An Interaction Model for Passively Influencing the Environment

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ABSTRACT
Adapting the environment in a user-centred view is at the core of ambient intelligence. This adaptation involves both context-awareness and interaction mechanisms that can be classified into active and passive. While active mechanisms have been fully explored in existing prototypes and systems, passive mechanisms and their implications need to be more deeply studied. In this work, we present some theoretical principles on passive interaction as well as their application to EMI^2: an AmI architecture we are designing combining active and passive environment interaction via mobile devices.

Keywords
Ambient intelligence, environment, passive influence, active influence.

INTRODUCTION
We are now in the initial phases of ambient intelligence engineering, where almost everything has to be defined and redefined. Frequently, practical work results in initial knowledge acquisition that serve as the basis for creating a theoretical framework backed up by experimental results. Our work designing an AmI architecture called EMI^2 (Environment-to-Mobile Intelligent Interaction) has been the reactive process that has prompted us with problems related to users interacting with their smart environment formed, after all, by individual coordinated devices.

In EMI^2 the user's mobile device acts as his representative sensing the environment, and interacting with it, based on user's preferences, history and behavioural patterns. This architecture is heavily based on the concept of agent, where an agent is defined as any entity that takes part in environment adaptation.

In EMI^2 the distributed knowledge and intelligence is supported by three types of coordinated agents:

- *EMIProxy*: is an agent representing the user. Being part of the mobile device, it acts on behalf of the user, adapting the environment for him. It stores the user's profiles and preferences as well as previous interaction history to determine the adaptation process.
- *EMIDevice*: is an agent representing a device that supports actively the AmI system by adapting its behaviour depending on ambient conditions. It is able to interact with other EMIDevices, the EMIProxy and the EMIBehaviourRepository.
- *EMIBehaviourRepository*: is an agent where knowledge and intelligence are combined to support adaptation decisions. Limited EMIDevices require services from external EMIBehaviourRepositories to coordinate their adaptation. Users' behavioural patterns when interacting with EMIDevices are logged and saved there to perform further analysis and pattern recognition. In this way, an EMIDevice can relay its adaptation on the external EMIBehaviourRepository, which empowers it with guiding about how to behave when interacting with a concrete user based on previous situations. The user's device can also be powered with an internal EMIBehaviourRepository with personal information and profiles that tries to minimize interaction with the owner by predicting his behaviour based on previous conduct.

Fig. 1 represents a basic diagram of EMI^2, labelling the main agents as well as the different steps in the communication flow:

1. Discovery / Perception
2. Get-Profile Request
3. Get-Profile Response
4. Adaptation
5. Update Profile

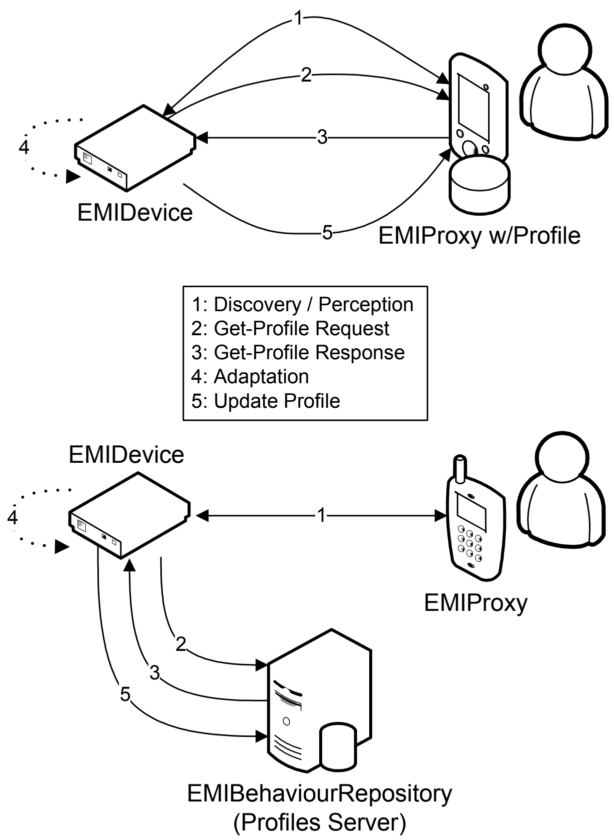

Fig. 1. EMI^2 diagram illustrating the different agents of the architecture and the communication flows.

ACTIVELY AND PASSIVELY INFLUENCING THE ENVIRONMENT

Ambient Intelligence Principles of Adaptation

Environments are populated by agents that live inside them and adapt themselves to the environment as well as, in a certain grade, they adapt the environment itself. For the purposes of defining Ambient intelligence principles of adaptation, an agent is any entity, being human, device or process, that takes part in environment adaptation.

Proposition 1: as any other system, an agent's state in a particular moment of time *t* can be described through a number of properties that adopt a corresponding set of values.

$$s_t = \{v_0, v_1, v_2, v_3, ..., v_n\} \quad \textbf{(1)}$$

Example 1: the state of a TV set can be defined by means of a determined set of parameters such as volume_level, power_state, channel, etc. that contain concrete values for the instant *t* = *now*: 4, on, 34, etc.

Of course, the agent's state at a further moment of time *t+1* can be different and, in consequence, this is reflected in its properties' values:

$$s_{t+1} = \{v_0', v_1', v_2', v_3', ..., v_n'\} \quad \textbf{(2)}$$

Proposition 2: an environment is a coordinated set of individual agents. The environment's state for an instant of time *t*, can be defined as the combined set of all the individual states of the agents $a_0, a_1, a_2, a_3, ..., a_m$ that constitute that environment.

$$E_t = \{s_t^0, s_t^1, s_t^2, s_t^3, ..., s_t^m\} \quad \textbf{(3)}$$

The environment evolves as the individual constituent agents evolve themselves changing their state accordingly. This is expressed by the environment's state at the further moment of time *t+1*:

$$E_{t+1} = \{s_{t+1}^0, s_{t+1}^1, s_{t+1}^2, s_{t+1}^3, ..., s_{t+1}^m\} \quad \textbf{(4)}$$

Active and Passive Mechanisms

A concrete agent can influence the environment, and thus, its constituent agents' state, via active or passive methods. Active methods are those in which the agent explicitly commands other agents to change their state or perform an action. Examples of active methods are configuration processes and operation invocation.

Example 2: as a user enters the building, a sensor identifies him and *commands* the elevator to be ready at the ground floor. When the user stands by the room door his mobile phone *commands* the electric lock to open.

Active methods can be implemented using any of the well-known distributed computing technologies such as CORBA [1], SOAP (Simple Object Access Protocol) [2], OBEX, etc. In EMI^2, strongly based on XML technologies, SOAP over HTTP is used for representing invocations back and forth between the different agents, while Bluetooth or GPRS are used as the message bearers in local and global contexts respectively, since invocations can be targeted to local or external agents.

Passive methods to influence the environment are those in which an agent disseminates certain information, expecting that other agents change their state or perform an action at their discretion to create a more adapted environment.

Using passive methods an agent does not command the target agents to do anything concrete, it simply publishes/broadcasts information preferences expecting the others react changing their state in a positive way. We can sentence that passive mechanisms are not intrusive, but they are less predictable.

The particular set of information to disseminate by the agent is dependant on the configuration of the environment in which is going to be published.

Example 3: a user behavioural profile can be formed by thousands of different parameters, but only a subset of those are required to adapt a hotel room (with TV set, telephone, temperature and lights) to his preferences. Identification of relevant information is a matter of context-awareness and we refer to previous studies about this area [3][4].

Anyway, an agent must be aware of the surrounding environment to identify and disseminate the proper information that can influence the neighbour devices in the desired way.

Proposition 3: if we call I to the overall set of information an agent stores about its preferences in the universe of contexts, $I(E_t)$ would be the subset of I that can influence the environment E at the time t.

$$I(E_t) \subseteq I \quad \textbf{(5)}$$

In EMI^2, passive mechanisms are implemented through XML-based messages representing user's profile information. The subset of relevant profile information $I(E_t)$ is created by identifying the requester EMIDevices present at the environment, so that depending of the device type (TV set, access control, car) only related information is sent back by the EMIProxy or EMIBehaviourRepository. EMIDevices process that data, deciding the actions to carry out adaptation (turn on channel 36, open the door, etc.). Finally, user behaviour is monitored (change to channel 22, close the door and log in the computer) and logged in the EMIBehaviourRepository for future prediction.

Environment Adaptation Issues

Active and passive methods are complementary, but for the purposes of this work, passive methods are considered at the core of AmI adaptation since they demand distributed intelligent behaviour in the surrounding environment without active intervention of agents. On the other hand, active methods perform in a master-slave way, where advanced smart features in agents are not required except for authorization processes. Frequently, smart environments are based only on "command and control" mechanisms that centralize intelligence in only one or few agents that control a greater number of "dummy" entities.

Proposition 4: the objective of Ambient intelligence is to promote environmental changing, through individual adaptation of agents, to achieve a more adapted environment state in a user-centred view [5][6][7]. Based on this definition, the users are the unique agents that are able to influence the environment, since changes must be performed for the users' sake.

Mathematically, this can be expressed as the need to find a function f able of evolving E_t into E_{t+1}, where E_{t+1} is a more suited environment state for a particular user or set of users than E_t, considering that the adaptation depends also of the information $I(E_t)$ disseminated by the influencing agents.

$$f(E_t, I_0(E_t), I_1(E_t), I_2(E_t), I_3(E_t), ..I_p(E_t)) = E_{t+1} \quad \textbf{(6)}$$

$I_0(E_t)$, $I_1(E_t)$, etc., represent the information delivered by agents a_0, a_1, etc., probably on behalf of users (note that several users can be present at the same environment). For every individual agent a_i, its adaptation function can be expressed as:

$$f(s_t^i, I_0(E_t), I_1(E_t), I_2(E_t), I_3(E_t), ..I_p(E_t)) = s_{t+1}^i \quad \textbf{(7)}$$

In EMI^2, the adaptation function for an EMIDevice generates the corresponding output s_{t+1}^i, guiding that EMIDevice about the changes to be performed in its state to carry out required adaptation, in a similar way as other ECA (Event-Condition-Action) mechanisms perform [8].

CONCLUSIONS AND FUTURE WORK

Active and passive mechanisms for environment influence are both needed and complementary in ambient intelligence scenarios. While former home automation and emerging AmI architectures [9] [10] use only active interactions, passive influencing is possibly the most powerful method to implement smart environments without user intervention.

We have illustrated how these mechanisms can be managed and implemented in a real ambient intelligence architecture such as EMI^2, based on well-known and standardized technologies. We also provided a simple propositional model for understanding relationships between the elements of ambient intelligence architectures that can serve as background for future work.

There are still some open issues that derive from the above model for adaptation definition that need to be explored:

1. If an agent both disseminates information and is influenced by the information disseminated by agents (including itself), its state, and consequently the environment state, can evolve indefinitely trying to adapt to the constantly changing conditions, maybe subtlety. This is an example of a system that feeds itself back until stability is achieved, if achieved.
2. If two or more agents disseminate opposing information $I_0(E_t)$ *and* $I_1(E_t)$ to influence the environment, the influenced agents must take a position about their adaptation under these conditions. While some agents can find a middle-point between the declared extremes, other agents can take party for one of the influencing agents, ignoring the others.

The first implication is the basis for continuous adaptation in the environment, even if the initial conditions are not present (the user is gone). The second implication involves political issues about users' adaptation priorities and how to accomplish them. In both cases, future work must be accomplished since they are natural problems that will arise when implementing ambient intelligence scenarios.

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REFERENCES

1. Object Management Group. *Common Object Request Broker Architecture (CORBA/IIOP). Version 3.0.2.* Object Management Group. 2002.
2. World Wide Web Consortium. *Simple Object Access Protocol (SOAP) 1.1*. 2000.
3. Crowley, J.L.: Context Driven Observation of Human Activity. *Lecture Notes in Computer Science, Vol. 2875: Ambient Intelligence*. Springer-Verlag, Berlin Heidelberg New York (2003) 101–118.
4. van Kranenburg, H., Salden, A., Eertink, H., van Eijk, R., and de Heer, J.: Ubiquitous Attentiveness - enabling context-aware mobile applications and services. *Lecture Notes in Computer Science, Vol. 2875: Ambient Intelligence*. Springer-Verlag, Berlin Heidelberg New York (2003) 76–87.
5. IST Advisory Group. *Ambient Intelligence: from vision to reality*. EU Publication. 2003.
6. IST Advisory Group. *IST Research Content*. EU Publication. 2003.
7. IST Advisory Group. *Scenarios for Ambient Intelligence in 2010*. EU Publication. 2001.
8. López de Ipiña, D. and Katsiri, E. *An ECA Rule-Matching Service for Simpler Development of Reactive Applications*. IEEE Distributed Systems Online, vol. 2, number 7. 2001. Available online at http://dsonline.computer.org/0107/features/lop0107.htm
9. Arnold, K., Waldo, J., and The Jini Technology Team. *The Jini Specifications*. Addison-Wesley. 2000.
10. UPnP Forum. *UPnP Device Architecture1.0*. UPnP Forum. 2003.