

# Context-Awareness in Pervasive Environments

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## INTRODUCTION

Pervasive computing is emerging as the new paradigm for the XXI century. Although it may be a new concept for many, its first ideas were introduced in 1991, in the seminal paper of Mark Weiser (Weiser, 1991). The primary vision of such a paradigm is that computing becomes part of our lives, being available anytime and anywhere. In other words, it replaced the idea of each person using a single computer at a time (i.e., the personal computer paradigm) to the one where each person can use many computers, which are embedded in everyday life objects (e.g., clothes, phone and automobile).

One of the reasons for embedding computing in such objects is to give them some level of intelligence, in order to make human life more comfortable. For example, a smart phone should be able to recognize when its owner is at a conference and forward any call to his/her voicemail. However, to support this kind of application, it is necessary that these computing devices be proactive (Loureiro, Oliveira, Almeida, Perkusich, & Ferreira, 2005). In the previous example, the user should not need to configure his/her smart phone to forward calls. Instead, the smart phone should perform it automatically, by recognizing that the user is at a conference. Also, these devices are enhanced with wireless communication capabilities, allowing interaction among them.

Together, embedding computing and wireless communication allow the creation of pervasive environments, which is the main idea behind pervasive computing (Satyanarayanan, 2001). However, to enable the appearance of such environments, two other key concepts are involved: *context* and *context awareness*.

Given our initial discussion, in this article we present an overview of context and context-awareness concepts as well as their role in pervasive computing environments, which is a base technology to support virtual organizations (Mohyuddin, Gray, Morrey, & Jones, 2006). The article is structured as follows: in section Pervasive Environments, we present the ideas behind pervasive computing environments. Section Context discusses historical aspects of context and its definition in the pervasive computing area. The importance of context-awareness in pervasive computing and how to acquire contextual information is presented in section Context-Aware Computing. After that, we discuss some work in this area. Finally, in section Conclusion we discuss final remarks.

## PERVASIVE ENVIRONMENTS

As mentioned before, pervasive environments are those saturated with computing devices, with the intent of providing anytime and anywhere services for us. More specifically, the idea is to create intelligent spaces, that is, environments where the devices can take some “in-

telligent” actions, acting proactively on our behalf.

The two main characteristics of pervasive environments are dynamism and heterogeneity. The former is characterized by the fact that computing devices can join and leave these environments at anytime. The latter, on the other hand, is concerned with the variety of computing devices (e.g., handhelds, notebooks, cell phones, tablet PCs, Internet tablets, PCs) and the differences among them, concerning features such as operating system, network protocols, screen size, processing power, amongst others.

In order to ease the understanding of pervasive environments, consider a pervasive classroom scenario, in which some ordinary devices are placed, such as a computer, a projector, and an air conditioner. Moreover, each student and the teacher have their own personal device, like a handheld or a cellular phone. All these devices communicate with each other using wireless connections. As we are talking about pervasive environments, such a classroom should have some level of intelligence. To this end, a few minutes before the beginning of each class, the classroom automatically sets the illumination level and turns on the air conditioner, computer, and projector, still setting it to exhibit the presentation programmed for that class. When it starts, the classroom automatically assigns the presence list, by perceiving which students are present in the classroom. The class proceeds normally, and a few minutes to the end, the teacher sends a mini-test to students through their devices. Once the students have finished it, the answers are automatically sent to a server, which evaluates them, and generate a report. As the teacher prefers to receive such a report in a print format, at the end of the class, the server searches for a print service and prints the presence list along with the reports. Although scenarios like this are certainly fascinating, they are still futuristic. Even having hardware conditions, such as powerful mobile devices and wireless interfaces, the conception of pervasive computing scenarios like that is a complex task.

To deal with characteristics such as heterogeneity and dynamicity, applications must be aware of the information available in the environment at run time. They must acquire information about people in the environment and their respective profiles (e.g., preferences, personal information). In addition, they also need to be aware of neighbor devices as well as their properties, such as screen resolution, battery level, services provided, and so on (Loureiro, Bublitiz, Oliveira,

Barbosa, Perkusich, Almeida, & Ferreira, 2006). This kind of information has been known as context.

## CONTEXT

The study about context has a long story in literature, philosophy, artificial intelligence, and linguistics (Mostéfaoui, Pasquier-Rocha, & Brézillon, 2004). In the Cambridge Dictionary,<sup>1</sup> context is defined as “the situation within which something exists or happens, and that can help explain it.” Due to the great number of areas which the term context is used, it may have a vague signification for more specific areas, like pervasive computing. Therefore, researchers have been proposing a more precise definition of context for pervasive computing.

One of the first attempts within this scope was made by Schilit and Theimer (1994), who identify three kinds of context: *computing context* (e.g., computer network, workstations), *user context* (e.g., profile, location), and *physical context* (e.g., lightning and noise levels). Chen and Kotz (2000) added one more characteristic to the work of Schilit and Theimer, the *time context* (e.g., day, hour, month, season), which is an important feature in order to analyze historical information. There are some other researchers that have defined context in this way, but the problem with all these definitions is that they are too associated with examples, making them too specific.

A more general-purpose definition of context was provided by Dey (2001), who states that context is “any information that can be used to characterize the situation of an entity.” An entity is a person, place, or object relevant to user-application interaction, including the user and the application themselves.

## CONTEXT-AWARE IN PERVASIVE COMPUTING

To be aware of context is a natural task for us. We usually consider the context around us to take decisions. For example, when we are at the theatre, we usually do not speak aloud to avoid bothering the audience. Therefore, we are naturally aware of our context. However, what about the applications? When are they considered to be aware of their context? According to Dey (2001), a context-awareness system uses context “to provide

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