ABSTRACT

Nowadays, our living environments already provide ubiquitous network connectivity and are populated by an increasing number of artefacts (objects enhanced with sensing, computation, and networking abilities). In addition, people are increasingly using mobile devices as intermediaries between themselves and the artefacts. In order to create, manage, communicate with, and reason about ubiquitous computing environments that involve hundreds of interacting artefacts and cooperating mobile devices, we propose to embed, in these entities, social memory, enhanced context memory, and shared experiences. In this context, we describe an engineering approach and a framework to deal with emergent ecologies of locally interacting artefacts that provide services not existing initially in the individuals, and exhibiting them in a consistent and fault-tolerant way. Because they are emergent, their structure or availability are not predefined or known beforehand; we draw from swarm intelligence methods to describe such ecologies.

INTRODUCTION

Already, an increasing number of sensors are becoming embedded in the everyday objects or in the environment at a low cost. As a result of this continuing trend, an elementary ambient intelligence (AmI) infrastructure has become installed (though still fragmented), information appliances are commercially available, and ubiquitous computing (UbiComp) applications (currently in the form of games and informative services) are being deployed. As Norman (1998) anticipated, with the
proliferation of networks, information appliances, and artefacts, large amounts of data start being diffused in our living environment, and knowledge about patterns and context of human activities are generated. In addition, new generations of mobile devices (such as mobile phones, tablet PCs, PDAs) are being developed having increased capabilities and resources. These devices can now be considered as powerful information processing, storage, and access tools that can be used as facilitators between people and a smart environment, as they can be aware of the artefacts in their vicinity (Lopez de Ipina, Vaszquez, Garcia, Fernandez, & Garcia, 2005).

These developments have the potential to greatly enhance human activities (i.e., by automating dull or ordinary tasks; by speeding up time to exchange data, records, and files; by providing ubiquitous access to services and infrastructures, etc.). We need, however, to overcome the current limitations of distributed and context sensitive computing basically due to the classical client-server approach that is embodied in most, if not all, object-oriented environments and move towards reusable components and peer-to-peer (P2P) networks. By encouraging the adoption of agents and services as a building block for future advanced applications, full delegation of tasks in societies of interconnected computational and human resources can be achieved.

As a consequence of the availability of new technologies, the nature of the human activities eventually assisted by artefacts is rapidly changing. People have to (consent to) build new task models or adapt the ones they have already been using, a task not trivial at all. Execution of new tasks may become difficult due to the inherent systemic complexity of UbiComp applications that, among others, result from device incompatibility, and a huge number of interactions among visible and nonvisible actors. As ambient intelligence becomes widespread, people with low levels of IT literacy will be increasingly asked to interact with smart objects. Humans, with their “analogue” way of thinking and acting, have difficulties in using digital systems, because the latter demand precision, cannot tolerate misuse, and are unable to adapt to changes in operating environments (Norman, 1998). In addition, people will have to adjust to task execution involving high degrees of interruption and task switching. This situation might lead to the social exclusion of those not able to cope with this complexity, and to possible failure of realizing the AmI vision (ISTAG, 2001). Mobile devices are expected to play an important role in the adoption of ambient intelligence because we have already become familiar with using them, albeit in a simpler context.

This work builds upon the envisaged structure of the AmI environment as one populated by thousands of communicating tangible objects and virtual entities (Kameas, Bellis, Mavrommati, Delaney, Colley, & Pounds-Corning, 2003). Following an agent-oriented approach and adopting principles of Nouvelle AI (an alternative to the symbolic representation of internal models of the world, promoting that intelligence, as expressed by complex behaviour, “emerges” from the interaction of a few simple behaviours), the next sections describe a conceptual framework, which has been inspired by biological structures and is capable of dealing with phenomena emerging in such an environment. Finally, an engineering approach related to new research issues and requirements is introduced.

On the road to realising UbiComp applications and AmI spaces, several technical issues need to be resolved in order to make these systems adaptable and usable. Some of the major requirements a UbiComp system has to confront are: mask the heterogeneity of networks, hardware, operating systems, and so forth; tackle mobility and unavailability of nodes; support component composition into applications; context awareness; preserve object autonomy even for resource constraint devices; be robust, fault tolerant, and scalable; adapt to environmental changes; and be usable by novice users via understandable designed models (Drossos, Mavrommati, & Kameas, 2007). The approach followed by current efforts assumes a network infrastructure that allows direct communication of application components, that is, UbiComp systems are largely treated as (a) distributed systems with resource constrained nodes,