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 EMI²: 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 EMI² (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 EMI² 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 EMI² 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 EMI², 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. EMI² 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.

\[
S_t = \{v_0, v_1, v_2, v_3, \ldots, v_n\} \quad (1)
\]

**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 \( t = \text{now} \): 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:

\[
s_{t+1} = \{v'_0, v'_1, v'_2, v'_3, \ldots, v'_n\} \quad (2)
\]

**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 \( a_0, a_1, a_2, a_3, \ldots, a_n \) that constitute that environment.

\[
E_t = \{s_0, s_1, s_2, s_3, \ldots, s_n\} \quad (3)
\]

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 \( t+1 \):

\[
E_{t+1} = \{s_{0}^{t+1}, s_{1}^{t+1}, s_{2}^{t+1}, s_{3}^{t+1}, \ldots, s_{n}^{t+1}\} \quad (4)
\]

**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 EMI², 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,
The universe of contexts, information an agent stores about its preferences in the EMIBehaviourRepository for future prediction.

In EMI, monitored (change to channel 22, close the door and log channel 36, open the door, etc.). Finally, user behaviour is decided the actions to carry out adaptation (turn on EMIDevices process that data, information is sent back by the EMIProxy or present at the environment, so that depending of the EMIDevice. 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 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, 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 subtly. 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.

ACKNOWLEDGEMENTS
This work has been partly supported by the Cathedra of Telefónica Móviles España at Deusto University, Bilbao, Spain.

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