approach useful in Ubiquitous Computing to achieve intelligent agents embedded in the environment. This vision can be considered a real intelligent ambient.

Keywords
Agent model, embedded agent, Android Google.

1. INTRODUCTION
The Ubiquitous Computing or Pervasive Computation [9] is a paradigm in which the technology is virtually invisible in our environment, because it has been inserted in the ambient with the objective of improving people’s life quality, creating an intelligent ambient [5]. In the Pervasive Computation, awareness is becoming an habitual characteristic of our society with the appearance of electronics devices incorporated in all class of fixed or mobile objects (Embedded system), connected by means of networks to each other. It is a paradigm in which computing technology becomes virtually invisible as a result of being embedded computer artifact’s into our everyday environment [6].

One approach to implement pervasive computing is to embed intelligent agents. An intelligent agent is a hardware or (more usually) software-based computer system that has the following properties: autonomy, social ability, reactivity and pro-activeness [12]. Embedded-computers that contain these agents are normally referred to as embedded-agents [11]. Each embedded agent is an autonomous entity, and it is common for such embedded-agents to have network connections allowing them to communicate and cooperate with other embedded agents, as part of a multi-embedded agent system.

The challenge, however, is how to manage and to implement the intelligent mechanisms used for these embedded agents due to the limited processing power and memory capability of embedded computational hardware, the lack of tools for the development of embedded applications and the lack of standardisation. By these challenges and other found problems [8], a remarkable difference between the conceptual agent model and the implemented or expected agent has been detected.

Today, the appearance of the Android SDK made by Google as a platform for the development of embedded applications in mobile phones creates a new approach for implementing embedded intelligent agent. Android is an open source platform and the application development is made with a new Java library (Java Android library) that is very close to Java for personal computers (J2SE) [1]. Furthermore, there exists the possibility that the Android Linux Kernel can be migrated to other platforms or electronic devices, allowing to such agents to be executed in a wide variety of devices.

To sum up, the basic idea is to present an agent model that can be designed using components or abstractions that can be deployed on any programming platform, and how the Android SDK allows the implementation of this agent model. This will show the feasibility of implementing embedded agents using these abstractions, reducing the gap between the design of embedded agents and their implementation. The rest of the document is structured as follows. Section 2 describes the proposed agent model. Section 3 details agent implementation in Android. Finally, conclusions are shown in section 4.

2. AGENT PLATFORM INDEPENDENT MODEL
Major challenges in pervasive computing include invisibility or unawareness, proactivity, mobility, privacy, security and trust [5]. In such environments, hardware and software entities are expected to function autonomously, continually and correctly.
Traditionally, agents have been employed to work on behalf of users, devices and applications [11]. The agents can be effectively used to provide transparent and invisible interfaces between different entities in the environment. Agent interaction is an integral part of pervasive (intelligent) environments because agents acquire and apply effectively knowledge in their ambient.

At the moment, there is a large amount of agent models that provide a high-level description of their components and their functionality. To define the agent model presented in this paper, some of the most used and complete agent model proposals have been studied. The first step was to extract their common features and adapt it to the new proposal. In this way, Tropos [3], Gaia [13], Opera [7], Ingenias [10] and AML [4] have been considered, because they are some of the most commonly used.

An agent model provides an abstract vision of its main components and their existing relationship. The approach to build the agent model uses the MDA (Model Driven Architecture) philosophy, which divides the different models into two classes: a set of platform independent models (PIM) and another set closely related with the supporting platform (platform specific model - PSM). It is a way to develop applications which allows us to separate the logic of the application from the platform used to its implementation. This philosophy, used in “classic software”, is also valid for agent development. Figure 1 shows the agent model presented in this paper, that is called APIM (Agent Platform Independent Model).

![Figure 1: APIM structure.](image)

The highest-level entity to be considered in this model is the agent. At this level, organizations of higher order, group belonging rules or behaviour norms, are not taken into account for reasons of brevity.

2.1 Agent

An Agent has an identifier and a public name. The environment is represented by means of its relationship with Environment, allowing to define input and output ports to communicate with the outside. Agent’s knowledge base is kept in its belief set and its goal set. The agent has two messages queues, Input and Output, to communicate with the outside, which temporarily store incoming and outstanding messages respectively. Besides messages, the agent can be aware of event arrival, being stored in EventQueue. Lastly, the agent has a State, related with its life-cycle and with its visibility by other agents.

With regards to the problem-solving methods, the agent has a set of core components. The Capabilities which represent the know-how of the agent and follow an event-condition-action scheme. To improve the efficiency of the agent, Capabilities are grouped into Behaviours that define the roles the agent can play. By doing that, can be kept active (ready) any Capability related with the current situation, avoiding overload the agent with unnecessary knowledge.

2.2 Behaviours

A set of Behaviours is defined in the agent to distinguish between different environments and attention focuses. Basically, Behaviours are used to reduce and delimit the knowledge the agent has to use to solve a problem. So, those methods, data, events or messages that are not related with the current agent stage should not be considered. In this way, the agent’s efficiency in problem-solving process is improved. A Behaviour has a Name to identify itself. It also has associated a Goals set that may be used either as activation or maintenance conditions. Lastly, it includes a state indicating its current activation situation. It is important to remark that more than one Behaviour may be active at the same time.

2.3 Capabilities

An event is any notification arriving to the agent informing that something that may be of interest for the agent has happened in the environment or inside the agent. It may have caused the activation of a new Capability.

The Tasks that the agent knows how to fulfill are modelled as Capabilities. Capabilities are stored inside the Behaviours and they model the agent’s answer to certain events. A Capability is characterised by a Name that identifies it, its trigger Event, an activation Condition and the Task that have to be executed when the event arrives and the indicated condition is fulfilled. It is also indicated the State the Capability has. Only the Capabilities belonging to current active Behaviours are executed.

All the Capabilities of an active Behaviour will be in a state marked as Active. When an event arrives, the Capability state changes to Relevant and its activation condition is evaluated. If this condition is fulfilled, the state passes to Applyable and the associated Task begins its execution. When this Task ends, the Capability return to Active again and it remains waiting the arrival of new events. When a
Behaviour becomes Inactive, all its Capabilities stop their execution and change their state to inactive. It is assumed that all the Capabilities of an active Behaviour can be concurrently executed, so that the system have to provide the needed methods to avoid deadlocks and inconsistencies during their execution.

2.4 Tasks
The last component of the agent model is the Task. Tasks are the elements containing the code associated to the Capabilities of the agent. One Task in execution belongs only to one Capability and it will remain in execution until its completion or until the Capability is interrupted because the Behaviour it pertains to is deactivated. It is not defined any method of recovering nor resuming of interrupted Tasks. On the other hand, the agent must have some mechanism of “safe stop” to avoid the agent to fall in inconsistent states.

3. IMPLEMENTING APIM IN ANDROID
The developing of APIM in Android was made using Android building block APIs (the API Version m5-rc14) [2]. There are four main components to model APIM agents: Agent, Behaviour, Capability and Task [1]. Table 1 shows the Android blocks used for building components of the APIM model and another necessary components.

The design presented can be seen as an interface to implement the agent according to the users requirements and needs. This interface uses specific components provided by the API, as previously commented. Thereby this model inserts a new layer in the Android system architecture[1]. This new layer, called Agent interface, modifies the architecture as it is seen in the figure 2.

The Agent class is designed to handle the arrival of events. Therefore an agent has to consider the changes in its environment (may be of interest for the agent) to determine its future actions activating and deactivate the appropriate Behaviours to respond to any internal or external situation. In this way, Agent class is implemented as one Android Service and one Activity as screen interface.

To implement the APIM model, some methods of Service class have to be overloaded. The onCreate() method allows to initialise the agent variables. After the onStart() method is executed that enables the agent components. The agent is executed until the user decides to stop its execution. In this moment, the user call selfstop() or stopService() method, allowing effectively to terminate the agent execution. Every agent component is stopped and destroyed (Tasks, Capabilities and Behaviours).

The agent interface designed has several methods that allow to implement the APIM, but there are two methods that are important to mention: the init() method, where the user may write the code necessary to initialise the agent, and the run() method, that activates roles that the agent has to play (active the Behaviours). The init() is executed within Service’s onStart(), that is called when the agent starts for first time. The Agent class can also launch a UI (User Interface), one Activity, to interact with users and to show its internal state and progress.

3.2 Behaviour
The Behaviour class works as a container of the Agent Capabilities and it can group as many Capabilities as the user desires. All of them can be activated and deactivated when events arrive. Behaviours are implemented by mean of an IntentReceiver class of the Android APIs. This base class receives intents sent by events of the Android platform. An IntentReceiver have to be dynamically registered to treat intents, using registerReceiver() method.

The IntentReceiver will be running on the main agent thread. The Receiver will be called when any intent arrives and it matches with the intents filters, i.e. bind an intent to object that is the receiver of the intent. As the agent may play one or more roles at any moment, the Behaviour class can activate new roles to register the respective handlers (of intents). For example, a role may be activated as a special Agent Behaviour when the battery phone is low. This can be done by an IntentReceiver that receives the intent LOW_BATTERY.

The Behaviour interface designed has several methods, but two main methods are provided to add and to remove the Capabilities: add(capability) and remove(capability).

3.3 Capabilities
Capabilities are characterised by its trigger Event, an activation Condition and the Task that must be executed when some event arrives and the indicated condition that is fulfilled. The Capability is implemented by means of an IntentReceiver class of the Android APIs. This base class receives intents sent from events of the Android platform, so this is similar to Behaviours.
Table 1: The Android components used in the APIM model.

<table>
<thead>
<tr>
<th>APIM Components</th>
<th>Android Components</th>
<th>Overloaded methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agent</td>
<td>Service + Activity</td>
<td>onCreate(), onStart(), onDestroy()</td>
</tr>
<tr>
<td>Behaviour</td>
<td>IntentReceiver</td>
<td>registerReceiver(), onReceiveIntent()</td>
</tr>
<tr>
<td>Capability</td>
<td>IntentReceiver</td>
<td>registerReceiver(), onReceiveIntent()</td>
</tr>
<tr>
<td>Task</td>
<td>Service</td>
<td>onStart(), onDestroy()</td>
</tr>
<tr>
<td>Goals</td>
<td>Intents</td>
<td>IntentFilter()</td>
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<tr>
<td>Events</td>
<td>Intents</td>
<td>IntentFilter()</td>
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<tr>
<td>Beliefs</td>
<td>Contentprovider</td>
<td>–</td>
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<tr>
<td>ACL Communications</td>
<td>http</td>
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</table>

A Capability is always running an IntentReceiver. When an intent arrives and the condition is fulfilled, then the code in onReceiveIntent() method is considered to be a foreground process and will be kept running by the system for manipulating the intent. In this moment then the Task is launched. The Capability interface designed has one important method for matching a Task to its corresponding Capability, the addTaskRun(task) method.

3.4 Tasks

Finally, Task class is one special process to run as an Android Service. To implement the Task, some methods of Service class have to be overloaded. The onCreate() method allows initialise Task variables when it is launched the onStart() method allows to execute the user code, throughout a call to a doing() method that has to be overloaded by the programmer. Now, the main method of Task interface is doing(), in where the user writes the Java program to be executed.

4. CONCLUSIONS

A general agent model to build intelligent agents in Android platform has been presented in this paper. This model can be easily adapted to almost any hardware/software platform or architecture. Moreover, the agent model has been implemented and tested in the new Android platform. The agent interface designed makes possible the implementation of embedded agents according to the users requirements.

The use of the Android platform shows the utility and proves the feasibility of designing platform independent agents. Moreover, the use of the proposed model abstractions for the APIM agent reduces the gap between the theoretical model and its implementation.

As future works, the services the agent can deliver will be enriched and enhanced from this first version. At the moment, the prototype has been developed using an Android emulator. A more precise evaluation of the proposed agent architecture will be done when the first mobile phone using Android system will be launched.

5. REFERENCES