Introduction to Ubiquitous Computing

Module Overview

This module introduces students to the key concepts of ubiquitous computing, contextualises why ubiquitous computing is emerging as a new paradigm for computing systems and provides an overview of the main implications of this new paradigm for the development of information technology. It also analyses the relationship between ubiquitous computing and many of its related paradigms, such as Pervasive Computing or Ambient Intelligence

Instructional Objectives

At the end of this module, students are expected to be able to:

- [O.1.1] Identify the key assumptions behind Desktop Computing and explain in what ways those assumptions are being challenged by current trends in computing and in the way computers are used
- [O.1.2] Explain in your own words the basic principles of ubiquitous computing
- [O.1.3] Describe the key enablers for ubiquitous computing and contextualise the emergence of ubiquitous computing in relation with existing trends in society and information technology
- [O.1.4] Explain in your own words the meaning of ubiquity when applied to a technology and its specific meaning in the case of computing technology
- [O.1.5] Describe 4 likely characteristics of a computing system in a post-desktop era
- [O.1.6] Compare ubiquitous computing with other related paradigms, such as Pervasive Computing or Ambient Intelligence

What is Ubiquitous Computing?

Ubiquitous Computing has been emerging as a new paradigm for computing systems, and essentially corresponds to a vision where computation is embedded into everyday objects, where everything communicates with everything else, and where virtual and physical environments are closely interconnected. With computing devices becoming progressively smaller and more powerful, it is sensible to expect that almost any device, from clothing to coffee mugs, will be embedded with some sort of computational capability and able to connect with an infinite network of other devices. This will dramatically change our perception of what a computer system is, as the entire environment, with all its integrated devices and associated services, becomes indistinguishable from the computer. In such scenario, the environment becomes the interface and computation devices, as we currently know them, fade into the background. Ubiquitous computing systems are thus radically different from traditional distributed systems, and set many new research challenges that cut across various disciplines. More specifically, we can associate Ubiquitous Computing with the following key challenges:

Extreme heterogeneity

Heterogeneity in Ubiquitous computing systems is an order of magnitude greater than what is expected today even in federated distributed systems, where the differences essentially accommodate various operating systems and relatively less powerful devices. In Ubiquitous Computing, heterogeneity will be extreme because of the co-existence in the same system of very diverse devices, from very tiny and limited sensors that only awake up occasionally to emit a few bits to very powerful and fully connected computing devices. Despite the huge differences in their capabilities, they will all have to cooperate and offer an integrated functionality.

Self-organised and continuous systems

There is no power-off button for a Ubiquitous computing system. It should always be available and continuously evolving, as new entities enter and leave the system. The set of entities that compose the system is therefore very dynamic and unforeseen at the beginning. In this environment, the mobility of users and devices is the rule and not an

exceptional situation, and system functionality must emerge from the dynamic composition of the individual entities in the system, which must be able to discover each other and coordinate their actions.

Physical integration

Ubiquitous Computing systems are an integral part of their physical environment. Today, the physical world of the atoms, and the virtual world of the bits, remain essentially disjoint worlds, but the increasingly Ubiquitous presence of all sorts of sensors in our physical world, together with the capability to network those sensors and infer information from their data, is greatly expanding the ability of the virtual world to perceive the physical world and react accordingly. On the other hand, new interaction paradigms, such as ambient displays or tangible bits, explore the use of the physical world and its objects as interaction devices. We are therefore converging for a scenario in which both realities are strongly intermixed, and in which it is the physical space, with all its devices and virtual services that provides the execution environment for applications.

Locality

Locality of reference, generically, defines the set of services or resources in use by a system. In Ubiquitous Computing, physical proximity becomes a crucial element in defining the locality of reference of a system, i.e. interactions will be stronger with nearby entities. This is not the case with most mobile and distributed systems that tend to make location as irrelevant as possible, and where the focus is on maintaining the same functionality anywhere, all the time. In those scenarios, the mobile user, despite being mobile, is always using the same set of services and network regardless of her or his current location. On the contrary, in Ubiquitous Computing, and resulting from the integration with the physical world, it is assumed that there are strong interactions with the surrounding devices. As a consequence, as a user moves away from a particular environment, the level of interaction with that environment is expected to decrease.

User centred paradigm

Defining Ubiquitous Computing as being user centred is much more than acknowledging the relevance of the user in the process of interaction design. In Ubiquitous Computing, the user must be the absolute centre of the entire system, which must be designed around user concepts, such as user attention, tasks, context or data, instead of focused on devices or applications. For example, it should be possible to initiate a task in a particular environment, suspend it to do something else, and latter, at another environment and possibly with a totally different set of devices, resume the same task. Therefore, applications can no longer be seen as pieces of software targeted to a particular device but rather, as high-level descriptions of the user activities that can be instantiated to the devices and services available at a particular environment. Additionally, that functionality must be designed for specific situations, which not only includes user tasks, but also the social setting in which those tasks are inscribed.

Activities

Recommended Reading

Mark Weiser's work on Ubiquitous Computing

Mark Weiser's seminal papers on ubiquitous computing constitute the inevitable starting point for anyone being introduced to ubiquitous computing. These papers are relatively old and clearly outdated from a technological perspective, but they remain a fundamental reference for anyone working in ubicomp because of their major role in shaping the ubicomp vision.

- Weiser, M. The Computer for the 21st Century Scientific American, 1991, 94-104.
- M. Weiser, "Some Computer Science Issues in Ubiquitous Computing," Communications of the ACM, vol. 36, pp. 75-84, 1993.
- M. Weiser, "The world is not a desktop," ACM Interactions, pp. 7-8, 1994.
- M. Weiser and J. S. Brown, "The Coming Age of Calm Technology," PowerGrid Journal, vol. 1, 1996.

These papers, as well as some additional notes on ubicomp, are all available at Mark Weiser's original page on ubicomp:

- http://www.ubiq.com/hypertext/weiser/UbiHome.html

Pervasive Computing: Vision and Challenges

This paper describes the evolution of Ubiquitous and Pervasive Computing from their origins in distributed systems, through mobile computing up to the integration with smart spaces. This pape is also interesting for the enumeration of challenges associated with Pervasive Computing, which in this paper are presented as the motivation for a particular Pervasive Computing infrastructure called Aura.

- M. Satyanarayanan, "Pervasive Computing: Vision and Challenges," IEEE Personal Communications, vol. 8, pp. 10-17, 2001.

HCI2020

This is a report about the evolution of HCI in a broader sense of our relationship with computers. The report can be downloaded at:

- http://research.microsoft.com/en-us/um/cambridge/projects/hci2020/

Chapter 1, Our Changing World, introduces some emerging trends in the use of computers and analysis how they are affecting in a fundamental way the role and perception of computers in our society and in our everyday lives. This is an important and updated view on how ubicomp is being shaped, and is thus a fundamental introductory reading for this course.

ISTAG2001. Scenarios for Ambient Intelligence in 2010, EC

A visionary report on the future of Ambient Intelligence that has had a strong impact on research projects in this area.

- ftp://ftp.cordis.europa.eu/pub/ist/docs/istagscenarios2010.pdf