Mobile Agents: Can They Assist with Context Awareness ?

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Abstract

This position paper argues that the mobile agents paradigm is a useful and important technology enabling pervasive and ubiquitous computing. Context awareness drives adaptability of pervasive computing systems. It is asserted that mobile agents capable of discovering, extracting, interpreting and validating context will make significant contribution to increasing efficiency, flexibility and feasibility of pervasive computing systems.

We are witnessing an unprecedented use of the Internet, communication and computing technologies in commerce, business, government, health, defence and educational applications. Advances in software technology, ubiquitous devices and the increasing volume of digital knowledge offer the opportunity for more sophisticated and user-friendly digital services. Mobile software agents represent one of recently emerged paradigms related to pervasive computing that carry a tremendous promise in solving some of the real world problems and enabling "anytime, anywhere, with any device, within any context" access to digital information and services. Context-awareness and context management are in the focus of intensive ongoing research efforts by the pervasive computing research community. *Pervasive computing* is a computing paradigm incorporated in a variety of devices (computers, cars, entertainment units, appliances, etc.), which can carry out computing in a relatively non-intrusive manner and can impact and support many aspects of work and everyday activities [2, 4, 11]. Pervasive systems need to be aware of their environment and available resources (i.e. aware of their context), able to detect changes in the environment (context changes) and can adjust/adapt their functionality and behaviour to the changes. Context information (description) includes specification of user (profile), device and application requirements as well as measurements of quantifiable entities in the environment, just to name some.

Usefulness and viability of mobile agents have been debated since early 90s [1, 5, 6, 8, 9]. Mobile agent technology went through a number of splashes of interest in last 10-15 years. The interest to mobile agents is again on the rise. This rise is motivated by advances in enabling technologies, including wireless networks, diverse multifunctional devices, portable software platforms capable of supporting mobile agents, sensor networks. It is also motivated by better understanding of the needs of applications and capabilities of pervasive/ ubiquitous /mobile computing platforms.

Why the mobile agent paradigm seems to be so appealing and promising ? The answer could lie in reducing complexity by delegation as well as sharing the information overload with mythical software entities that can diligently, intelligently and tirelessly perform many tasks that otherwise may have to be done by users.

Figure 1 illustrates two interconnected worlds where users from the real world delegate routine or complex tasks to software agents. These agents should be able to move on their own volition if the task requires so, explore and discover resources, services, context and communicate with other software agents.

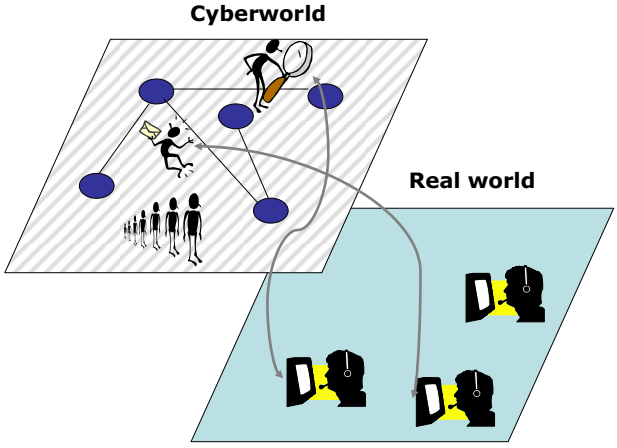

Fig.1 Two interconnected worlds

A virtual pervasive world would be characterized by large number of devices with limited resources and software services (either representing real people, tasks, or important operations of pervasive systems) that would need to navigate through complex heterogeneous networks, often crossing boundaries of multiple distributed systems.

Mobile agents in the virtual pervasive world are analogous to people in the real world. They should be mobile and intelligent and make use of dynamically available resources and make decisions according to changing situations. Having a pervasive world with

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autonomic mobile, context-aware and intelligent software (i.e. mobile agents) would be an efficient response to complexity challenge.

A pervasive system needs to be context aware. It must handle different situations in different ways. Context-awareness implies intelligence that enables an application to discover, reason and predict a situation and adapt to it in a dynamically changing environment. Applications operating in distributed environments would also need to become mobile, in particular when servicing people on the move. Although contradiction exists between intelligence and mobility (more intelligence implies bigger size, more data and resource consumption and mobility benefits by less data), we can also observe a degree of unity/harmony, by which intelligence contain or benefit from mobility. In order to produce real awareness in pervasive systems, intelligent embedded programs must become mobile and retrieve context related information in different locations. In other words, by moving to different locations and retrieving relevant information, the program's informed decision becomes better. We can imagine a scenario in which based on a discovered context a mobile agent autonomically migrates to a host in order to retrieve information not previously intended. Combining the recent information yields a more accurate description of the current situation or perhaps of a future situation. Thus, mobility aids in intelligent acquisition of context.

The ability of agents to be both mobile and intelligent (thus becoming autonomic) is ideally suited for performing adaptation in pervasive systems. This combination results in agents changing their information retrieval and locations according to newly available data. This dynamic behaviour can assist a pervasive system to perform adaptation, based on up to date information that could not have been otherwise acquired in a pre-planned or more static manner.

For mobile agents to deal with context awareness, the following challenges must be addressed.

Context Discovery, Sensing, Extraction and Manipulation. Mobile agents should be capable of discovering context producers, including sensor networks, software sensors, environments and applications [3, 10].

Context Interpretation. Software agents should be capable of interpreting the and reasoning about context, perhaps with the use of ontologies, or state-space theory.

Context Dissemination. Publish-subscribe mechanism is useful in disseminating context information to consumers [7].

Context Negotiation and Coordination. Mobile software agents should be capable of refining context attributes and share some of the tasks and operations on context.

Context Use. Software agents should be capable of using context in both reactive and proactive ways, where stability of pervasive systems could be maintained through controlled impact on essential context attributes [10].

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