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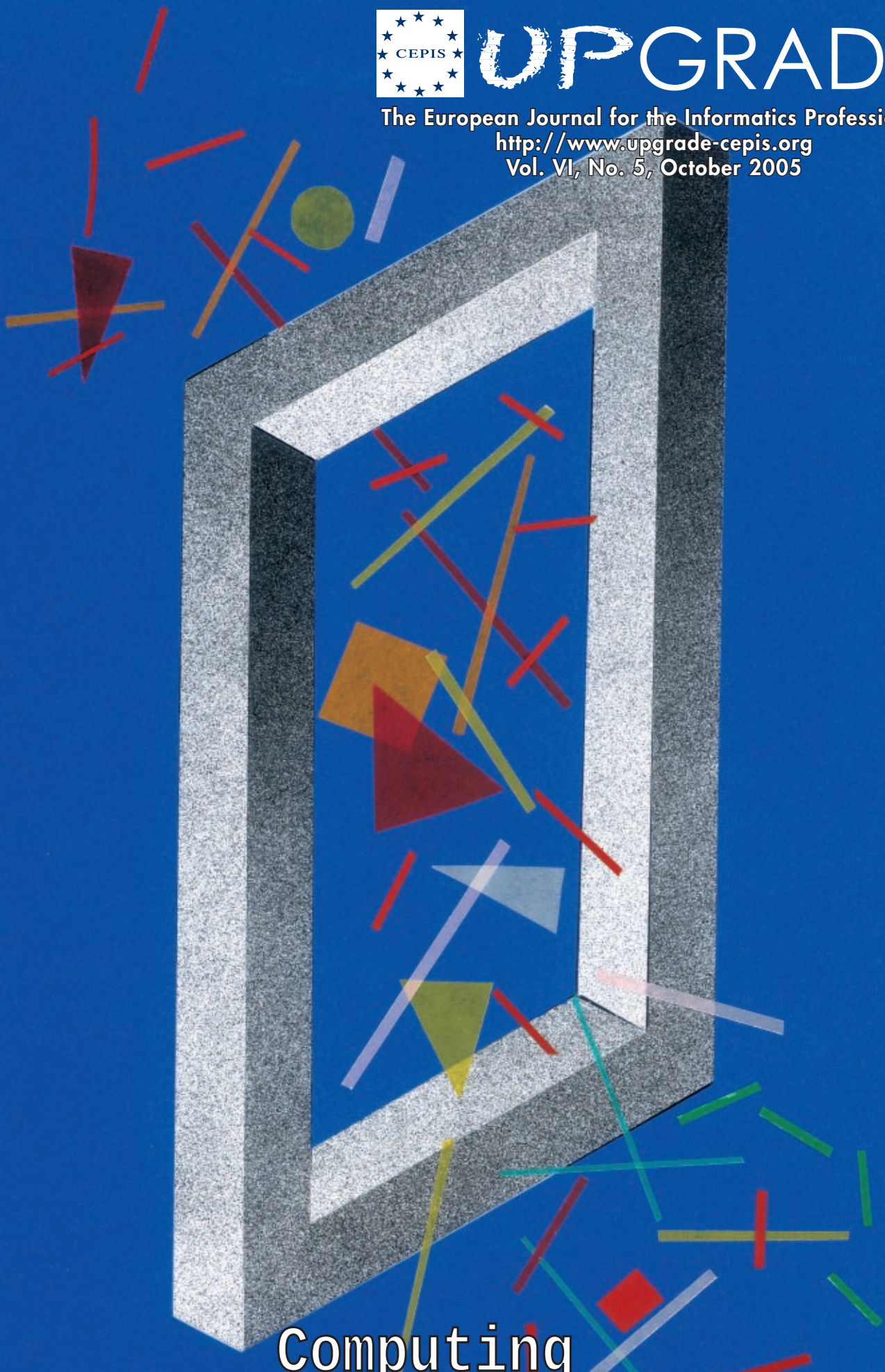

Computing Omnipresence

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• **Novática**, journal from the Spanish CEPIS society ATI
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Monograph of next issue (December 2005)
The Semantic Web
(The full schedule of **UP**GRADE is available at our website)

Monograph: Computing Omnipresence
(published jointly with Novática*)

Guest Editors: *José-Antonio Gutiérrez de Mesa, Daniel Rodríguez-García, and Miltiadis D. Lytras*

UPENET (UPGRADE European NETwork)

* This monograph will be also published in Spanish (full version printed; summary, abstracts, and some articles online) by **Novática**, journal of the Spanish CEPIS society ATI (*Asociación de Técnicos de Informática*) at <http://www.ati.es/novatica/>, and in Italian (online edition only, containing summary, abstracts, and some articles) by the Italian CEPIS society ALSI (*Associazione nazionale Laureati in Scienze dell'informazione e Informatica*) and the Italian IT portal Tecnoteca at <http://www.tecnoteca.it>.

Editorial

In The Fifth Anniversary of UPGRADE

It's a pleasant duty to welcome readers to the fifth anniversary edition of **UP**GRADE – the journal of CEPIS. We hope that readers find it an interesting and useful read. Its electronic presentation and international sourcing of material are reflective of the international nature of CEPIS and of our commitment to the promotion of beneficial new technologies.

We remain committed to increasing the scope of material included in **UP**GRADE, both in terms of the sources of material and the subjects covered. Encouraged by what we have seen of **UP**GRADE, the Executive Committee of CEPIS is developing a broader strategy for communications to its members, external stakeholders and partners and the world of IT users. That strategy, and **UP**GRADE's place in it, will develop over the coming months. We intend to make our publications more useful through this review.

CEPIS is particularly grateful to the Spanish society ATI (*Asociación de Técnicos de Informática*) and the editors of its journal **Novática** for their contribution in editing and managing the publication of **UP**GRADE from its inception. Such a contribution is easy to ignore, but it has been of crucial importance in getting the journal started.

We all wish **UP**GRADE and its editorial team a very happy birthday and a fruitful future. We're extremely grateful for the large amount of voluntary effort that goes into its production, which is in the best tradition of CEPIS. We also wish all readers a prosperous and happy 2006.

Geoff McMullen
President of CEPIS
<president AT cepis DOT org>

Presentation

An Outlook for Ubiquitous Computing: Computing Power Anywhere and in Any Device

José-Antonio Gutiérrez de Mesa, Daniel Rodríguez-García, and Miltiadis D. Lytras

*This article, in addition to introducing this monography of **Novática** and **UP**GRADE, looks into the mobile communications systems used in machine to machine communications (M2M). We see how wireless modules are proving to be the most appropriate technology for optimizing business processes in many industrial and service sectors. We also look at what we believe to be the two most interesting fields of M2M communications in terms of the ideas behind them and the innovative products they spawn: telemetry and telematics systems. As an annex to the article we offer a list of useful references on Ubiquitous Computing developer communities.*

Keywords: GPRS, GSM, J2ME, Mobile Devices, Modems, Ubiquitous Computing, UMTS, WiFi.

1 Introduction

It is traditional in **Novática** and **UP**GRADE monographs for the guest editors to write a presentation in which they describe the content and the salient features, followed by an article in which the same guest editors set out the main characteristics and the so-called "state of the art" of the subject of the monograph. In this particular monograph, for practical reasons we have decided to combine these two articles into one, so as to provide the reader with a single overview. We start by looking at the most common devices using ubiquitous computing technology: wireless modules and terminals which also make up the most innovative segment of mobile transmission and reception technology. Weighing in at just a few grams and optimized down to the smallest possible size, these modern high-tech components enable all kinds of objects, devices, and applications to communicate easily and at any distance. Wireless modules and terminals are able to transform anything into a mobile network connected device, opening up almost endless communication possibilities. This is no pipe dream: it is a foretaste of mobile applications to come, which will be based on wireless communication between machines (machine to machine or M2M technology).

The Guest Editors

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1.1 Ever Smaller Devices

Terminals are becoming smaller and smaller and, according to Moore's Law - first postulated in the sixties and still valid today - the processing power of microchips doubles every eighteen months. This has led technology providers to supply inter-connectable equipment to communicate "anything". In 1995 Siemens started the ball rolling in the machine to machine communications market with their M1, the first module to be compatible with the GSM mobile telephony standard. They were followed by NOKIA and WaveCom, and a number of other manufacturers who day by day brought improvements to the performance of wireless module (WM) technologies. Current wireless modules from the various manufacturers weigh in at a bare 8 to 12 grams. They incorporate (and in most cases support programming in) Java 2 Micro Edition (J2ME) or, in the case of the Windows Mobile devices, they incorporate .NET technologies.

Ubiquitous computing, or computing power anywhere and in any device, however familiar, is made possible by processors of this type connected wirelessly. By using tiny sensors, life is imbued with a new capacity for processing and communicating information wherever it is. This has given rise to a number of new applications which will have an economic and social impact beyond anything we can imagine.

In order to create this new type of ubiquitous computing software we need to distinguish between *modules* and *terminals*. On the one hand we can say that wireless modules are integrated in a solution; they are normally used to build new devices or they are embedded in domestic appliances or other more or less commonplace devices. On the other hand we have terminals which are independent units; they have their own case and can be connected to other devices by cable or by short range radio links such as Bluetooth or WiFi (Wireless Fidelity), as well as to data networks supported by the mobile telephony operators.

1.2 Devices Are Becoming Miniaturized

The miniaturization of components is making it possible for wireless module based ubiquitous computing to reach a world of applications that just a few years ago would have been unthinkable. For example, wireless modems used in home security systems enable householders to be kept perfectly informed about the state of their homes and even to remotely control certain devices, such as the heating, curtains or blinds, lighting, or the washing machine.

This brings us to the sectors currently enjoying the strongest growth: machine to machine (M2M) applications and the gadgets (or accessories) and applications used by the automobile industry. The latest ubiquitous computing terminals make it possible to monitor the correct functioning of the various modules to be found in a car. These permit insurance companies to be kept informed about the risk implicit in speeding or driving in areas with a large number of accident black spots, provide drivers with GPS-based (Global Positioning System) navigation, and even tell them where the nearest service station is when their car switches over to its reserve fuel supply. Or when the car detects that it needs some kind of service it can "negotiate" an appointment with the garage that best suits the user.

In homes, central heating and air conditioning systems can be remotely controlled, while refrigerators can be kept stocked up and consume-by dates controlled, in the same way that vending machines inform restockers when stocks fall below reorder levels.

Another important sector is telecontrol: wireless modules use sensors to obtain measurements of traffic flows, ambient air pollution, or weather data, process them, transmit them if necessary, and take decisions which are implemented via electronic actuators.

2 Good Prospects for Commercial Developments

Mobile telephony-based machine to machine applications and solutions are forecast to enjoy strong growth and stable market conditions in the future. In fact, it is expected that the vast majority of objects, devices, and machines engaged in mobile interaction will soon equal or outnumber human users of cellular telephony.

According to estimates from NTT DoCoMo, <http:www.nttdocomo.com>, Japan's top mobile phone operator, by the end of the first decade of this century only one in three of their customers will be human. The Fraunhofer Institute for Secure Telecooperation (SIT) predicts that in 2008 mobile devices will be the most common way to make a telephone call, connect to the Internet, and make electronic payments (see <http://www.sit.fraunhofer.de/cms/en/forschungs bereiche/forschungs bereiche.php>). Services and content for the household sector are also expected to be the most successful applications. And according to Forrester Research, in 2020 the number of mobile machine "sessions" will be exceed the number of personal "sessions" by a factor of 30 (see <http://www.forrester.com/my/0,7179,2-0,00.html>). Market research forecasts that the world market for wireless modules and terminals will turn over around 3,500 million euros in 2006. This market can be broken down into three main segments: M2M, automotive, and consumer products.

2.1 The Machine to Machine Communications Sector: Possible Opportunities for Application in Telemetry And Telematics Systems

In this section we look at some of the sectors in which M2M applications show the strongest growth.

The Telemetry Sector

On the one hand there is telemetry which enables the properties of systems and devices to be controlled remotely wherever they are located by sending numerical measurement information or capturing data within their reach. Meanwhile telematics systems combine telecommunications and computing to enable connected and normally mobile systems to exchange data. The effective operation of telematics systems allows companies to maintain a virtual presence

wherever it is needed, thereby improving their bottom line.

Thus, by way of an example, Siemens Mobile's latest M2M module is the XT55, the first compactly designed triband GSM/GPRS-enabled (General Packet Radio Service) module featuring a GPS receiver for satellite navigation. The combination of these two technologies enables users to seamlessly track goods, vehicles, and even people. The new tracking module will have a great many uses, especially in such fields as transport, logistics, and security services.

The Automotive Sector

One of the applications of this technology expected to gain a major boost from the incorporation of UMTS are multimedia and telematics systems for vehicles, providing infotainment services for drivers and their passengers while increasing the safety of the vehicle itself. Although this market is still in its infancy, according to analysts Frost & Sullivan [5] the total turnover from automotive infotainment technologies in Europe will top the 9,000 million euro mark in 2010. In the next few years telematics systems will become practically standard equipment in all new vehicles sold in Europe.

2.2 The Consumer Products Sector

Wireless terminals and modules provide connection with greater freedom of movement for both work and private use. Thanks to GPRS and 3G/UMTS (Third Generation/Universal Mobile Telecommunications System) technologies, connections can be kept active permanently (operators charge per byte transmitted, not by connection time). Current technology already allows us to enjoy mobile computing and multimedia services on our PDAs (Personal Digital Assistants) and laptops, and the multiplexer function permits parallel wireless voice telephony, faxing, text messaging, downloading, emailing, and Internet access so as to be able to stay connected without communicating if need be. The packet-based transmission mode in GPRS (i.e. packet switching) permits continuous operation, enabling users to keep their email accounts open without interruption so they can read their messages as they come in.

Some manufacturers, like Siemens with their Gericom model, have already started to install wireless modules in their portable devices. Panasonic, for example, offers wireless modules as an option in their "Toughbook" range of laptops and handhelds designed for use on construction sites and in maintenance, rescue, and research work and able to withstand extreme conditions.

By way of an example, some service providers are offering wireless handheld PCs (Personal Computers) to stockbrokers in Taiwan to enable them to keep up to date with stock market trends and to trade online. Another example is in Hong Kong where PDAs are used by betting offices to keep them in touch with their customers so they can place bets from anywhere at any time. A doctoral student is developing a ubiquitous computing based system to meet the quality management requirements of a major nationwide corporation, and a research team is developing a PDA-based system for use as a smart virtual tourist guide for programming routes according to the time the tourist has available, his or her tastes, and any possible overcrowdedness of tourist venues, plus other considerations such as the weather and traffic congestion.

More and more multiple use modems are coming onto the market. These small add-ons, also referred to as dongles, can be connected via a USB (Universal Serial Bus) interface, or when produced in the form of slim PCMCIA (*Personal Computer Memory Card International Association*) cards can be inserted into laptops, handhelds, and other units.

3 Communication Technologies

3.1 GPS Systems

GSM (Global System for Mobile Communications) is a digital system for land mobile communications which was initially used in Europe but later became a worldwide standard [5].

A GSM system is a radio cellular communications system. The area to receive coverage is divided up into smaller cells in order to make the best use of the spectrum assigned to each operator and to reuse the available channels.

Basically communication via GSM works as follows. When the mobile device is switched on, a signal is sent to the Base Station Controller (BSC) via the base transceiver station which is providing coverage to the mobile terminal at that moment so the call can be recorded in the VLR (Visitor Location Register).

In order to make a call the first thing the system does is to request a signalling channel to communicate with the network and send it the necessary information (contained in the SIM, Subscriber Indetification Module) to establish a call. Then there is a dialogue with the HLR (Home Location Register) to establish such parameters as routing, speed, target address, error correction technique, etc.) after which communication is established.

3.2 GPRS systems

GPRS systems were introduced by the ETSI (European Telecommunication Standard Institute) as part of the second phase of GSM. It uses packet switching communication permitting, among other things, always-on Internet connection and access to data networks. The transmission speed and bandwidth are also greater than with GSM and the service is priced by the amount of data transmitted rather than by connection time.

In addition to some software changes to the current GSM network, GPRS incorporates three new hardware elements (GGSN, SGSN and PCU), over an IP-based backbone.

3.2 UMTS Systems

UMTS (Universal Mobile Telecommunications System) is a member of the global IMT-2000 family of the ITU (International Telecommunication Union) third generation mobile standards. UMTS will play a leading role in the creation of the future mass market for high quality wireless

multimedia communications which will reach 2,000 million users worldwide in 2010. UMTS is the preferred mobile platform for tomorrow's large content services and applications. In the last ten years UMTS has been the focus of intensive research and development worldwide, and is supported by a many of the major telecommunications manufacturers and operators as it provides an opportunity to create a mass market for access to the Information Society for highly personalized and user-friendly mobile services.

UMTS extends current mobile wireless and satellite technologies, providing greater capacity, data transmission capabilities, and a much wider range of services by using an innovative radio access program and an improved core network.

4 Use of Modules

Wireless modules are typically governed by a PC or a PDA, but when the application has to fit into a small space it is normal to use an ad hoc circuit controlled by a small microcomputer, such as a PIC or similar.

It is now becoming normal for the microcomputer controlling the module to be capable of being manipulated by some sort of programming language provided by the module manufacturers themselves. This program is stored in part of the user's memory and generally communicates via AT type commands.

The development of truly robust business applications in which security aspects may be compromised is also a field which needs to be looked into, as is the entire lifecycle of ubiquitous computing based information systems.

5 Content of the monograph

This monograph comprises ten articles covering specific aspects of the ubiquitous computing world both from a theoretical and a practical standpoint. Some of these articles have been chosen from the First Iberoamerican Congress on Ubiquitous Computing (CICU) held in the city of Alcalá de Henares, Spain, from May 4 to 6 of this year, <http://www.cicu.uah.es/>, which took over the baton from the Mobigame conferences held at the same university the four previous years. Other prestigious European authors have also been selected to complete the view afforded by this edition.

To prepare this monograph we decided to divide the articles up into four broad thematic sections, the first of which deals with fundamentals and emerging technologies. For this section we chose the article "*The Critical Mass Problem of Mobile Ad-hoc Networks*" by ***Jörg Roth***, from the University of Hagen in Germany, written having in mind that mobile ad-hoc networks have become increasingly popular in the last years and promise a huge potential for the future for mobile and ubiquitous computing scenarios. In this section we also include the work "*Device and Context Influence on Wireless Infotainment Access: A Real World Story*", by ***Tacha Serif*** and ***George Ghinea***, from Brunel University in the United Kingdom, which describes the interesting results obtained from a real case study of the use of mobile devices.

The second section is devoted to new needs of today's mobile communications and is headed by ***Luis Bengochea-Martínez***'s article "*The Problems of Printing in Server-Based Computing Environments*", where the author, from the *Universidad de Alcalá* in Spain, looks at the need for standardised criteria for companies, and more specifically he proposes the use of PDF documents to try to alleviate the load on print controllers and servers. In their article "*Using FOAF to Support Community Building*", ***Brian Kelly*** and ***Leigh Dodds***, from the University of Bath in the United Kingdom, provide us with a practical case of how to use FOAF to capture metadata in XML (eXtensible Markup Language) capable of being used in the construction of a globally available semantic web for ubiquitous terminals. Meanwhile, the paper "*Towards Ubiquitous Computing with Quality of Web Service Support*", by ***Yannis Makripoulias***, ***Christos Makris***, ***Yiannis Panagis***, ***Evangelos Sakkopoulos***, ***Poulia Adamopoulou***, ***Maria Pontikaki***, and ***Athanasios Tsakalidis***, all from the University of Patras in Greece, stress the need to establish control parameters in order to select Web Services with sufficient quality, especially when they involve consumers of services using ubiquitous devices. This second section is completed by the article "*The Open Source Software vs. Proprietary Software Debate and Its Impact on Technological Innovation*", provided by a research group from several universities comprising ***Ricardo Rejas-Muslera***, ***Juan J. Cuadrado Gallego***, ***Javier Dolado-Cosín*** and ***Daniel Rodríguez García***; this article takes a look from a legal point of view at the possible future consequences of current policies and trends affecting legal software protection and the presence and accessibility of Open Source software, with a special focus on ubiquitous devices where any decision taken will affect millions of potential users.

The third section deals with initiatives for creating new services for ubiquitous, and the first article is from a group of lecturers from the Electronics Department of the *Universidad de Alcalá* (***Carlos-Manuel De Marziani***, ***Jesús Ureña-Ureña***, ***Álvaro Hernández-Alonso***, ***Manuel Mazo-Quintas***, ***Ana Jiménez-Martín***, ***Juan-Jesús García-Domínguez***, ***José-Manuel Villadangos-Carrizo***, and ***Fernando-Javier Álvarez-Franco***) entitled "*Localization in Ubiquitous Computing Using Acoustic Sensor Network*" in which they present their results regarding the processing of contexts or relevant information about objects, and the techniques and mechanisms that determine the spatial relationships that exist between those objects which enable them to be located. The other article in this third section is entitled "*Portable System For Patient Monitoring With Wireless Technologies*", by ***José-Manuel Rodríguez-Ascariz***, ***Luciano Boquete-Vázquez***, ***Ignacio Bravo-Muñoz*** and ***Pedro Martín-Sánchez*** - also from the Electronics Department of the *Universidad de Alcalá* - describes a hardware-software solution in a ubiquitous computing environment for processing electrocardiograms capable of performing calculations to help doctors make their diagnoses.

The fourth and final section deals with real applications in the world of computing mobility. Here we have chosen an article by ***José-Julio González-Pozo*** and ***Manuel Ortega-***

Cantero, from the *Universidad de Castilla-La Mancha* in Spain, entitled "*SIGLAS: A practical case of the application of Ubiquitous Computing in Warehouse Management*" in which they take a look at the processes that need to be undertaken in order to implement this kind of technology in specific business organizations. This section, and the monograph, close with the article "*Ubiquitous E-Management of Indicators*", written by ***Eladio Domínguez-Murillo***, ***Ángel De Miguel-Artal***, ***Beatriz Pérez-Valle***, ***Áurea Rodríguez-Villanueva*** and ***María-Antonia Zapata-Abad***, from the *Universidad de Zaragoza* in Spain, provides us with, among other things, an action protocol for the diagnosis and treatment central catheter related infections which focuses on those technologies of ubiquitous computing that involve the creation of environments with high processing and communication capabilities that respond to static changes.

Acknowledgements

The work that went into this current edition of **UP**GRADE and **Novática** would not have been possible without the selfless work of a great many people. First and foremost, the authors themselves, whose labours, under the guidance of the reviewers who I would also like to thank for their efforts, resulted in the articles making up this edition. I would also like to thank the members of the programme committee of the First Iberoamerican Congress on Ubiquitous Computing (CICU'2005) for their valuable work in disseminating these technologies and, finally, I would like to thank **Novática** and **UP**GRADE's editor in chief for all the contributions and improvements he has made since the inception of this monograph and all the encouragement and help he has provided.

*Translation by **Steve Turpin***

Useful references on Ubiquitous Computing developer communities

Developer communities are free membership associations in which tools can be found to develop J2ME applications. Normally manufacturers do not open up their websites to you unless you have registered as a community member. When you are a member of a specific community the manufacturer will allow you access to privileged information and let you download the relevant toolkits by using the user keys and passwords provided.

The toolkits contain compilers, device emulators, and even some examples for testing and training purposes, to help users build their own first applications.

One of the most important communities we should mention is the one belonging to SUN Microsystems, the JDC (Java Development Connection) community, which can be accessed at <http://developer.java.sun.com/developer>. The environment has the functionality required to create and compile projects and then test them on various wireless simulators, such as a colour phone, a black and white phone, and a widescreen phone. It is also integratable with Forte for Java project development.

IBM's user/developer community is accessible at <http://www.ibm.com/developerworks> and uses IBM's Visual Age Micro Edition for Java. The environment incorporates not only compilers and emulators but also a number of virtual Java machines to test several different environments and a support tool for project management.

Borland's Java community is at <http://community.borland.com/java> which provides JBuilder tools integrated to work with Nokia. The version, called Nokia Mobile Set, enables users to develop J2ME applications.

In some cases it is a good idea to use the developer environments provided by the mobile device manufacturers such as Motorola's community with their MAGNET (Motorola Applications Global Network) environment, available at <http://www.motorola.com/developers>. There is also a 30-day trial version of the development kit Metrowerks CodeWarrior which enables users to develop projects using J2ME, as in the previous environment, but which can be used to produce offline games as it has a Wireless Toolkit. The downside is that its software only emulates some of Motorola's own terminals, such as the i50 and the i85.

NOKIA's development environment, called Nokia Development Forum, is accessible at <http//www.forum. nokia.com> while Siemens' environment is to be found at <http://www.siemensmobile.com> by accessing the Developers Portal.

Other interesting information is to be found in KVMwp.pdf which is a set of general information about J2ME downloaded from SUN's website at <http://archives.java.sun.com/archives/kvm-interest.html>.

Other mobile communications fora and sites are listed below:

- <http://www.umts-forum.org> is the body promoting UMTS in the market.
- <http://www.3gpp.org/> from Third Generation Partnership Project, creators of 3G standards.
- With regard to standardization processes we should also mention the IEEE 802.16 committee whose purpose is to standardize broadband wireless access. IEEE 802.16 is, in fact, the WLL (Wireless Local Loop) standard today.
- Information on the Eighth International Conference of Ubiquitous Computing to be held in California is available at <http://ubicomp.org/ubicomp2006/>.
- A journal providing news and views on the subject of ubiquitous computing can be found at <http://www. personal-ubicomp.com/>.
- Information on ubiquitous computing can be found in "wikipedia" at <http://en.wikipedia.org/wiki/Ubiquitous_computing>.
- Information about initiatives from the Ubiquitous Computing Evaluation Consortium can be found at <http://ubiqcomputing.org/ubiq_initiatives.html>.
- Information about Carnegie Mellon University's Project Aura is available at <http://www.cs.cmu.edu/~aura/>.

The Critical Mass Problem of Mobile *Ad-hoc* Networks

Jörg Roth

Mobile ad-hoc networks have become increasingly popular in the last years and promise a huge potential for the future for mobile and ubiquitous computing scenarios. Ad-hoc networks allow users to communicate without a fixed network infrastructure, thus are interesting for many mobile communication scenarios. Multi-hop ad-hoc networks extend the communication range of individual nodes with the help of ad-hoc routing protocols. Many researchers focused on lower communication layers and developed several protocols in the past. In this paper, we want to abstract from the physical layer, the data link layer and routing issues, and want to measure the quality of an ad-hoc network independently from network and hardware issues. In order to achieve this, we first introduce a formal network model and a set of metrics. Then, with the help of a simulation tool, we measure the quality of ad-hoc networks in specific scenarios. We especially want to discover the prerequisites for sufficient connectivity, stability and coverage. We call the number of nodes to form a reasonable network the critical mass. As a result of our simulations, we get a considerable high critical mass for realistic usage scenarios.

Keywods: *Ad-hoc* Networks, Evaluation Metrics, Mobile Computing, Wireless Communication.

1 Introduction

Mobile *ad-hoc* networks are self-organizing structures in which mobile nodes are temporarily connected without the aid of any fixed infrastructure or centralized administration. Mobile *ad-hoc* networks promise a high potential for mobile and ubiquitous computing scenarios. As they do not need any fixed infrastructure, they even work in environments where a pre-installed wired network is too cost-intensive or even impossible. Typical areas for *ad-hoc* networks are public places such as airports, fieldwork areas, disaster areas or military battlefields. In addition, *ad-hoc* networks may serve as access networks for commercial (e.g. cellular phone) networks.

As mobile devices and wireless networks get increasingly powerful, many researchers expect *ad-hoc* networks to play an important role for mobile users in the future. Many encouraging simulations affirm this view. Having a closer look however, these simulations are often based on idealistic assumptions. Often, a wide radio communication range (e.g., 250m) and a homogeneous distribution of nodes are assumed. In reality, we often have restricted communication ranges of 10 to 30m. As users usually walk on specific ways (e.g. streets or sidewalks) and assemble at interesting places, we have a strongly inhomogeneous distribution among the observed area.

In this paper, we want to investigate the prerequisites to form a reasonable *ad-hoc* network for a certain realistic environment. For this, we abstract from specific routing protocols, packet throughputs, network hardware etc. and measure the quality of a network with the help of a set of metrics. We applied our metrics to a realistic scenario: the *Minneapolis Skyways* with its shopping levels and ways for pedestrians. Simulating this scenario leads to a discouraging observation: we need more than 2000 nodes in an area of about 500m x 500m to establish a reasonable network. Compared to approx. 50 nodes under idealistic assumptions, this is a very high number, thus the whole idea of *ad-hoc* networks may be questionable.

2 Related Work

In this paper, we follow the IETF (Internet Engineering Task Force) definition of mobile *ad-hoc* networks (in the following called MANETs - Mobile *Ad-hoc* NETworks) [10]: MANETs are wireless multi-hop networks which organize themselves and whose topology may change rapidly. To enable communication between nodes which are not directly connected via the wireless communication technology (e.g. Wireless LAN IEEE 802 or Bluetooth), networks use *ad-hoc* routing protocols such as LMR (Land Mobile Radio) [5], Link Reversal [6], DSR (Dynamic Source Routing) [13], OLSR (Optimized Link State Routing Protocol) [11], DSDV (Dynamic Destination-Sequenced Distance-Vector Routing) [17], o TORA (Temporally-Ordered Routing Algorithm) [16] to find routes to a receiver.

A number of approaches have been published in the last years, which deal with quality analysis of MANETs. Gupta

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and Kumar [8] assume *n* randomly located nodes, each capable to transmit with *W* bit/s over a wireless channel. Their analysis show that the throughput obtained by each node is $\Theta\left(W / \sqrt{n \cdot \log(n)}\right)$ bit/s, i.e., the throughput dramatically decreases with higher number of nodes. Jinyang et al. [12] examine the throughput of WLAN 802.11 networks (WLAN stands for Wireless Local Area Network). They find out that the capacity of long chain of nodes inside an *ad-hoc* network is 1/4 of the channel capacity obtainable from the radio connection. Glossglauser and Tse [7] show that inside an *ad-hoc* network the per-session throughput can increase when nodes are mobile rather than fixed. However, they made several idealistic assumptions und use loose delay constraints. Santi et al. [18] investigated, which wireless communication range ensures a strongly connected network. They assume an n-dimensional region with a homogeneous distribution of nodes. Their analysis focuses on a strong connected network, i.e. each node is connected to each other. This is a very difficult requirement, usually not achieved in real *ad-hoc* network.

In contrast to the approaches above, we do not have the assumption of homogeneously distributed users among the observed area. As we do not have a simple model to describe the movement of mobile nodes (e.g. the random waypoint model), a closed analytical or probabilistic approach is very difficult to achieve. In this paper, we thus specify the metrics and restrict the analysis on simulations.

Compared to other approaches, we introduce a number of new metrics that measure the quality of a MANET; especially the combination of *reachability*, *vulnerability* and *coverage* is new and reflects the end-user's demand of a stable network with a high degree of connectivity.

3 Measuring Manet's Properties

In the following, we introduce a network model which does not deal with physical aspects. We assume that two nodes, which are in communication range, are linked together with a maximum throughput without any errors. Beyond a certain distance, the communication breaks down immediately, i.e. the communication quality does not smoothly decrease when the distance between two nodes gets larger.

We observe a specific MANET in a time interval $[t_1,t_2]$ in an area *A*. Let $N = \{N_1,...,N_n\}$ denote the set of all network nodes, which have been active at least once in the area *A*. Every node $Ni \in N$ has a position, denoted by $p_i(t)$.

Let $O(t) \subseteq N$ denote the set of network nodes, which are active (i.e. online) at a certain time $t \in [t_1,t_2]$. Active nodes can send, receive and route packets. We introduce *O* for two reasons: first, nodes may participate in the MANET, but are temporarily switched off. Second, nodes may only pass through the MANET, i.e. only participate for a short time and then disappear. *N* does not change over time, thus we use *O* to model the behaviour of such nodes. For every node $N_i \in O(t)$, we introduce the sets $c_i(t)$ and $r_i(t)$:

· $c_i(t)$ denotes the set of *directly* connected nodes. Only active nodes can be connected, i.e. $c_i(t) \subseteq O(t)$. We only consider bi-directional connections, thus $N_i \in c_j(t) \Leftrightarrow N_j \in c_i(t)$.

· $r_i(t)$ denotes the set of nodes reachable by *multiple hops*. $N_j \in r_i(t)$ if either $N_j = N_i$ or N_j $c_i(t)$ or N_i and N_j can communicate with the help of directly connected intermediate nodes.

This model implies an important simplification of real MANETs: after a topologic change, both $c_i(t)$ and $r_i(t)$ *immediately* contain the correct sets of communicating nodes. In reality, changes have to be propagated via the network with a finite speed and inactive or unreachable nodes could be falsely viewed as reachable.

Based on this network model, we introduce a number of metrics. Our metrics should not be confused with metrics used to find optimal routes from sender to receiver in routing protocols (e.g. hop counts). Our metrics measure particular characteristics of the entire network. We asked ourselves following questions:

· When a new node enters the area of a MANET, how high is the probability to be instantly connected?

· Once a node is connected to the MANET, how many nodes can it access, or in turn, how many nodes can access the new node?

· Once a node accessed another node, how stable is the communication link?

If we knew the surface or volume covered by the MANET, the first question could be answered, using p_i and the communication range. Examining the sets r_i leads to an answer to the second question. The third question is more difficult to answer: moving specific nodes may disable an ongoing communication where other nodes are less important to existing communication links. We measure this effect by introducing so-called *important* nodes later.

3.1 Segmentation

The first metric is called the *Segmentation*, which is used as a basis for further metrics. The Segmentation *S* denotes the number of segments in the MANET. Nodes inside a segment can only communicate to nodes inside the same segment. Equation (1) shows how *S* is related to r_i.

$$S = \sum_{N_i \in O} \frac{1}{|r_i|} \qquad (1)$$

To get a measurement, which is independent from the current number of nodes, we introduce the *Normalized Segmentation SN*:

$$SN = \begin{cases} \frac{S-1}{|O|-1}, & \text{if } |O| > 1 \\ 0, & \text{otherwise} \end{cases} \qquad (2)$$

SN has values between 0 and 1 where *SN* = 0 means *no segmentation* and *SN* = 1 means *maximum segmentation* (all nodes are separated).

3.2 Coverage

To measure the surface or volume a MANET covers, we first introduce the Coverage Area *(CA)*. The Coverage Area is the area inside *A* where an inactive node can become active without increasing the number of segments. Note that activating a node inside the Coverage Area does not necessarily mean to be connected to *all* nodes in the MANET. We define the *Coverage C* to get a value, which is independent from the size of the area *A*:

$$C = \frac{vol(CA)}{vol(A)} \tag{3}$$

Here, *vol* denotes the size of a volume or surface.

3.3 Reachability

We now define how reachable nodes are inside a network. Let $R(N_i)$ for $N_i \in O$ (called *Reachability* of N_i) denote the ratio of active nodes which N_i can access:

$$R(N_i) = \begin{cases} \frac{|r_i| - 1}{|O| - 1}, \text{if } |O| > 1 \\ 0, \quad \text{otherwise} \end{cases} \tag{4}$$

We use $|O|-1$ as denominator, since we do not count the node N_i itself as reachable. To measure the reachability of all nodes, we define the *Average Reachability (AR)*:

$$AR = \frac{\sum_{N_i \in O} R(N_i)}{|O|} \tag{5}$$

AR is only defined, if $O \neq \{\}$, i.e. we have at least one active node in the MANET.

3.4 Importance and Vulnerability

Inside a MANET, some nodes are more important for communication than others. Some nodes in the 'centre' of a MANET may disable an ongoing communication when they are moved or switched off, as they may separate nodes from each other. On the other hand, some 'peripheral' nodes can be turned off without affecting the rest of the network. We want to formalize this issue.

Let $I(N_i)$ denote the *Importance* of $N_i \in O$. The Importance returns, how many new segments are caused by a turning off N_i:

$$I(N_i) = \begin{cases} S'(N_i) - S, \text{if } S'(N_i) > S \\ 0, \quad \text{otherwise} \end{cases} \tag{6}$$

$S(N_i)$ denotes the number of segments, if we remove N_i from *O*. To measure the entire network, we define the *Vulnerability V*, which returns how the network reacts on average to deactivating nodes:

$$V = \begin{cases} \frac{\sum_{N_i \in O} I(N_i)}{|O| - 2}, \text{if } |O| > 2 \\ 0, \quad \text{otherwise} \end{cases} \tag{7}$$

We can easily proof that the maximum value of the numerator is, thus the value of *V* is in the interval [0,1]. Our list of metrics is now complete.

4 Evaluations

The metrics provide a tool to measure the quality of a specific MANET, i.e. a network where nodes reside at specific positions at a specific time. We now want to abstract from a specific MANET and want to examine general prerequisites for 'good' MANETs, which offer a sufficient connectivity for end-users and applications.

In principle, we could use physical nodes in real environments for this. The Ad-hoc Protocol Evaluation (APE) test-bed [14], e.g., follows this approach. To evaluate MANETs with APE, users with mobile nodes have to move in real environments. Initial experiments were carried out with only 37 nodes.

Since real experiments are very cost-intensive and time-consuming, we use a simulator in our approach to evaluate a reasonable number of nodes (e.g. some hundreds). A huge number of network simulators (e.g. NS-2 [20]) exist. Broch et al. extend NS-2 to address mobility issues [2]. *Adhocsim* [1] is especially designed to simulate *ad-hoc* networks. These tools, however, focus on MAC (Medium Access Control) or network level. They can simulate packet delays or errors, which is too fine-grained for our intended goals. To measure our metrics, we developed a new simulation tool.

The tool easily allows a user to specific the number of nodes, the communication ranges and the observed area. Running a simulation, the nodes move randomly across the area. The tool presents current and average metric values.

In principle, the tool is able to simulate three-dimensional networks. Nevertheless, even in buildings, where a three-dimensional network could be formed in principle, ceilings are often impenetrable; thus, MANETs fall apart to independent, two-dimensional MANETs. The following simulations are thus only two-dimensional.

Often, smaller locations such as aircrafts, busses or apartments are considered as locations for MANETs. In these scenarios however, it is more sensible to install a low number of access points connected via a fix network, rather than using a MANET. Thus, the following simulations examine larger areas. We carried out two types of simulations: the first type simulates moving nodes in an unstructured plain area. In the second, more realistic example, we simulate a shopping centre.

4.1 Simple Areas

In the first scenario, we put a number of mobile nodes in a square area. The nodes choose a random direction and speed and move straight forward until they reach the border. They then choose a new direction and move again. All nodes are active all the observed time.

Although this scenario is very artificial, it is a first step towards a more realistic example in a later section. We use this simple scenario to derive first results. It especially leads to a definition of the *critical mass* – the number of nodes that form a reasonable MANET.

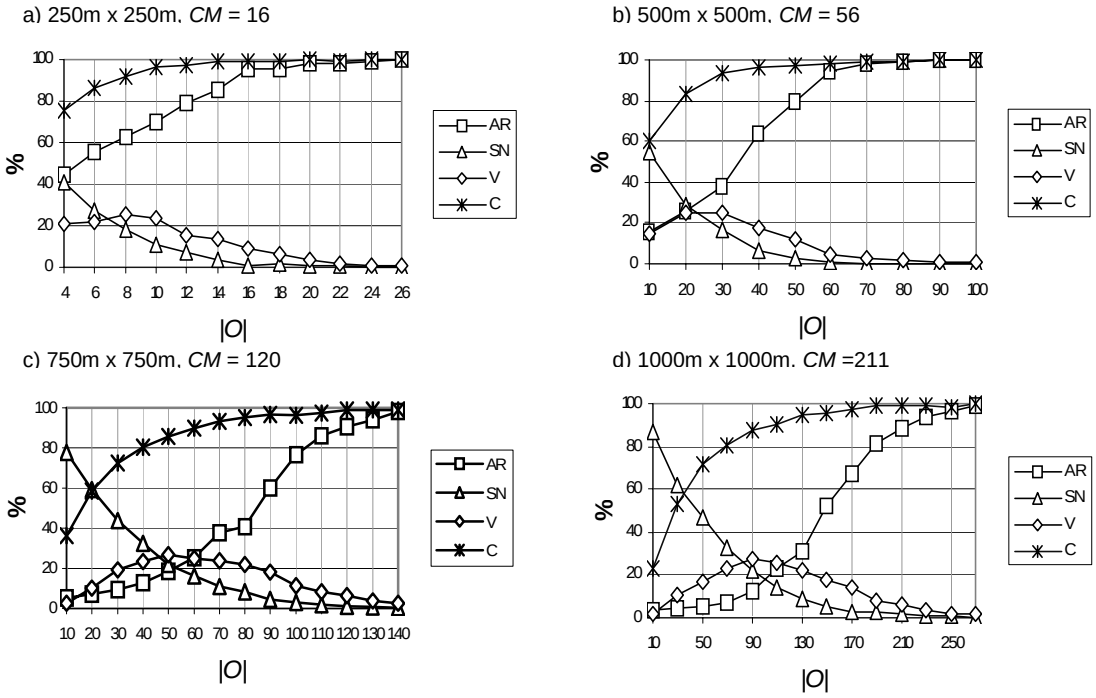


Figure 1: Evaluation of MANETs in Simple Areas.

We chose 100m as the transmission range. The range of *Wireless LAN IEEE 802b*, e.g., is between 30m and 300m, where the latter only occurs under ideal conditions [9]. Low power Wireless LAN adapters for handhelds often only reach 90m even in open environments [22].

We carried out the simulations for a number of areas: 250m x 250m, e.g. a yard of a small company; 500m x 500m, e.g. a university campus; 750m x 750m, e.g. a pedestrian zone; 1000m x 1000m, e.g. a city centre. We simulated the MANETs for different number of nodes. Figure 1 presents the results. Not surprisingly, *C* and *AR* are monotonic increasing and converge to 100% for increasing. *SN* is monotonic decreasing and converges to 0% with nearly the same speed as *C*.

V starts at 0%, reaches a maximum of approx. 30% and then converges to 0% for higher number of nodes. *V* has values of about 0% for low number of nodes, since we have a high segmentation, thus there is no multi-hop routing in the network. Values above 30% are rare in real networks, as only very specific constellations cause nodes with high importances *I*.

After the metrics reach a specific value, we can increase the number of nodes without a significant change. Basing on this observation, we define what we mean by a 'good' MANET:

- values of *C* and *AR* have to be greater than 90%,
- values of *SN* and *V* have to be lower than 10%.

We now define the *Critical Mass (CM)* of a specific scenario: *CM* is the minimum number of nodes, which are necessary to reach values of *C* and *AR* greater than 90% and *SN* and *V* lower than 10%.

Note that at this point, we assume that each node is continuously active. In reality, nodes often are switched off, which significantly increases the critical mass. We discuss this issue in a later section.

4.2 The Minneapolis Skyways

The simple area scenario gives a rough impression of the capabilities of MANETs. Thus, we conducted a more realistic simulation: the shopping centre in the downtown of Minneapolis (USA). The first floor of the towers in the centre of Minneapolis are connected via the so-called *Skyways*. Skyways and shopping levels form a network of ways for pedestrians. This scenario has several advantages:

- We have an exact map of all skyways (Figure 2a) and can easily put this map into the simulator (Figure 2b).
- Users and the corresponding *ad-hoc* nodes follow simple paths, thus it is easy to simulate a realistic behaviour of users going from one shop to another.

From all skyways, which have a total length of some kilometres, we chose a segment of nine towers. These nine towers cover an area of 440m x 408m. From this area, only the ways which are open for the public are used to compute *C*. Other areas, e.g., offices, hotels and museums, are not taken into account. In addition, we restrict the area to the first floor of each tower.

All nodes are indoors, thus we assume a communication range of 30m (which is the communication range of Wireless LAN IEEE 802b inside buildings). In our first simulation, we further assume that all nodes are continuously active. Figure 3a shows the results. In this scenario *CM* = 510.

4.3 The Role of Online Time

Until now, all nodes in our simulations are continuously active. In reality, power consumption is a limiting factor of mobile nodes, thus the operating system or the user often switches a mobile node off to safe valuable battery power. This problem becomes even worse if battery is drained by wireless network connections used to transfer foreign packets.

Batteries of current PDAs (Personal Digital Assistants) have capacities of 2Wh (PalmOS device) to 10Wh (Windows CE device). Wireless LAN adapters consume about 2W when transmitting packets. In addition, the Wireless LAN hardware, CPU and memory consume power to perform the *ad-hoc* routing protocol. Some Wireless LAN adapters have separate batteries to save power of the PDA's battery, however they typically have power for 2 hours network activity [22].

Notebooks have battery capacities of about 50Wh, but have to supply much more power-consuming parts. Typically, notebooks can be active for 2-3 hours. Assuming an online time of two hours in an observation time of 10 hours, we have a five times greater value of *CM*. In our skyway example, we have a *CM* value of 2550.

During the last few decades, mobile battery technology has made only moderate improvements in terms of higher capacity and smaller size [3]. There exist approaches addressing the battery problem especially in MANETs (e.g. [21]). However, if the battery technology does not significantly improve in the future, it will be a high barrier to introduce MANETs into a wider community.

4.4 The Role of The Communication Range

To examine the influence of the communication range, we carried out a number of simulations with different ranges in the skyways scenario and measure *CM*. Figure 3b shows the results.

We start the simulation with a range of 10m, which is the range of Bluetooth transmitters [19]. One observation is that the communication range has a very high influence on the critical mass. Using, e.g., Bluetooth instead of Wireless LAN, we have a four times greater value of *CM*.

As an important output, the communication range plays an important role for *ad-hoc* networks. Assuming unrealistic communication ranges, we can easily form a reasonable MANET. However, as we can see in our simulation, the critical mass dramatically increases when the communication range goes below a certain value. One could argue that the communication range for radio transmitters will increase in the future. However, having a larger communication range more nodes use the same radio resources (e.g. frequencies), thus the number of unwanted collisions increases. As a result, the communication range cannot go beyond a certain value, depending on the potential number of communicating nodes.

5 Conclusion and Future Work

In this paper, we introduced a number of metrics to measure the quality of MANETs. These metrics can be used as a tool to answer questions such as "*How many nodes are necessary in a specific area to obtain a reasonable MANET?*" or "*What communication range is required if we have a specific number of nodes?*". These metrics, together with the simulation tool, could help people who plan to form a MANET to investigate the effects of relevant parameters.

We carried out a number of simulations in different scenarios. One observation is that a relative high number of nodes is required to get a useful connectivity among the users. This number is even higher if we take into account that mobile nodes may not be active all the time or that we have smaller communication ranges (e.g. with Bluetooth).As a general result, the whole idea of *ad-hoc* networks may be questionable for many scenarios. The work has currently an analytical character. We can find out,if a specific network scenario leads to an acceptable MANET or not. This is a starting point to explore alternatives and variations of MANETs.

a) The original skyways map [15] b) The simulated skyways

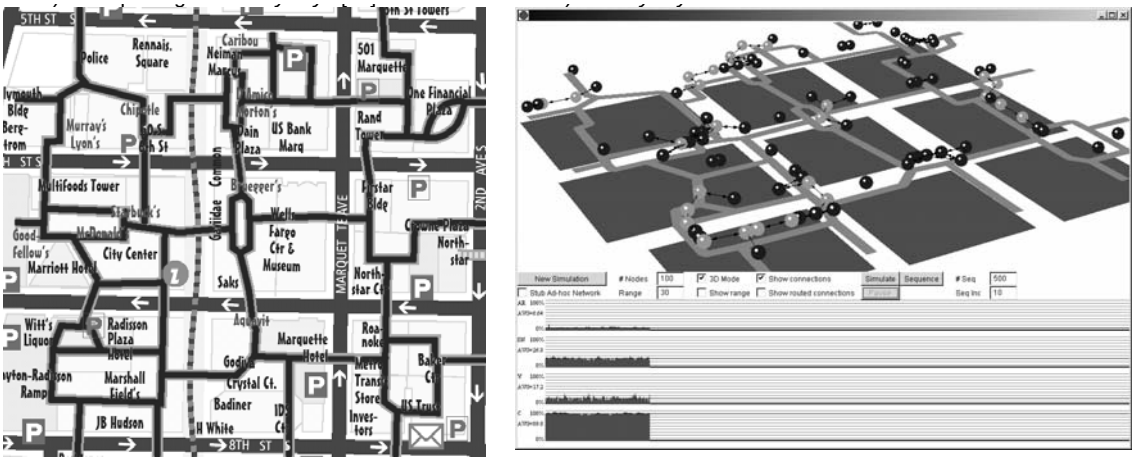
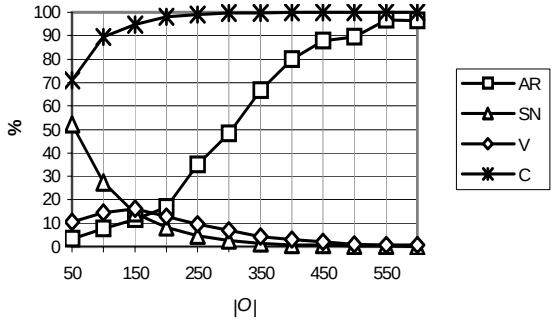


Figure 2: The Minneapolis Skyways.

a) Metric values for different number of nodes



b) The influence of range

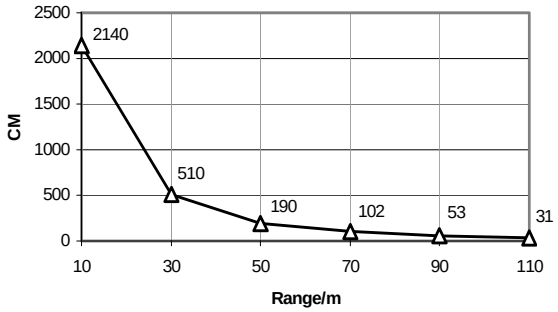


Figure 3: Results of The Skyway Simulation.

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Device and Context Influence on Wireless Infotainment Access: A Real World Story

Tacha Serif and George Ghinea

User considerations are paramount when it comes to take up of technologies, and even more so in the case of mobile devices, in which the success of a particular device often depends on its novelty appeal. However, relatively little work has been undertaken exploring how day-to-day tasks are affected when mediated by such access devices. This paper reports the results of an empirical study placed in a 'real-world' setting, in which participants undertook typical infotainment - combined information and entertainment access tasks on three different wireless-enabled mobile devices. These were a laptop, a Personal Digital Assistant and a Head Mounted Display device. Our results show that, with the exception of participants' level of self-consciousness when using such devices in public environments, the user wireless infotainment access experience is generally unaffected by device type. Location was shown, though, to be a significant factor when users engage in tasks such as listening to online music or navigation.

Keywords: Experimentation, Multimedia Access, Ubiquitous Computing.

1 Introduction

Portability, convenience and affordability are all factors behind the increase in take-up of wireless devices. Improvements in technology, especially in respect of computational processing capabilities, together with the homologation of the IEEE 802.11 family of wireless networking standards have pushed the barriers of anywhere / anytime multimedia communications.

While the allure of ubiquitous multimedia access still has novelty appeal, it is unlikely that appeal per se will stil l be enough in the future to sway customers to adopt such technologies if the expected infotainment (i.e. combined information and entertainment) return is not going to justify the initial outlay. However, whilst research in the area has focused on themes such as usability, multimodal interaction and haptics [1][4], the field of context aware computing has primarily concentrated on application-centred issues [5], and adaptation based on location and device [6][8]. Nonetheless, comparatively little work has been done examining the user context dependent infotainment access experience when this is mediated by different devices – which is the precise issue we address in this paper.

Accordingly, the structure of this paper is as follows: Section 2 presents an overview of mobile information access devices and reviews work done with respect to user experiences of mobile computing. Such work provides the foundation for our project, whose experimental method is described in detail in Section 3. Whilst Section 4 presents the results and implications of our study, Section 5 draws conclusions.

2 Mobile Information Access Devices and The User Experience

2.1 Laptops

It is only relatively recently, with the advent of 2.5-3G and WiFi technology that laptops have been able to harness the full potential of the Web wirelessly. Thus, a study on evaluation of clinical response to wireless technology by Seckman, Romano and Marden [9] focuses on measuring perceived usefulness, easy of use and impact of wireless technologies. Their results show that the nurses were the most frequent users of the wireless laptops, with 86.9 percent, and staff feedback show that the new technology is easy to use with no interference with medical devices. From another viewpoint, Rodriguez et al [10] compared PDA (Personal Digital Assistant) and laptop based versions of a nursing documentation application. In the study, both of the devices were wirelessly connected to the hospital mainframe system to enable collecting and entering patient's data at the point of care. 18 staff nurses participated in this study, selected from local teaching hospitals. They had no prior PDA experience, and their computer literacy ranged between 0.1 and 20 years. The results of the experiment show that it took nurses less time to look for vital signs me asurement and acknowledge a pending medical order on a PDA. How-

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ever it took them less time to read text and enter the vital signs measurements on a laptop.

On the other hand, from an applied computing aspect, Chu and Ganz [11] examined portable teletrauma system that assists health-care centres in pre -hospital trauma care. In this study, simultaneous transmission of patient's video, medical images and electrocardiogram signals, which is required though the pre -hospital procedure, is demonstrated by coupling a laptop computer with a commercially available 3G wireless cellular data service. The evaluation of the system revealed that the tool has the potential in reducing patient mortality when it is used by emergency services personnel to provide immediate care to the patient. However, the quality of the images and video transferred is reduced significantly due to the jitter and the delays caused by 3G wireless network (CDMA, Code Division Multiple Access) limitations.

2.2 Personal Digital Assistant

Personal Digital Assistants (PDAs) probably exhibit one of the most popular and easily recognisable showcases of portable computing, manifesting a 28% market growth in Western Europe in the second quarter of 2004 [12]. Nonetheless, they do inherit issues typical of mobile devices, such as small screen size, slow input facilities, low bandwidth, small storage capacity, limited battery lifetime and relatively slow CPU speed [1][2][13].

The apparent contradiction between the increasing popularity of PDAs and the above enumeration of problems have made PDAs a popular area of research. For instance, the Power Browser [1] was created to provide easy navigation in complex web sites using small screen mobile devices. Here, a proof-of-concept application implemented on a Palm operating system PDA uses an HTTP (HyperText Transmission Protocol) proxy that receives the requests from the mobile user and, based on the request fetches of the user, dynamically generates a summary view to be transmitted back to the client. Top Gun Wingman [13] is another transcoder targeted for the Palm operating system PDAs. Although similar to the Power Browser, this application not only provides ease of navigation but instead also converts the pages, images, and files (Zip / PalmDoc) to a browser-specific suitable format.

2.3 Head Mounted Devices

Head mounted displays (HMDs) are a sub-set of wearable computer technology, which aim to allow hands free access to computer functionality. They consist of two canonical displays, and usually comprise either two liquid crystal display (LCD) or cathode-ray tube (CRT) screens that are either mounted on a helmet or on a glasses frame structure.

It should also be noted that ergonomic and usability factors vary considerably between different types of HMD devices, with issues such as display size, weight and adjustability of physical and visual settings all affecting the usability of a particular head-mounted display for any specific task [14]. Additionally, the large and encumbering size of CRT -based HMDs is also an identified obstacle towards their adoption [15], as is the current high cost of HMDs that display both high resolution and a wide field of view.

However, despite the computational costs and usability drawbacks of the head-mounted displays, they are widely used in current research, ranging from virtual environments to wearable Internet applications. Thus, the Smart Spaces [16] project promises to implement anywhere / anytime automatic customisable, dynamically adaptable collaboration tools with the use of augmented reality and ubiquitous information access devices. The main driving force of this research is information access anytime / anywhere, whilst the user is engaged in other tasks.

Whilst such application-oriented research is attractive, the emphasis of our study, though, is on the user experience of mobile multimedia access. Accordingly, in the next section we provide an overview of work in the area.

2.4 Context and The User Experience of Mobile Multimedia Access

Context represents one of the main research themes in ubiquitous computing, with issues being examined ranging from an actual definition of the term itself [17], to the tailoring of context -dependent multimedia content [18], and the development of appropriate middleware support [19], to name but a few.

However, relatively little work has been done to explore how the user infotainment experience is affected by context, with most studies concentrating on user evaluations of tailored multimedia content and totally ignoring multimedia's infotainment nature – i.e. focusing either on informational or entertainment content and tasks, but not both. Thus, Freire et al. [20] developed WebViews, an application which performs transcoding of traditional web content so that it could be accessed via mobile devices. Here, the user creates views o f any web content that would like to access on -the-move and saves them into his/her profile. The WebViews server then reformats the profile contents and sends the data to the requesting mobile device (PDA, WAP-enabled phone or mobile phone, where WAP stands for Wireless Application Protocol) accordingly.

From a different perspective Muñoz et al. [21] studied the use of context -aware handheld systems in hospitals. The implemented system attempts to manage the hospital information flow using the Internet Messenger (IM) paradigm and by getting the support of context. The contextual elements used by the system are location, delivery timing, role reliance and artefact location and state. Using this system, with the support of IM -like approach on a handheld device, the doctors, nurses and support staff can share information about the patients between their colleagues in the same shift or other shifts. The evaluation of the system, by 28 hospital staff members, showed that 91 percent of the participants would use the system. Additionally 84 percent believed that using the system would enhance their job performance and 78 percent perceived that the system would be easy to use

Although in their work Gulliver et al. [22] have explored how user perceptions of variable multimedia quality are affected by access devices of different mobility, however, to the best of our knowledge no work has been done exploring how a user's experience of mobile information access is affected by the user context as well as the different access devices that (s)he is utilizing. This forms the focus of our current investigation, whose methodological approach we now detail.

3 Experimental Method

3.1 Participants

Participants in our experimental study were aged between 18-53 years old and were drawn from various professional backgrounds (students , academics, psychologists, nutritionists, bankers, blue-collar workers). A total of 36 people participated in the study.

3.2 Experimental Variables

Experimental variables in our study included: device type, computer expertise, user location, and task group type. Accordingly, our study incorporated three different types of mobile access devices – a laptop, a PDA, and a head mounted device – all of which boasted varying information display capabilities, as shall be described in Section 4.3 and varying degrees of portability (these range from a relatively bulky laptop, to a handheld PDA, to a wearable HMD The experiment took place in two different settings – one was an 'on-the-street' setting, in which participants accessed information whilst physically being on a busy high street bench; the other was a 'coffee shop' setting in which participants accessed the Web from a café. Lastly, as part of the experiments, users were asked to perform two groups of tasks, each of which reflected one of the main reasons behind users' wishes to access multimedia content – accordingly, one group of tasks was mainly informational in nature, whilst the other was entertainment-related.

3.3 Experimental Material

Three different types of devices were used in our experiments. The firs t device was a Hewlett Packard laptop equipped with a 54Mbps Netgear PCMCIA wireless network card. The laptop ran the Microsoft Windows XP operating system, and was equipped with 128MB RAM, a 15-inch screen transflective Thin Film Translator (TFT) screen and a 910 MHz Mobile AMD Athlon XP 2000+ processor (Figure 1a). In our experiments, the laptop represented mature technology.

The second device was an HP iPAQ 5450 PDA with a 16-bit touch-sensitive TFT LCD that supports 65,536 colour. The display pixel pitch of the PDA device employed is 0.24 mm and its viewable image size is 2.26 inch wide and 3.02 inch tall. The device incorporates WiFi 802.11b connectivity as standard and runs the Microsoft Windows for Pocket PC 2003 operating system on an Intel 400Mhz XSCALE processor.

The third and last device employed in our study was an Olympus Eye-Trek FMD 200 head-mounted display. This used two LCD displays, each one of which contains 180.000 pixels with a viewing angle of 30.0° horizontal and 27.0° vertical (Figure 1b). Although the HMD by itself is not wireless enabled, it was interfaced via a Lifeview Fly Jacket with the PDA employed in our study, and thus connectivity was ensured.

3.4 Experimental Set-up

Our study involved real participants engaged in real-life tasks in realistic scenarios. These tasks involved users searching for their nearest shopping centre on the Web, and then locating sports stores in the centre, also via the Web. Once this was done, participants had to physically go to the identified sports stores (there were two) and had to obtain price information on a specific good (a sports shoe, in our case), Once this was done, participants had to find the corresponding price for the good over the Web and e-mail the cheapest price found to a friend via e-mail.

The second task was mainly entertainment-related. This comprised users listening to a mainstream online radio station, noting down the details of the track currently being played and then searching for the album cover of the respective track on the Web. Once this was done, users were asked to download the cover on their device for future reference in a music store.

These two tasks were undertaken in two different real world environments. The first involved users accessing the

Figure 1: a) On-the-street Scenario Using A Laptop); b) Coffee-shop Scenario Using An HMD.

Information	Entertainment
Q1: It is easy to logon to the Internet.	**Q1:** It is easy to navigate through the *Virgin Radio* website.
Q2: It easy to navigate through search results on the device.	**Q2:** It is easy to listen to online radio.
Q3: It is easy to find sports shops in the malls near to you.	**Q3:** It is easy to identify the track that is playing.
Q4: It is easy to read maps on my device.	**Q4:** It is easy to interact with the device.
Q5: It easy to find online prices of the product and make a comparison. **Q6:** It is easy to send e-mails.	**Q5:**It is easy to do searches on the Web. **Q6:** It is easy to access information and save it on my device.
Q7: I am comfortable using the device in a public place	**Q7:** I am comfortable using the device in a public place

Table 1: Infotainment Questionnaire.

required information needed to fulfil their tasks on a busy high street bench, whilst the second involved users undertaking the same set of tasks in a comparatively secluded café. Both locations were covered by WiFi blankets.

The 36 participants involved in our study were evenly assigned to one of the two environments and, moreover, participants were also evenly distributed as far as the use of the three experimental devices is concerned, with 12 participants being allocated for the laptop, PDA and HMD, respectively.

3.5 Experimental Process

Before undertaking the experiment, all participants were verbally explained that the experiment consisted of two main groups of tasks, which they should accomplish at their own pace. Once this was done, they were given the respective experimental devices they were to use towards the accomplishment of the tasks. Although users did not need to log on to any of the devices, they were given the user name and password needed to log on to the wireless internet service provider employed in the study.

For each of the tasks involved, participants were asked to indicate their opinions on a 5-point Likert scale (strongly agree, agree, neutral, disagree, strongly disagree) to a series of seven statements concerning the tasks (Table1). Once this was accomplished, users could indicate in writing any further comments that they had about their experience. Lastly, participants were thanked for their time and effort.

4 Results

4.1 Device Impact

A one way Analysis of Variance (ANOVA), with type of device as independent variable revealed that, with the exception of four tasks, across the two scenarios of our study, the particular device type does not have a significant impact on the user infotainment access experience. This observation holds true, even though, as Figures 2 and 3 show participant mean opinions scores for the HMD were (with only one exception) consistently lower than that of the other two devices considered in our investigation. The one exception to this trend is users' ability to identify the currently playing track on the visited online radio station – in the case of the HMD this was facilitated by three factors: the first is that the online radio site had a mobile version tailored for PDA browsers (the HMD accessed the web through the PDA, as previously mentioned); moreover, in this version the details of the current track being played were placed on top of the page, in an instantly viewable location.

The particular type of device employed was shown to have a significant impact on the user infotainment access device in the case of reading maps from the screens of the device ($F=9.420$, $p<.01$), and users' comfort factor with respect to using a mobile information access device in a public place ($F=6.492$, $p<.01$). We believe that reasons for the first finding is that most maps that people found online had virtually unreadable labels – this problem was exacerbated in the case of the small screen PDA, whilst in the case of the

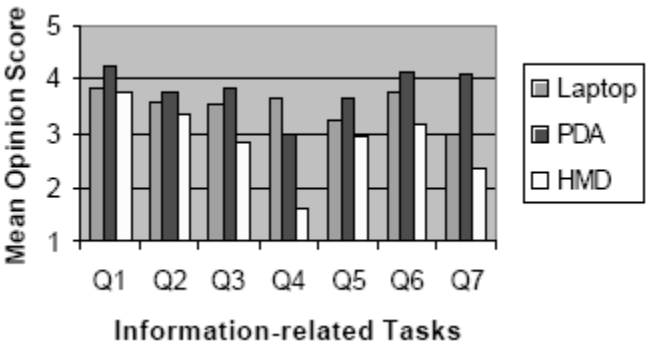

Figure 2: Device Type Impact on Participant Mean Opinion Scores for Information-related Tasks.

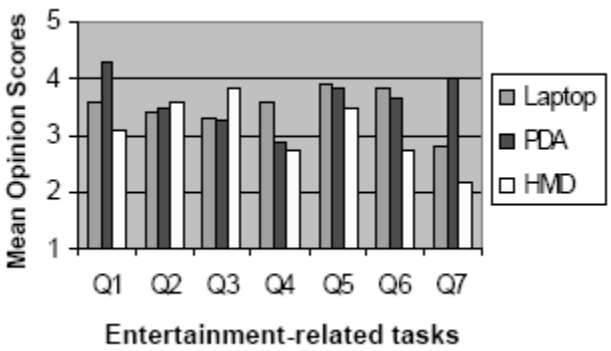

Figure 3: Device Type Impact on Participant Mean Opinion Scores for Entertainment-Related Tasks.

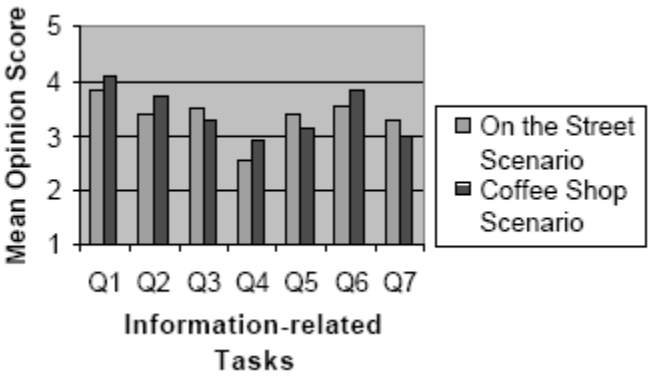

Figure 4: Impact of Location on Information-related Tasks.

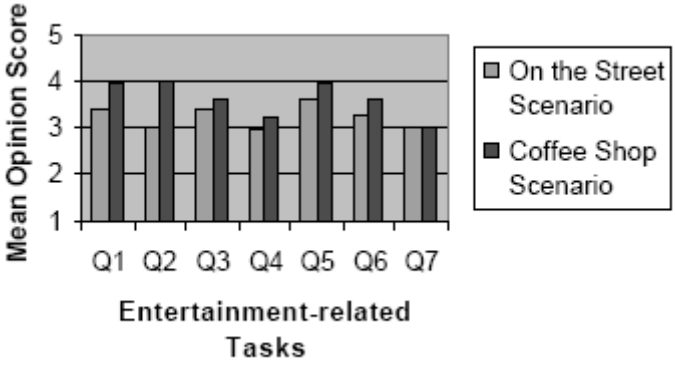

Figure 5: Impact of Location on Entertainment-related Tasks.

HMD, which did provide full immersion, this was done so at the expense of resolution. As far as the second observation goes, the participants who wore HMDs should feel particularly self-conscious in public places, as would those accessing information via relatively bulky laptops – people were most comfortable with using the PDA as an information access device in a public context, which might be one of the main drivers behind their popularity. In the case of entertainment-related tasks, type of device was found to have a significant effect on users' navigation on the online radio website ($F= 4.295$, $p<.05$) and, again, on their comfort factor associated with using a wireless access device in public ($F=7.869$, $p<.01$). Whilst we have already elaborated upon what we believe are the reasons behind the latter, we believe that the reason for the forme r observation lies in the fact that many users found it difficult to navigate through a website using the point-and-tap functionality of the stylus whilst wearing the HMD.

4.2 Location Impact

An independent samples t-test revealed that information-related tasks were not affected by the particular location of the user (Figure 4). However, as far as the group of entertainment-related tasks is concerned, navigation ($F=14.331$, $p<.01$) and ease of listening to online radio ($F=11.824$, $p<.01$) was found to be significantly affected by user location (Figure 5).

These results highlight that when a user is engaged in accessing content for informational purposes, (s)he is prepared to disregard possibly detrimental environmental factors such as noise and lighting levels. However, when accessing entertainment related material, levels of lighting (brighter and sunnier in the 'on-the-street' scenario) affect the glare of the device being used, and, as such, negatively impact upon the user experience. In the relative seclusion of a café the experience is perceived to be more enjoyable than when attempted in a busy and noisy outdoors environment.

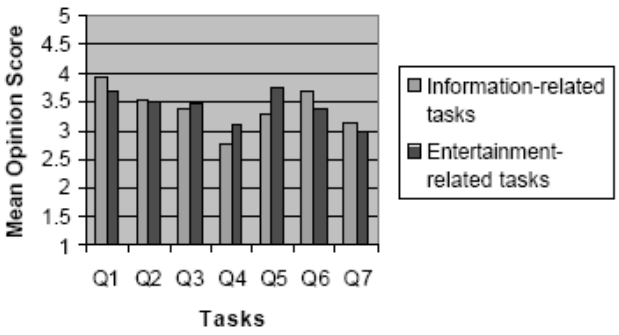

Figure 6: Information vs. Entertainment – The Impact on User Mean Opinion Scores.

4.3 Infotainment Impact

Most Web users access content comprised somewhere on the infotainment spectrum – and in this empirical study we wanted to investigate whether a user's perception of ease of information access varied significantly between situations in which one was engaged in primarily informational-related tasks and those where wireless Web access was done for predominantly entertainment purposes.

Analysis of our results revealed, however, that there were no significant differences in users' perceived ease of information access between the two main categories of tasks considered in the study (Figure 6). Although we are surprised at this finding – for we were expecting user tolerance levels to be higher in the informational-related tasks – we believe it highlights the fact that users have equally stringent expectations for both information- and entertainment-related tasks. Whilst in the former case, emphasis might be put on the quality of information retrieved, in the latter the focus might be on the quality of the playback media – whilst the emphasis might be different in the two scenarios, expectations are certainly not.

5 Conclusions

This paper has explored the user wireless infotainment access user experience, when this is mediated by three different access devices in two real world settings. Whilst we recognize that participant sample size could be improved in our study, our results highlight that although mobile device types seem to heighten user levels of self-consciousness in public places – particularly if the device in question is a wearable one – generally the user experience is unaffected by the type of wireless device responsible for it. Moreover, whilst ambient noise and light do impact on users' efforts to wirelessly access entertainment content; such factors, however, are ignored when informational content is soug ht, though.

Our work has raised the prospect of interesting future research, the main thrust of which will be covered by context and location-based adaptation, and it is in this direction that our future efforts shall be concentrated on.

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The Problems of Printing in Server-Based Computing Environments

Luis Bengochea-Martínez

Server-Based Computing (SBC) allows to run native applications installed in remote servers and accessing them from thin devices such as a personal computer, a PocketPC, a Smartphone or a PDA (Personal Digital Assistant). The TCP/IP (Transmission Control Protocol/Internet Protocol) connection with the server could be made through public switched telephone networks, mobile data services like GPRS (General Packet Radio Service) or UMTS (Universal Mobile Telecommunications System), Ethernet, wireless networking, or VPN (Virtual Private Networking). This technology permits the employees of a company to run the corporate applications from any location. Nevertheless, SBC environments have problems to print documents generated by those applications, firstly due to the need to install, in the servers, many printer drivers, but also due to the high bandwidth required by the printing data flow. In this article, an overview of the SBC technology is offered, showing the specific printing problems in these environments and proposing a solution based on the use of PDF (Portable Document Format) files to replace all print outputs produced by the applications executed in this way.

Keywords: Free Software for Ubiquitous Computing, Server-Based Computing, Thin Client.

1 Introduction

Before the irruption of personal computers, all computer applications were run from physical terminals (VT220, IBM3270, etc.) connected to the enterprise mainframe or central computer either locally, or from a remote location through the use of a modem and a phone line.

When the use of personal computers was generalized and applications started to be developed for them, - with development costs much smaller than those that the applications in the great systems or mainframes use to have -, the client-server paradigm became popular. In these programs, the applications are divided in several layers, the first of which, including the presentation and local data validation levels, is executed in the personal computer – "Client" -, while the other application layers execute in the central computer – "Server" – where, at the same time, several application layers could exist, speaking then about "client-server-server", etc. One server program can simultaneously serve several client programs, which, for years, allowed the companies to distribute programs between their clients to carry out different tasks (to see accounts' balances, to carry out an order, etc.).

The main problems of this paradigm were:

1. The need to distribute the "client" piece of the application the first time that it was going to be installed in the remote computers, as well as every time that modifications and improvements were carried out.
2. The different operating systems on the client side's computers require developing specific programs for each of them. This fact complicated the process of deployment and maintenance.
3. The same customer could be required to install numerous applications sent by the companies he worked with, sometimes to do identical tasks, but with different interfaces and terminology.
4. Low levels of user expertise in the installation and use of the "client" programs, together with the resolution of the incidences produced, forced companies to create and maintain costly call centers for attention and support.

Internet and its associated technologies, based on the use of Web servers to run applications that are accessed through universal browsers such as Internet Explorer or Netscape Navigator, caused the decline of the client-server technology, since they came to give solution to some of the problems previously described.

The "webization" of applications appears so as the ideal solution to implement an ubiquitous office, in which the employees – and also the company's customers - can use corporative applications regardless their location – in his/her office, at home, in an airport, - or the kind of terminal they are using – a desktop computer, a tablet PC, a PDA (Personal Digital Assistant), etc. Likewise, the arrival of Java and all its associated technologies has permitted a fast transformation of existing applications, thus favoring the wide deployment of this new way of working.

Nevertheless, a large quantity of applications used in enterprises it still remains that, for different reasons, can not be redesigned to take advantage of this new paradigm, for example:

- Legacy applications, for which the lack of knowledge or the necessary technology avoids redesigning them.

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- Applications acquired from software vendors, whose license agreements oblige to use them just as they are designed.
- Applications developed by public organisms (as community aids, settlements of taxes, etc.) of obligatory use by the companies, which must be used as they were conceived.
- Applications that, due to their own nature, do not accept a design that would allow their execution on a Web server.

Most of these corporate applications, except for legacy applications or those that are executed in a mainframe, have graphical user interfaces and cannot therefore be accessed from a simple text terminal emulator. Besides, we can find other applications that are executed under different operating systems and in different environments. The solution to this problem consists in executing the applications in its natural environment and transporting to the user device, by means of an appropriate communications protocol, each and every screenshot produced by the application. At the same time, the strokes in the keyboard and the mouse events produced by the user should be also sent to the computer where the application is being run. This technology, which requires multi-user capacities on the application servers, is called Server-Based Computing or SBC.

It is in fact a hybrid solution between the use of Web applications and the traditional client-server applications, which avoids installing and maintaining pieces of software in the remote user's computers and facilitates a rapid deployment and an effective maintenance of the applications, due to its centralized character [1].

2 Server-Based Computing

2.1 The Predecessors

The X-Windows system, developed in the MIT (Massachusets Institute of Technology) in the eighties [2], can be considered as the predecessor of SBC systems. Initially developed to be used in small workstations with access to applications running on large Unix systems, X-Windows became a *de facto* standard for remote access to operating systems such as OSF and Linux. At the beginning of that decade, hardware terminals were built for the mentioned purpose and known as X-terminals, although they were replaced by emulation programs due to the subsequent popularity of the use of desktop computers running Windows systems. The problem of X-Windows was the need of utilizing a complex protocol, with a very rich set of functionalities, that required high bandwidth, which made it useful only when the X-terminal and the applications server were both connected to a local network or to a high-speed WAN (Wide Area Network).

Besides, the X-terminal that executes a heavy X-server needs heavy computing resources, what makes impossible to use a thin client, like a PDA, precisely one of the premises for ubiquitous office. The security model of X-terminals also suggests the existence of a number of problems, since the traffic could be scanned and passwords could be extracted for malicious access to critical enterprise resources. This is the reason why some system administrators forbid its use out of the militarized network area.

The following step to SBC was the VNC (Virtual Network Computing) system [3], developed by the Oracle Research Laboratory. It consisted in two software pieces: the VNC Server, which should be installed in the server – that could be a simple desktop computer running Windows or Linux operating systems –, and the VNC Client, installed in the client device and based on Java (this allows the existence of different versions for all kind of thin clients). The underlying technology is a simple protocol that acts at frame buffer level and therefore is susceptible of being used on any operating system and with any transportation protocol, like TCP/IP (or even with USB - Universal Serial Bus). VNC has the additional advantage of being distributed under GNU (Gnu's Not Unix) license. It is mainly used to implement solutions for ubiquitous office where a company's employee can access his/her desktop computer (placed in the corporate headquarters), from anywhere in the world where his/her thin device can be connected to a network. It would be able to do it even from a Internet cafe or from a public console with Internet access like those installed in some airports. Once s/he takes control of his/her computer, s/he would be able to run any application as if s/he was seated in his/her workplace.

The arrival of Windows NT Server had a very significant impact on commercial computation. Numerous applications, like database systems, e-mail servers, Web servers and other, migrated from large systems such as Unix or VMS to the new NT servers. A small company, Citrix, had the idea of taking advantage of NT's multi-user capacity to make the server work not only in providing services to the network applications, but also in opening several users' sessions. In each of these sessions, a user with his/her computer works against the server, and his/her computer screen visualizes the graphical output produced by the server that, simultaneously, is receiving his/her keyboard and mouse events. The system, called Winframe (a word derived from the fact that this system was aimed at converting a NT server in a Windows mainframe) also included an optimized protocol to transport screen, keyboard and mouse information flows between the server and its clients. This protocol was called ICA (Independent Computing Architecture).

There have been other different approaches to SBC, like the launching of a new ultra light device by Sun, in September of 1999, called Sun Ray Enterprise Appliance, a device without a CPU (Central Processing Unit) and without a memory. Its only mission consisted in sending the keyboard and mouse events to the server and receiving the pixels in order to represent images on the screen. Nevertheless, it lacks an optimized communications protocol, what forces a connection with the server to be made through an Ethernet network. This kind of devices can be useful in environments where workstations are not PCs, but they cannot be considered thin clients good enough as to be part of a ubiquitous office.

2.2 SBC Today

When Microsoft understood the potential of the SBC solution – developed by Citrix for its operating system NT Server -, it acquired a part of the Citrix technology used in Winframe, to develop its own SBC solution, called Terminal Server. It included a new communications protocol called RDP (Remote Desktop Protocol).

At present both solutions coexist, although in both cases they are proprietary solutions, what means that licenses must be acquired, involving a cost, to use them. Microsoft's Terminal Server provides multi-user capacity to a Windows server that can be accessed from client computers running any Windows operating systems, by using the RDP protocol. This allows the applications running on the server the use of local devices, such as disks and printers, in the thin client. In order to install and use Terminal Server a CAL (Client Access License) license is required for each thin client using the SBC, except for those having Windows 2000 or a newer "professional" operating system installed.

On the other hand, Citrix's Metaframe requires having Terminal Server previously installed (for Windows servers), and provides several additional services:

- Different thin clients can be used (not only Windows-based ones), what includes Java based devices.
- It can be used on UNIX and Linux servers to provide access to applications developed in these operating systems.
- Many devices in the then client, like disks, printers, serial or USB ports, or audio cards can be accessed from the server.
- It provides a centralized management of "farms" composed of hundreds of application servers, with load balancing.
- The ICA protocol, optimized for low bandwidth, permits to use any type of communications, from local networks to mobile GPRS (General Packet Radio Service) or UMTS (Universal Mobile Telecommunications System) ones.
- It uses the RSA (Rivest-Shamir-Adleman) encryption to protect the information transmitted between server and client, what could be a mandatory requirement to run given applications from locations out of the enterprise internal network.

Other solutions exist, like Tarantella (before known as Santa Cruz Operation), a proprietary solution mainly oriented to provide access to Unix and Linux servers, although also supports Windows servers using Terminal Server or Metaframe.

3 The Mobility Challenge

Many enterprises believe that the mobility of their employees is a competitive advantage. There are studies, as the one carried out by Volchkov in 2002 [1], showing that currently more than 10% of the employees run corporate applications from remote locations during more than a half of their worktime. Therefore, a challenge to the data processing departments consists in providing good systems for mobility, minimizing maintenance problems and guaranteeing the security.

At present, SBC technologies allow, in the client side, minimizing hardware and software maintenance costs by avoiding connections from computers with local applications, different antivirus protection, etc. On the server side, installation and maintenance of applications are carried out in a centralized form, these applications being accessed in an identical form both by employees physically located in the building and by those that are traveling [4].

Although Internet could be utilized to access the enterprise servers, a VPN (Virtual Private Networ) can be established before using an application, and then utilize the same mechanisms of logon and the same passwords as those used

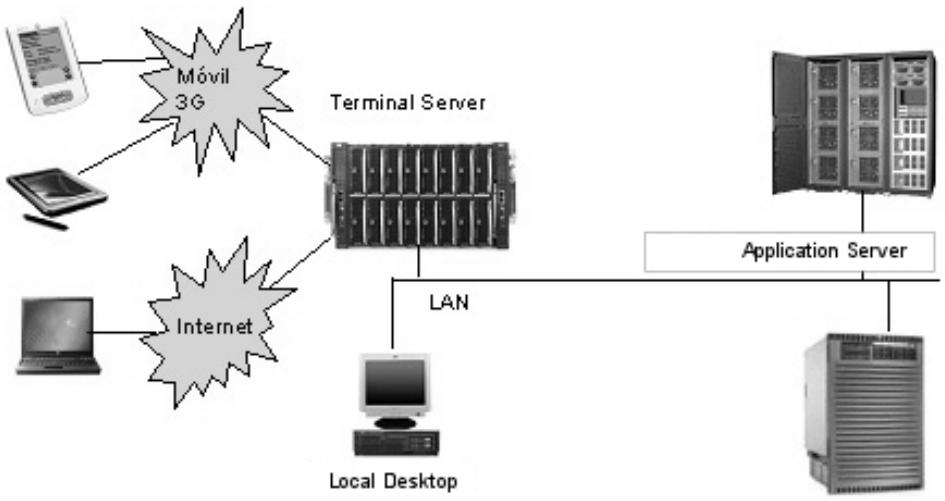

Figure 1: A Terminal Server Can Act as An Intermediate Level between All The Corporate Applications (Including Web-Based Ones) and Thin Client Devices.

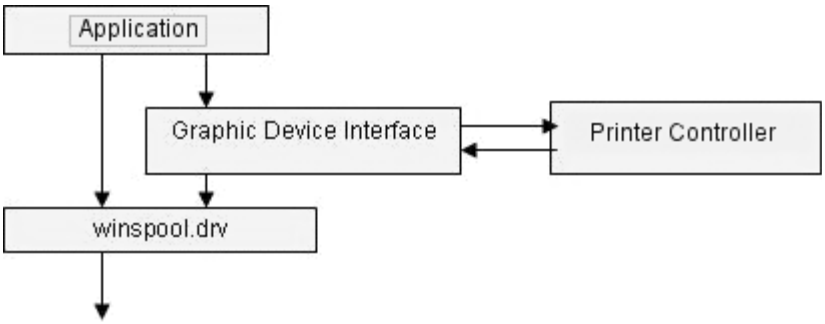

Figure 2: The First Part of A Print Process Consists in Submitting A File to The System Spool with Instructions about how The Designed Printer Should Produce the Desired Printed Output.

in the desktop computer. SBC systems that encrypt communications provide additional confidentiality. Besides, by centralizing also the office applications, the risk for the company's security associated to loss or theft of a laptop computer is prevented.

The SBC technology appears as well as a universal solution to mobility, since it permits the use of thin clients and mobile communications with low bandwidth, and transforms the terminal servers in the entry point for all the enterprise applications, from Web applications to classical client-server applications or even specific applications on Unix or mainframe systems, as shown in Figure 1.

Of course, when very light devices with small size screens and very limited capacity of process are used (e.g. PDAs), the number and kind of corporate applications that can be run decreases.

On one hand, the nature of the application could make impossible its use in this type of devices, but, on the other, the perception that users themselves have of these devices, particularly if they are connected through a low speed network with a high latency, persuade them from running applications not specifically designed for the device. In this sense, studies have been carry out [5] to measure the relation existings between the degree of satisfaction of mobile users employing light devices and the typical metrics in a communications network (as bandwidth and latency), with the objective of identifying the limits associated to the use of very light mobile devices.

4 The Problem of Printing in SBC Environments

Although almost all SBC commercial systems provide the capacity of "mapping", from the server, the local printers at the thin client - if those printers exist –, printing remains one of the weak points for the mobility solutions provided by SBC.

The problems arise, fundamentally, from the nature of the printing processes implemented in the different operating systems, most designed under the assumption that physical printers are directly connected to the computer where the application is being run or, in other cases, to a print server connected through a high bandwidth communication access.

4.1 Basic Description of The Print Process

Although the description of the print process and the proposed solution that follows correspond to Windows-based operating systems [6], it is also applicable, with very light changes, to other operating systems.

When an application needs to produce a printed output, the first step is to call the Graphic Device Interface (GDI) that is responsible for creating a visible output. In order to do this, it should call the specific driver associate to the chosen printer. With the document information originated in the application, the GDI interface exchanges data with the driver to process the print work in the printer's language and, subsequently, the data to be printed are transferred to the printer's queue (see Figure 2).

The type of data generated by the print work can be RAW, that is directly interpretable by the printer, or EMF (Enhanced MetaFile), that permits a little reduction in the file size and improves the traffic between the system spool where the printed output originates and the print server the printer is really connected with (however, this is true only in the case that both elements use Windows). In the case of printers supporting the PostSscript language, PostScript files (PS) could also be used.

Depending on whether it uses or not a print server, the print spooler, which is a set of DLLs (Dynamic Link Libraries) and drivers that receive, process, plan and distribute the print works, submits the work to the local printer provider or to the remote printer provider (who will in turn transfer it to the spool in the print server connected to the printer). In the case of a printer connected to the thin client and mapped by the application server, the file is submitted to the client spool where it will be processed by the local operating system as if it was a local printing.

Once the file has been placed in the spool of the server computer the printer is connceted to, it is submitted to the printer monitor (if the printer has bidirectional communication, a language monitor supervises the bidirectional communication between the sender and the printer), who transfers it to the port (LPT, COM, TCP/IP port, etc.), whose monitor, at the same time, submits it to the target printer. Finally, the printer receives the work, translates each page into the appropriated format and 'physically' prints it.

4.2 Printing in SBC Environments

According to the discussion in the previous section, it can be noticed that the two main problems related to printing in the design of a solution for an ubiquitous office based on SBC are the following ones:

- Application servers need that the drivers of all printers connected to the client devices are installed. Each time a new local printer is connected to an employee's laptop, it will be necessary to install its driver in all SBC servers of the company.
- Since the RAW, EMF or PS files to be printed were not designed to be transmitted through a communications network, they use to have a disproportionate size that could prevent receiving them in a client computer in a reasonable time (see Table 1).

The first problem can be alleviated by implementing centralized procurement polices, in such a way that only printers that have been previously approved by the managers of the data processing department are acquired, printers whose drivers should have been tested and installed beforehand in every SBC server. Nevertheless, the huge amount of new models of printers that appear every day at the marketplace, including new improvements and different features, as well as the disparity of mobile devices that can be use to connect them, makes this solution scarsely realistic.

In SBC proprietary solutions, universal controllers are provided (usually PCL) that can be used for almost any class of printer, but with the inconvenient of being too rigid an approach.

For the second problem, the only possible solution is forbidding the transmission of RAW print files, establishing only one final format for all printed outputs – e.g., PDF (Portable Document Format) - and transmit the print files in this format to be locally printed in the client device. This solution also permits that employees with mobile devices without printing capacity can keep their printed outputs in disk for subsequent uses, send them to the printer in a business office close to their location, submitting them via e-mail to another employee or to any other person, etc.

5 A Free Software-based Solution

In order for any application running on a server to be able to produce printed outputs in PDF format, it is necessary to define a logical printer (not connect to any real printer) that produces a PDF file every time a print job is submitted. Although proprietary solutions exist, like Adobe's Acrobat Distiller, the proposed solution is based on the use of two free tools:

- RedMon (Redirect Monitor) that permits to define ports whose monitor, instead of sending the print file to a physical device, redirects it to the standard input (stdin) of a program set by the user. It is distributed under a free public license, and is available at <http://www.cs.wisc.edu/~ghost/redmon/>.
- Ghostscript, a PostScript interpreter that permits to generate an output in PDF format. It is available, under GNU license, at <http://www.cs.wisc.edu/~ghost/>.

5.1 Defining A PDF Virtual Printer

Once the above mentioned products have been installed, we can define a new virtual printer for each SBC server, which will be the one to be used by the thin clients connected to that system. To do this, the following steps should be followed:

- Create a new port (RPTn:) of type "redirected port" to connect the new printer.
- Select, among all the postscript printers run by the operating system, the model that better fits our printing needs, basing the decision on criteria such as whether it permits or not the use of colors, resolution, and the like.
- Install as if we had a real printer of that model, defining the default printer parameters (paper class, resolution, color, etc.).
- Open the printer properties and modify the configuration of the RTPn: port where it is connected, using the following parameters:

- Redirect the port to program: C:\gs\gs8.50\ bin\ gswin32c.exe (or a different folder where Ghostscript was installed).

- Program arguments: -q -sDEVICE#pdfwrite -dNOPAUSE -dBATCH -dSAFER -dCompatibility Level# 1.2 -sOutputFile="%1" -_ (where "-_" indicates that "stdin" will be the data entry and "%1" that the output file name will be the one that the user decide before a work is printed).

- Output: choose the option "Prompt for filename" for a value to replace the default "%1".

File format	Size
Original (MS Word)	4.052.480 bytes
RAW file in PCL with 600dpi	34.828.288 bytes
RAW file in PCL with 300dpi	15.265.792 bytes
PS file with 600 dpi	9.654.261 bytes
PS file with 300 dpi	9.631.344 bytes
PDF file	2.052.096 bytes

Table 1. Original Size of A Test File and The Sizes Of Print Files Generated According to The Printer Type and Resolution Used.

When a remote user opens a session in a server where a PDF printer of this kind has been set, s/he will be able to use it as a normal printer. S/he will also be able to use the PDF files produced this way in the form that s/he considers to be more convenient according to the type of device that is using and the bandwidth of the communications network to which is connected.

6 Conclusions

The SBC technology permits a company to establish a unique way of accessing all its corporate applications, including personal productivity ones such as Microsoft Office. This can be done by using any thin devic for which a SBC client exist, from anywhere, and using any communications network.

In the case of applications that produce printed outputs, PDF virtual printers can be defined to be used by the thin clients that have no physical printer available, as well as to reduce the size of the print files that must be transmitted from the server to the client. This gives also new possibilities for using those documents in PDF format, such as sending them out via e-mail or keeping them stored in disk for subsequent processing.

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Using FOAF to Support Community Building

Brian Kelly and Leigh Dodds

The Semantic Web seeks to build a global distributed database through the integration of data from independent communities without the requirement for prior agreement on the structure of this data. This basic concept can be applied to the development of online communities. This paper outlines the potential for the FOAF (Friend Of A Friend) Semantic Web technology to ensure that resources can be defined in a way that promotes their ability for being shared with third-parties with a minimum of integration effort. The paper outlines FOAF's potential for community-building in conferences.

Keywords: Community Building, FOAF, Friend Of A Friend, Semantic Web.

1 Introduction

There is increasing potential for Web-based systems to support collaboration in many areas including education, business and social activities. As might be expected at this early phase of development we are seeing many products being developed. The wide range of different approaches used to construct collaborative tools is also evident, covering the well-established use of email, through to bulletin boards, instant messaging, video-conferencing, virtual conferencing, online voting, annotation, blogging, etc.

The dangers of application lock-in are well-known. The dangers apply in both commercial and open source software environments: in the commercial marketplace companies go out-of-business or are taken-over resulting in products becoming unavailable or unsupported; open source projects have similar longevity issues, with projects becoming moribund, unfashionable or superceded by other more successful solutions.

The data created within collaborative systems of all kinds has a potential to be of long term interest; indeed in the long term it is the data and not the individual products that are likely to be of real interest. We can envisage a need to ensure that not only message archives can be ported across collaborative systems but also richer forms of data, such as voting results, calendar entries, etc. Even in the short term there are advantages to be gained from easing data migration between systems, avoiding the need for end-users especially to reinvest effort in entering the same data into multiple systems. There is therefore a need to address the issues of migration of data across collaborative systems.

2 About The Semantic Web

The main advantage of XML (eXtensible Markup Language) is that developers can rapidly devise new document types that, because of their adherence to a basic syntax, can be easily manipulated in a number of standard ways. Beyond basic parsing these manipulations are described by the larger "XML family" of specifications that define standardized methods of transformation, inclusion, linking etc. With the addition of standard programmatic interfaces for manipulating XML data, this results in a great improvement in interoperability, allowing much easier processing and movement of data between systems. The end result has been that XML has been tremendously successful and has penetrated into many different kinds of application.

However at a slightly higher level XML adds little to the ability of applications to interpret or combine the data being transferred: XML applications have to be extended each time a new document type must be processed. Building knowledge of a wide range of XML formats into an application can be very time-consuming; only in the most trivial of cases can simple transformations be applied. This results in a continuing investment in application integration. One solution to this problem is to define a standard document type for interchange. However consensus-building is always a time-consuming process and such a solution only works for well-defined communities. For a looser community discovering the common ground ripe for standardization is much harder, typically resulting in extensions or variants in a format which mitigates some of the sought-after benefits.

The Semantic Web effort is aimed at tackling these integration efforts head-on, by building an infrastructure which greatly facilitates the merging of disparate data sets, allowing the creation of what might be regarded as a global "web of data". The key to this infrastructure is the Resource Description Framework (RDF) [6]. While RDF is an XML application, it emphasizes the data model over syntax: while

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XML may be said to provide benefits by defining a common syntax, RDF derives its benefits from mandating a common underling model for representing data.

The RDF model is graph-based, containing resources (nodes) that are identified by a URI (typically a URL) and statements about them (arcs). The reliance on URIs means that RDF is intimately tied into the web infrastructure, while its mathematical underpinnings give it a rigorous definition. Although its basic elements are quite straight-forward, RDF can be a difficult concept to grasp and interested readers are directed to the RDF FAQ [7] for more information.

3 FOAF

Due to perceptions about complexity many Semantic Web applications are still being developed within the Web research community [8] with a slow but growing penetration into other areas; growth has certainly been nothing like as rapid as that of XML. One Semantic Web application noteworthy because of its active grass-roots development and user-centric focus is FOAF (Friend Of A Friend).

The core of FOAF is simple: provide a RDF vocabulary for capturing metadata about people. One interesting piece of metadata is a person's relationships to others; it is from this aspect that FOAF derives its name: "Friend-Of-a-Friend".

FOAF then, captures data pertinent to social networking applications and studies. Social networks are a current hot topic, with many applications appearing that are intended to allow people to mine their social networks for business and employment contacts, dating and friendship opportunities, product and reading recommendations, etc.

As well as directly relating people, FOAF also provides a vocabulary for describing a persons interests, their membership within groups of people and their project involvement. Other terms in the vocabulary allow statements such as "I made this" (e.g. declaring the author of a document) or "I own this" (e.g. items in a book or music collection). As a whole this provides a very rich set of metadata elements, enabling many different kinds of application. As an RDF vocabulary FOAF can be easily integrated with other RDF vocabularies allowing for example, the publishing or music community to define the optimum way of describing a book, album or other creative work, while still allowing this data to be related to people (the owner or creator).

One key premise of FOAF, and of RDF generally, is that data is inherently distributed across the Internet rather than centralized in a single database. There is no single source of FOAF data: individuals maintain their own FOAF descriptions, either directly or by using tools provided by their community. This data is then harvested using indexing applications that share many similarities to the web crawlers employed by Internet search engines. FOAF provides a facility for linking one FOAF document to another in the same way that HTML documents are linked across the Web; this has resulted in a web of interlinked FOAF data sources.

3.1 FOAF Applications

To date FOAF application development has centered on FOAF authoring tools, e.g. the FOAF-a-Matic [1] as well as tools capable of viewing and browsing FOAF data, e.g. FOAF Explorer [3] which generates Web pages from FOAF data allowing a user to read a person's self-description and browse to related information such as project homepages, lists of interests, or information about their friends and collaborators. One of the most interesting FOAF applications is FOAFNaut [4] which provides a visualization of the social network described by the distributed FOAF data set. This visualization is displayed in the browser using SVG (Scalable Vector Graphics) creating an easily navigable graphical view of the relationships between people. This social network browser is made possible from the metadata that people have included in their FOAF descriptions.

4 Using FOAF to Support Community Building

While FOAF has already generated interest from a number of existing online communities, including the Blogging community, the authors are interested in the ability for FOAF to foster community building. Specifically, the authors are exploring the use of FOAF to support community building amongst conference delegates by allowing delegates to record their past and intended attendance at conferences, along with their interests and other pertinent data. As well as providing an application to help delegates create the required metadata, the authors will produce supporting tools for exploration of this data allowing, for example, delegates with similar interests to find one another.

One of the authors (Kelly) organizes the Institutional Web Management Workshop, which has been held annually since 1997. The workshop provides a forum for members of Web management teams within UK Universities, and attracts over 150 delegates, many of whom are regular participants. For the forthcoming workshop it is intended to provide a tool for the delegates that will allow them to record their attendance at Institutional Web Management Workshop events, as well as other conferences; their interests; contact

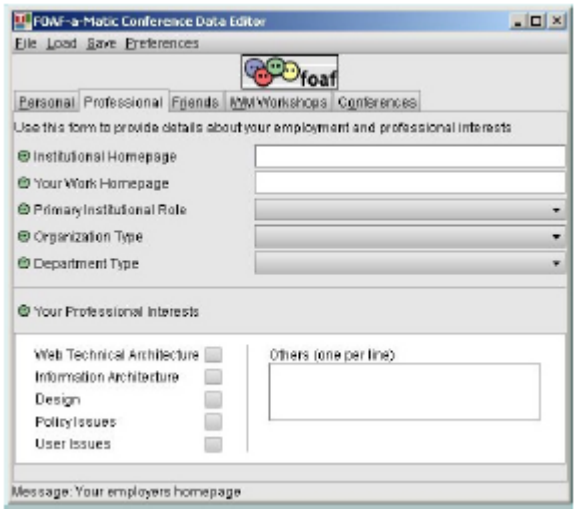

Figure 1: FOAF Authoring Tool.

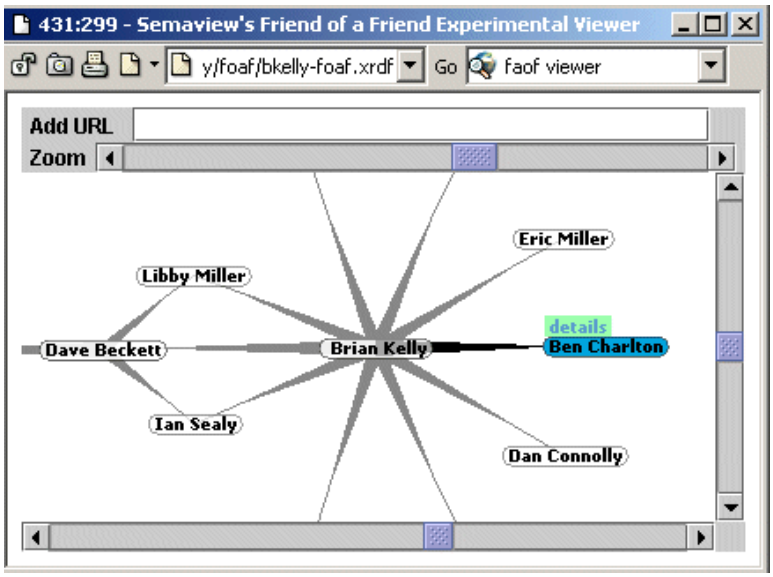

Figure 2: Example of A AFOAF viewer.

details; and other appropriate information, e.g. a photograph, job status, institutional affiliation, role at the event, professional interests and links to people they know.

Delegates will be able to use the tool prior to the event and workshop speakers and organizers in particular will be encouraged to use the tool to ensure a useful data set is available. The authoring tool is being adapted from the existing application [1] tailoring the interface to support this specific use as shown in Figure 1.

Rather than manage the data centrally, delegates will publish their own FOAF descriptions which can then be harvested to build a number of potentially useful services.

In particular the authors will demonstrate how existing FOAF visualization tools such as FOAFnaut and FOAF Explorer can be used to explore this Semantic Web space. Additionally a custom browsing interface will be created allowing users to answer queries such as (a) show all delegates at the event; (b) show delegates from a particular institution and; (c) show delegates with an interest in information architecture.

An example of a FOAF viewer is shown in Figure 2. It should be noted that this diagram illustrates very basic use of FOAF – a richer application would allow, for example, the user to access information by events attended and allow events attended by an individual to be displayed.

Once delegates have seen the potential we hope that this will provide motivation to provide information on attendance at other events. Once a proof-of-concept has been developed we can then justify the development of additional tools to complement the browsing interface.

5 What Does This Give Us?

It could be argued that this application outlined above could be implemented using conventional collaborative tools. However this fails to acknowledge the main point of an RDF-based approach – ensuring that the underlying data can be integrated with current and future applications. For example delegates with existing FOAF descriptions can easily supplement their existing metadata with that collected by this application. This can be achieved without any agreement with, or notification to, other consumers of FOAF data. Similarly other application developers interested in using the additional conference related metadata generated by this study can easily develop or extend applications to process it.

6 The Next Steps

We hope that the work described in the paper will provide a valuable tool. However it is recognised that the work is in early stages. Further work is needed in developing FOAF viewers which will exploit the conference data described in this paper; developing a range of addition FOAF creation tools, which can build on the Java tool described in this paper and engaging with user communities in encouraging use of the tools and ideas described. We hope that this approach described in this paper will help the delegates to gain a glimpse of the potential of Semantic Web applications such as FOAF and encourage further experimentation. We welcome feedback from the community and invite those who would like to be involved in further development work to contact the authors.

Acknowledgements

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Towards Ubiquitous Computing with Quality of Web Service Support

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Web Services (WS) have introduced an new era for distributed application development. WS are based on ubiquitously adopted internet standards, therefore supporting interoperability across different platforms. Further establishment of web services in the Information Technologies (IT) arena demands the capability to dynamically respond to different non functional requirements such as performance, network communication or requirements of maintenance and execution cost. Recent work has been presented mainly towards the support of Quality of Service (QoS) parameters of the WS selection. Up to now, WS requesting process is supported by a industry standard catalogue, the UDDI (Universal Description, Discovery and Integration) [6], which does not take into account QoS requirements. In this work, we discuss WS discovery infrastructure that allows ubiquitous consumption of a WS with consideration of quality factors. We build upon the design presented by [1] and present a more generalized solution that comprises dynamic WS categories. The key target of this work is to combine typical procedures of WS discovery roadmap with the benefit of QoS characteristics without loss in compatibility. To verify and measure functionality, feasibility and effectiveness of the solution presented evaluation in laboratory environment has been performed.

Keywords: Distributed Application Development, Quality of Web Services, Web Services.

1 Introduction

The current trend to augmently adopt ubiquitous com-

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puting leads a mainstream of changes in the way we live with technology. The key characteristics of such changes are elaborately described in the work of [21]. The successful statement of Mark Weiser that "*most profound technologies are those that disappear and they weave themselves into the fabric of everyday life until they are indistinguishable from it*" [22] instantiates the directions that Web Services (WS) need to follow in order to become successful and ubiquitous. Technologies such as pencils or faucets are nowadays just simply features of the world we take for granted. To progressively transform ubiquitous computing with web services into an everyday trivial business process several steps have to be fulfilled.

WS have transformed the area of distributed development into a technology that can automate business intelligence over the Web. WS are the latest member of a numerous group of OO (Object Oriented) interoperability platforms incorporating ideas from the Common Object Request Broker (CORBA), Java 2 Platform Enterprise Edition (J2EE), and .NET. They are fully based on XML (eXtensible Markup Language) like standards and other popular WWW (World Wide Web) technologies. While there are several performance issues of such remote objects, communication and processing capabilities allow most IT (Information Technologies) vendors to offer WS interfaces to their services and products. Even small wireless sensors' manufacturers are standardizing around WS interfaces.

However, a fundamental step that needs to be taken first is to provide a framework for the support of Quality of Service (QoS) of WS. This is the only way that will provide ranking and quality distinguishing among services with same functionality. The key concept in the proposed design and implementation is to maintain all compatibility features with the standard WS searching mechanisms and expand them to support QoS characteristics. Searching and selection of a WS is enhanced with the use of customer feedback and evaluation. As a result, a WS consumer can pick among services the one that suits him/her most and further refine his options using quality criteria too, such as price, network distance and execution time etc.

Our work is organized as follows. In Section 2 related work and motivation are outlined. Section 3 presents the system functionality. Following, Section 4 discusses experimental development and evaluation. Finally, Section 5 discusses conclusions and future steps.

2 Nature of Motivation

Enabling techniques for efficient WS discovery have been discussed thoroughly in [19]. Following, we point to some works focussing on WS discovery mechanisms that enable QoS characteristics during selection. An initial definition of Quality of Web Service (QoWS) has been presented in [15]. Ouzzani and Bouguettaya [20] were among the first to address the issues of fulfilling certain QoS constraints in WS searching.

In this work we present an architecture that extends ideas initially presented in [1]. The work of Yutu Liu et al [1] presents a methodology to compute QoS values for WS selection. Contrary to a broker based registry, we present a solution that enables QoS measurement and computation for any WS registered in a UDDI (Universal Description, Discovery and Integration) catalogue. Multiple UDDI registers can be queried transparently, analogously to the meta-searching logic where an intermediary searches for results to many different repositories and search engines returning a combination of results. Additionally, for typical UDDI catalogues that cannot extend to support QoS, a dedicated storage system stores separately QoS information.

In [1] a list of the most appropriate Web Services is returned for selection from a predefined list according to these

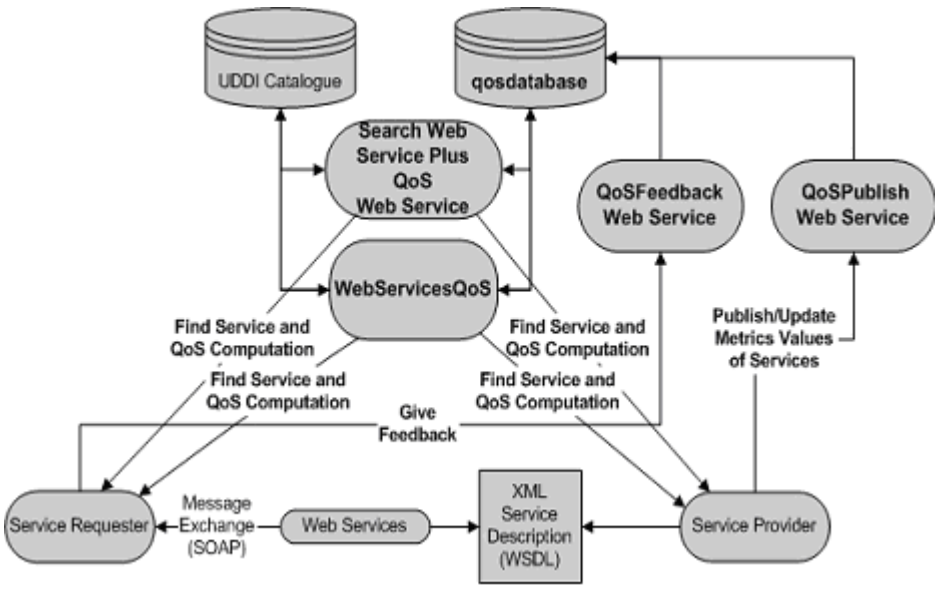

Figure 1: Outline of Architecture Diagram.

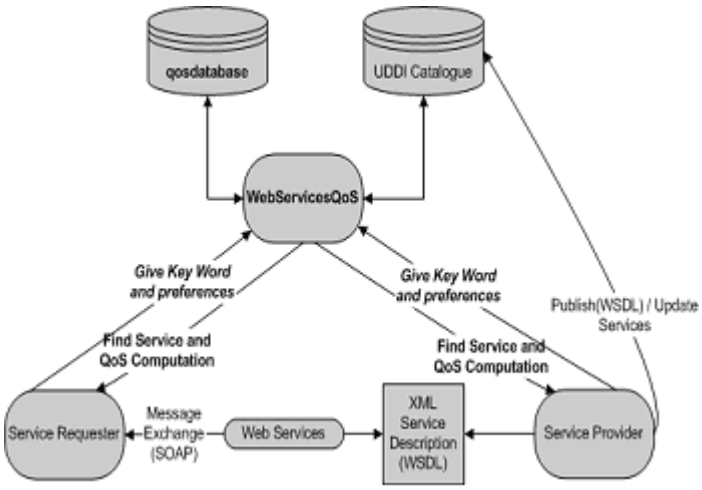

Figure 2: Architecture Diagram of Web Application WebServicesQoS.

criteria. Thus, neither functionality search nor any keyword lookup is conducted. Furthermore, the value of the QoS remains static as long as the predefined list doesn't change. In fact, QoS calculation is based on all the WS of the list in [1] with no prior control or checking for functionality of other relevancy. In this work, beside the criteria of interest, the WS consumer has facilities to perform a typical WS UDDI based search for a specific functionality. In return the requester gets an updated snapshot list of interesting WS, with their QoS values. So, QoS characteristics are produced dynamically, depending on the search's criteria. Finally our approach is flexible to take into consideration only the available metrics and it is not necessary to have values for all parameters of each Web Service to perform the computation. This is achieved by providing the appropriate value, to all those metrics which haven't already been defined, according to the nature of each one. A minimum value is given to a metric that is positive for the final value of QoS and a maximum value to a metric that is negative.

3 Functional Specifications

3.1 Architectural Roadmap

In order to support QoS characteristics transparently and facilitate legacy WS discovery mechanisms, we introduced a WS selection wrapper (UDDI discovery). We combined typical WS discovery procedure that happens at design or execution time with the added-value of QoS characteristics. The proposed solution is designed as a service-library itself that facilitates the alternative way to discover business components - Web Services. The overview is outlined in the

Figure 1 below. Following comes a short description that serves as a roadmap for the reader.

The main module is WebServicesQoS subsystem. It includes the necessary functionality to provide the requester an interface so as to define descriptive key words and proceed in discovering Web Services. In our system, apart from the UUID of each Web Service, QoS information is also returned as it is calculated by the enhanced version of [1] algorithm that we have introduced according to the results of the discovery. The requester also has the option to determine, via a check list, the categories, as for example the price and the reputation, in which one wants to focus on, so that the final value of QoS for each WS is defined appropriately.

Search Web Services Plus QoS provides even more functionality. It enables searching with more criteria, such as the BusinessKey and the TModel or further configuration for look-ups in different UDDI servers.

QoS database subsystem acts as the storage system for all the QoS metrics definition schema. For UDDI servers that do not support QoS property storage, WS QOS values are also stored in this sub-system.

To facilitate updates of QoS parameters the WS named QoSPublish and QoSFeedback are available.Both consumers and providers have the capability to deliver ad hoc updated values of QoS metrics for a specific Web Service that they utilized or manage respectively.

3.2 System Core Functionality

The central module of our system has been implemented as a Web Service and it is called WebServicesQoS. It facilitates WS searching taking into consideration both functional and non functional parameters. The application logic of the mechanism is depicted in Figure 2. Consumers submit their requirements and choices in order to query for WS in the available UDDI catalogues, based initially only on functional criteria. Augmented filtering is initiated upon completion of this last step in order to assess the QoS characteristics of each web service returned. Finally, WebServicesQoS returns the results to the requester.

3.3 Search Web Services Plus QoS

It is another version of the core system that supports communication and querying to multiple UDDI catalogues as well as all standardized criteria types to query for besides the standard WS keyword description. A WSDL (Web Services Description Language) description is composed to include the requested WS description, preferences and any of the extra criteria chosen. The consumer may also

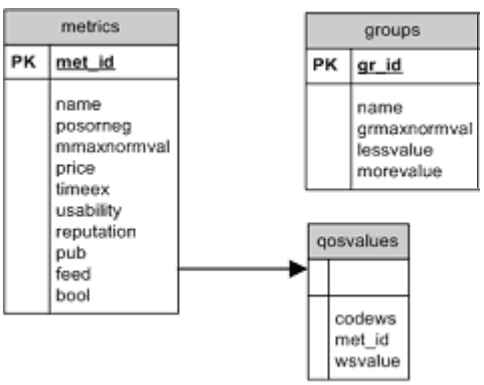

Figure 3: Main DB Entities.

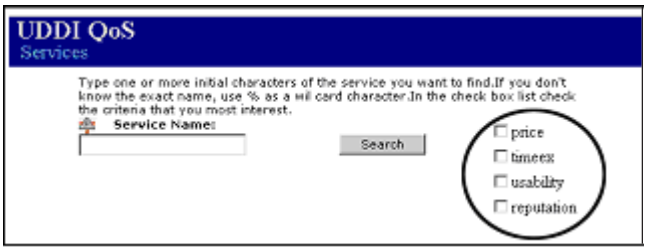

Figura 4: Core Evaluation Front-end.

specifically select or deselect UDDI catalogues for the discovery to maximize the results list or to minimize the response time. The service delivers a WS ranking list sorted according to the QoS values for each matching web service.

3.4 QoS Storage

To support scalability and future expansion of the QoS values storage system, we adopted a schema to allow dynamic definition of the QoS parameters both in terms of type and range values. The model introduced is able to accept extensions without affecting pre-registered WS that already make use of QoS values stored in the system. A persistence-like system keeps all different versions of metrics inserted into the system along time.

The developed QoS storage comprises three main entities:

1. The metrics entity contains the metrics information. Additionally it holds all corresponding metrics' properties. When new metrics or properties are inserted, a new version/instance of the metric is created to support full backwards compatibility.
2. The groups entity contains a category list which is used to group similar or related metrics according to the ideas of [1]. The attributes lessvalue and morevalue allow importance grading of groups.
3. Finally, the QoS values themselves are kept in qosvalues entity.

4 Experimental Development and Evaluation

Due to previous development experience of the laboratory personnel, the .NET platform [2] has been used for the implementation of the system (the reader may review related work by some of the authors in [16][17][18][19]). Generality is not lost though, as any WS enabled technology, it can be utilized to produce the proposed system such as J2EE or others. Applications as well as WS have been built using the programming language C#. Testing and experimental evaluation were conducted at Intel Pentium PCs with Microsoft Windows 2003 Server. To evaluate the functionality, feasibility and effectiveness of the mechanism proposed, a number of tester applications have been developed. In the following, details and snapshots of testing applications are provided for the discovery services as well as the user-based feedback about a consumed WS mechanism.

4.1 WebServicesQoS evaluation

We developed a consuming mechanism of the core subsystem for QoS enabled discovery. We have designed and implemented a typical UDDI QoS search front-end supporting all functionality of the MS test UDDI platform (http://test.uddi.microsoft.com). Our version is extended as a consumers may may also pick quality criteria to define non functional parameters (Figura 4).

The application utilizes the online UDDI catalogue for testing purposes [4] and returns pre-registered UUID and as well as the QoS parameters for each matching Web Service (Figure 5). The QoS value is calculated according to our enhanced algorithm where non-defined QoS values are overridden automatically.

4.2 Search Web Service Plus QoS Evaluation

The evaluation of the extended version of the core discovery system required the development of additional tester applications. The RetrieveGroups method is called at first and the list of the groups appears on the screen (Figure 6-2).

In the example below, the key word "card validation" is submitted as keyword description (Figure 6-1) for WS in design or just before execution time, the QoS preferences and also a business key as an extra parameter for a second call of the FindQoSService, we get the following results (Figure 6-3).

4.3 Testing Feedback Mechanisms

To evaluate the feedback and value setting mechanisms of QoSPublish and QoSFeedback, we built an interface where the ids and the names of the metrics appear and where a user may define the metrics' values of his choice.

All the tester applications have been available for evaluation in laboratory. Software developers and volunteer students have verified the proposed mechanisms functionality across a list of different arbitrary queries for WS discovery with QoS characteristics. The workflow of the evaluation procedure appears in the next figure (Figure 7).

Overall, the evaluation has indicated that our approach is technically feasible, supports scalability and returns efficient results.

Figure 5: Presenting WS Discovery Results.

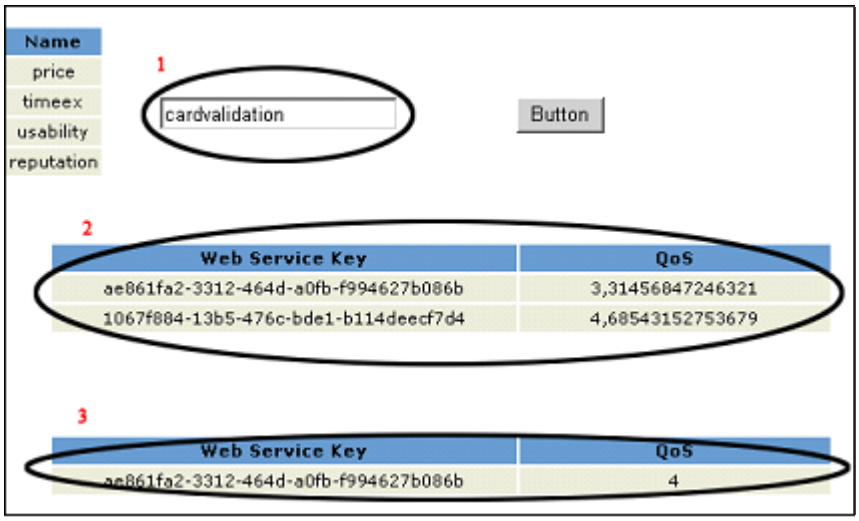

Figure 6: Search Web Service Plus QoS Evaluation Example.

5 Discussion & Future Work

The aim of this work is to support a step towards quality of service provision for Web Services that can be consumed in a ubiquitous business environment. An integrated solution is presented that can support existing generic UDDI-compatible catalogues. We presented an architecture for WS discovery supporting dynamic number of QoS groups/ categories. Moreover, we have presented a dynamic schema that supports different QoS metrics without affecting the discovery methods themselves. We have received encouraging feedback from experimental evaluation concerning the functionality, feasibility and effectiveness of the system.

Towards ubiquitous computing, Web Services need a lot of enhancements such as ubiquitous identity and contextual awareness. Missing functionality that are needed before making Web Services an integrated part of ubiquitous computing also includes life cycle services, dynamic object creation and garbage collection, state management, dynamically created object references, and a variety of reliability and transactional mechanisms [21]. Finally, work under development includes the semantic extension of our mechanism to support discovery for semantically annotated Web Services.

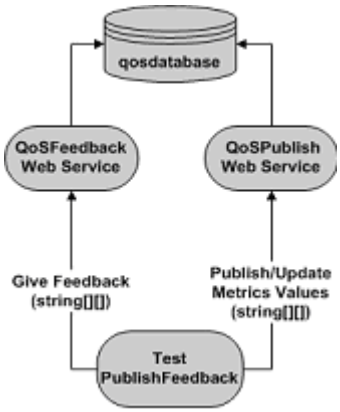

Figure 7: Testing Feedback Mechanisms Evaluation Workflow.

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The Open Source Software vs. Proprietary Software Debate and Its Impact on Technological Innovation

Ricardo-José Rejas-Muslera, Juan-José Cuadrado-Gallego, Javier Dolado-Cosín, and Daniel Rodríguez- García

Given the importance of the OSS (Open Source Software) vs. proprietary software debate - in economic and financial terms, and in terms of market opening and diversification, and even innovation - in this paper we examine the latest corporate movements and the most significant legislative trends in this area. At a Spanish national level, we make a brief review of domestic law, with special reference to the national anti-piracy plan, while at a worldwide level we take a look at the latest and most significant corporate movements and regulatory trends regarding this issue.

Keywords: Copyright Protection, Intelectual Property, Legal Protection of Computer Programmes, Open Source Software, OSS, Patents, Proprietary Software, Ubiquitous Software, Ubiquitous Computing,

1 Introduction

Technological innovation – in the field of information technology in general and in the field of software specifically – is emerging as a key factor in the development and general well-being of advanced industrial societies. The competitiveness of economic agents is in direct proportion to their capacity for innovation, and the wealth and level of development of nations is the result of the innovative capacity of each country.

One factor which will have a decisive impact on the structure and evolution of technological innovation policies and, more specifically, on software industry, is the final outcome of the OSS (Open Source Software) vs. proprietary software dilemma. This will depend on the dynamics of the market itself and, to a great extent, on the policies and regulations established by the national and supranational bodies working in this field.

The outcome of this debate will have a decisive impact on such important issues as business competitiveness, the opening and diversification of markets, and technological development in general.

All this is especially relevant to the area of ubiquitous computation, because the quest for innovation and the struggle for dominant positions in this field is particularly fierce, since ubiquitous computing has the potential to affect millions of consumers and virtually every market.

2 Legal Protection of Software in Spain and National Anti-Piracy Plan

The legal protection of software under the Spanish system is based on intellectual property rights - or copyright to be more precise - the main features of which are outlined below:

1. The exclusion of software from patentability – i.e. from the protection afforded by industrial property rights. This has also been incorporated into the legislation of other European Community countries such as Germany, France,

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[1] Available at <http://www.oepm.es/internet/legisla/dcho_eur/22cpe.htm>.

[2] Available at <http://www.wipo.int/treaties/es/ip/berne/pdf/trtdocs_wo001.pdf>.

United Kingdom, and Italy, in accordance with the Munich Convention of 1973 on patents[1].

2. For legislative purposes software is treated in the same way as literary, scientific, or artistic works which are protected by copyright under the 1883 Berne Convention for the Protection of Literary and Artistic Works[2].

3. The reference legal framework in this field is the European Union Directive on the legal protection of software [1] and the Spanish Intellectual Property Law [2]

4. The holder of these rights is a natural person who has created and "fixed in any tangible means of expression" a literary, artistic, or scientific work which is transferable to another natural or legal person. Rights over software are acquired at the moment of its creation.

5. With regard to copyright life, there are two situations depending on who the holder is. If the holder is a natural person, the exploitation rights of the work are deemed to belong to the author while he or she is still alive and a further seventy years after the author has died or been declared dead. In the case of a legal person the period is seventy years from January 1 of the year following the first lawful publication of the software, or the date of its creation if it has not been published. At the end of these periods the software passes into public domain, when it can be used by anyone providing that the authorship and integrity of the work are respected.

6. These rights are dual in nature:

a. Exploitation rights: Considering the property as an economic asset. In other words the right to make an economic gain from the software, and maintain an exclusive control over the exploitation of the work: reproduction, distribution, transfer, or public disclosure.

b. Moral rights. Of a strictly personal nature. Based on the authorship of the work, they are inalienable and unrenounceable. Among others, the right to publish the work under one's name, modify it, disseminate it, or withdraw it.

2.2 National Anti-Piracy Plan

Here we take a look at what is officially known as the Integrated Plan for the Reduction and Elimination of Intellectual Property Rights Infringements of April 8, 2005. The plan has a dual aim: to raise public awareness of such infringements and to bring offenders to justice, and is based on a series of urgent measures and a number of mid- and long-term strategies.

1. The plan aims not only to punish those who infringe intellectual property rights but also to raise consumer awareness of the harm that piracy does.

2. Among urgent measures to combat copyright infringement are:

a. The signature of a collaboration agreement between the Ministry of Culture and sectoral associations at a local authority level, intended to raise public awareness, establish guideline criteria for the measures to be undertaken, map the incidence of piracy in Spain, and implement training actions and advisory services in the matter at a local level.

b. Increased policing: creation of a special police task force, greater coordination between police forces, drawing up of permanent area action plans for the policing of piracy, and increased international and institutional cooperation.

c. Training and coordination measures and actions for the Department of Public Prosecutions.

d. The Ministry of Culture and the Ministry of Industry, Tourism and Trade will set up a working group involving intellectual property management offices and the technology industry in order to set up and develop self-regulatory mechanisms aimed at detecting and removing any unauthorized content in digital networks, and determining the identity of the infringers. The working group will also monitor the effectiveness of the plan's actions and measures.

3. The plan includes a series of measures intended to reduce or eliminate copyright infringement:

a. Measures of cooperation and collaboration between various government bodies, and between government bodies and the private sector. A commission is to be set up for that purpose.

b. Preventive measures aimed mainly at describing the problem of piracy in its various facets.

c. Public awareness campaigns in order to make the public aware of the serious harm caused by the infringement of intellectual property rights.

d. Regulatory measures, based primarily on an analysis of sector specific regulations.

e. Training measures with a dual purpose: to increase the effectiveness of agents engaged in the fight against piracy, and to promote research and development in this area.

3 International Corporate Trends and Movements

3.1 European Union Policy on OSS and Patents

As we mentioned earlier, the outcome of the debate between OSS and proprietary software will depend to a large extent on the policies and regulations that are in place at a national and a supranational level. We therefore need to take a look at where the European Union (EU) stands on this issue, as this may be enough to tip the balance one way or another.

Up until now it seems that there has been a slight bias towards the use of OSS, especially in ICT-related (Information and Communications Technologies) research projects and policies implementing framework programmes promoting *libre* and open source software, such as the eEurope 2000 action plan, the IDA programme (promoting Governmental Data Exchange), R&TD framework programmes, and other actions implemented by EU member states, usually associated with the acquisition of or migration to libre software by their respective government bodies.

However, a bitter debate has been raging within European institutions as to whether or not software should be patentable. This is evidenced by the fierce confrontation between the European Commission and the European Parliament over the famous "*Directive on the patentability of*

computer implemented inventions", which was finally resolved in July of this year with the almost unanimous rejection of the proposal by the European Parliament. According to official European Commission sources, they have no intention of submitting a new proposal either now or in the near future.

This controversy is fuelled by two clearly differentiated viewpoints:

1. Supporting the EC Directive are major corporations such as Microsoft or Nokia, Ericsson or Alcatel who maintain that this Directive will encourage innovation by protecting the rights of inventors and helping them to obtain a return on their R&D investment.

2. Against the Directive are the *libre* software user groups for whom the patentability of software would render more than half of the computer programs currently in use in the EU illegal. The Directive would only benefit the major software companies, to the detriment of small and medium size companies and software consumers, since it would allow the major software multinationals to legally prohibit the use of certain algorithms and computing formulas which have hitherto only been subject to copyright fees.

The manner in which this issue is resolved will to a large extent shape the future structure of the software market. If governmental and legislative institutions opt to encourage the use of OSS, they will give a huge boost to competition in this sector and will drive a change from a highly polarized oligopolistic market to a more competitive and open market which will benefit both the consumer and the general public. The downside is that it will be harder for companies to obtain a return on their innovation and development investment. If the decision goes the other way, the consequences will be the opposite of the above, since we should not lose sight of the fact that when a patent is granted for an invention or process, ultimately the State is awarding that invention a monopoly.

3.2 Corporate Concentration in Pacific Asia and Mobile Device Compatibility: *Libre* Software - TRON

The plethora of corporate movements taking place worldwide underscores the practical importance of the outcome of this debate. As an example of this in the field of ubiquitous computing, and more specifically in relation to mobile terminal, we go on to look at the strategies adopted by major companies in the sector to capture the massive Asian market.

This market is a good example of how a number of overly aggressive decisions taken by corporations and countries have stirred up the market to such an extent that from the dominant position in the mobile terminal software market held by Microsoft, founded on patent protection, the pendulum has swung to practically the opposite situation in which Microsoft's systems will have to be compatible with TRON (The Real-time Operating-system Nucleus) *libre* software, something akin to Windows XP having to be compatible with Linux.

In broad terms, this is what happened: Microsoft targeted its marketing strategy at the Asian market and, more specifically, the Chinese market, leveraging its monopoly position in operating systems for mobile devices. At the same time, the region was being influenced two parallel developments:

1. On the one hand, China was migrating en masse to Linux as away of achieving technological independence while saving money on the computerization of the nation's public administration.

2. On the other hand, the Japanese technological industry was wilting under Microsoft's monopoly.

In an attempt to revive his country's ailing technological industry and at the same time take advantage of China's initiative, Japanese prime minister, Junichiro Koizumi, drew up a pact with the most important economic and governmental agents of Pacific Asia with the purpose of resurrecting the TRON operating system. Under the terms of this agreement, mobile device manufacturers would have to install software compatible with TRON if they wished to enter the Asian market. Encouraged by the prospect of accessing a huge market all set to usher in third generation mobile telephony, Microsoft changed its strategy and duly made their new systems TRON compatible in a joint project with Motorola and Symbian.

3.3. Software Rights, with Special Reference to the Kodak vs. Sun Case.

Another interesting example of how patent based regulation can affect the market is the Kodak vs. Sun case. This case had a direct bearing on the world of ubiquitous computing since the lawsuit centred around the programming language Java.

In February, 2002, Kodak sued Sun Microsystems for infringing patents 5206951, 5421012 and 5226161, protecting a mechanism by which a program can request help from a processing system to delegate functions without Java implementation. The main characteristic of the Java is that it is a multiplatform language since it is interpreted by a built-in virtual machine.

In October of the same year a jury of the Rochester Federal District Court found in favour of Kodak who were claiming damages of some 1,000 million dollars from Sun. Payment of such damages would practically wipe Sun out, as its delicate financial situation could not withstand a payout of that magnitude.

The court's ruling also meant that, in practical terms, any language based on mechanisms similar to Java bytecodes, such as Microsoft's .NET or Python could be liable to similar lawsuits.

Sun appealed against the ruling and reached a settlement with Kodak whereby Sun would pay Kodak the sum of 92 million dollars in patent royalties. This meant that Sun, one of the world's leading companies in technological innovation and especially in Java programming languages, was able to stay in business and Kodak could not file any further lawsuits for the same infringements.

The importance of this matter lies in what would have happened if the court's initial ruling had been enforced. It

would have led to a serious brake on innovation in this area, since the patents in question affect not only all the drivers behind multi-task systems or frameworks such as OLE, COM or CORBA, but also the major manufacturers of Java-based products (such as SourceForge, Kronos, BEA Systems Inc) who have Sun Java licences.

4 Conclusions

The regulatory policies that eventually govern the legal protection of software, and consequently the accessibility and presence of OSS, will have a decisive impact on technological innovation and development in general and the software development market in particular.

If the balance tips in favour of the promotion and defence of competition by encouraging the dissemination of libre software, this should lead to a more plural and accessible market, the elimination of monopolies over technologies, and greater diversification in the development of technological innovation, though possibly at the price of making it difficult for companies to obtain worthwhile returns on their R&D investment. If the opposite outcome prevails, technological development will be concentrated in the major technological multinationals which would come to form a de facto oligopolistic market, with all the consequent social costs, barriers to new technologies, and economic inefficiencies. However, it would be easier for companies to get a return on their R&D investment, which would presumably encourage them to increase that investment and so give a boost to technological development.

All the above is possibly of even greater importance to the world of ubiquitous computing, since as its name implies, any regulatory, political, or corporate movement may affect millions of potential consumers across practically every economic and social sector.

*Translation by **Steve Turpin***

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Localization in Ubiquitous Computing Using Acoustic Sensor Network

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Systems that characterize the state of an entity or object are very important in "smart spaces" and "ubiquitous computing"; this information is usually known as the entity's "context". In order to offer an object the most suitable services one of the most important pieces of information required is its position. The mechanisms and techniques that determine spatial relations are named "location". This article presents an indoor localization system in order to make a positioning among entities, fixed or mobile, without using an external infrastructure and only using acoustic transducers. Also, an analysis of the positioning algorithm, based on Multidimensional Scaling Technique (MDS), is carried out in order to verify errors originating from the mechanisms for measuring distances to estimate an object's position.

Keywords: Acoustic Sensor Network, Complementary Set of Sequences, Localization, Simultaneous Times-of-Flight Measurement, Ubiquitous Computing.

1 Introduction

Those applications, in ubiquitous computing and smart spaces, which describe or characterize an object and interact with it, are commonly called "context-aware computing" [1]. One of the most important dimensions of the context is location, and the applications that are based on this context are known as "location-aware computing" [2]. This is useful in emergency services [3]; office applications, for example to find the nearest printer resources, also called "follow-me" services [4]; and for supervision of surround-

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ings, for example in hospitals to track medical staff or to monitor patients.

Within this scope the researches concentrated on designing location mechanisms, which were robust, safe, and easy to set up with very low cost and minimal infrastructure, by taking advantage of the great advances in hardware and the new developments in Micro-ElectroMechanical Sensors (MEMS) that allow the functionality of sensors technologies to be extended. In addition improvements in wireless communications, and new capacities of COTS (Commercial-Off-The-Shelf) products such as PDA´s (Personal Digital Assistants) and notebooks, promote the development of new location applications.

Three kinds of location information can be distinguished: absolute, relative and symbolic [3]. The first, absolute location, reports the position of an entity given its coordinates (*x*,*y*,*z*), from a reference point whose position is known. The second, relative location, determines the position of an entity among several objects, generally mobile, without any interest in the surrounding location, only given a geometric configuration that holds the spatial relations between them. Therefore, all the entities in the system need the necessary technology to compute their positions. Finally, symbolic location consists of determining if there is an entity in a specific zone without providing any other detail.

This work presents a positioning system for fixed or mobile devices with no need to use an external infrastructure and only using acoustic emissions as sensing technology. The following section gives a brief revision of the most popular works about location in indoor spaces for their application in ubiquitous computing. Section 3 presents the proposed location system, showing its mains characteristics and methods used to solve the location problem. Finally, Section 4 shows the simulations and results about positioning algorithm considering errors on the measurement of distances according to the proposed ranging technology.

2 Location Systems Review

There is a wide range of works developed by different research groups with the aim of solving the location problem and its application in smart spaces and ubiquitous computing. The simplest and well-known solution would be to provide each object with a Global Positioning System (GPS). This solves the outdoor localization; nevertheless, in the field of mobile computing, size, cost, and energy constraints exclude these systems. Additionally, in indoor environments GPS signals are not available for positioning, due to their very weak signals. These factors led to the development of various indoor positioning systems using different sensing techniques [3] such as: Active Badge®, Active Bat, CRICKET, RADAR, etc.

The Milibots project [5] is focused on the design of a cooperative team of robots. In this case, the position of each object is very important; the relative position among robots being determined through the "triangulation" technique, using ultrasonic signals (US). This system has the advantage of not using fixed beacons, which is an important requirement when unknown environments are explored, but it needs some of signals working as a reference to the others.

In Wireless Local Positioning [6], a location system for General-Purpose Computers (GPC) such as PC´s, notebooks or PDA's is developed. The system takes advantage of the acoustic transducers and radio frequency (RF) available in these devices, in order to range distances and make the necessary communications. Since this system does not use external beacons, some of them work as a reference for the others.

There has been a considerable development of absolute location systems, consisting of an external infrastructure, which operates as a reference of the object to be located, and measures distances between the entity and the infrastructure. After that, the computation of the position can be made through a central system or in the object to be located.

Nevertheless, due to the requirements of mobility and "peer to peer" interaction of entities with a computing application, it is necessary to develop location systems that can work in non-prepared environments, with the minimum possible infrastructure. As a result, a relative positioning between devices is more suitable. The objects should have the necessary technology to execute all the operations of the location process. This trend allows the development of non-centralized applications, which do not depend on one object for the positioning and are able to compute its location relative to others in a local way.

Regardless to the type of data location that would be provided, the most common location technique, because of its low computing requirements, consists of measuring distances among objects or to a reference system. After that, a non-linear equations system, using the spatial relations, is solved by any method, such as: minimums square, SVD, etc. The techniques for ranging distances in indoor spaces are usually based on the determination of the propagation time of an emitted signal. Three versions of this method are known: the calculation of Times-of-Flight (TOF) in direct way, by the method of double way (RTOF), or differences of TOF (DTOF) of emitted signals by every object [7]. The sensing technologies often used to compute the TOF can be acoustic transducers, RF or infrared (IR). The US signals are also used due to their easy synchronization and also their high precision; acoustic transducers of the audible band (20 Hz-20 kHz) are starting to be used because they are more readily available in many mobile computing devices than US.

3 Proposed Architecture of Location System

Figure 1 shows the basic architecture of the system, where every object carries a node with acoustic transducers as sensor technology in order to make a relative positioning of entities or objects, usually mobile. The more important characteristics of this system are: 1) there is no need to use an external infrastructure; 2) there is local computing of the relative position of every object with all the other objects; 3) all nodes are equal in their architecture and functionality; 4) there is no physical connection among them; 5) only

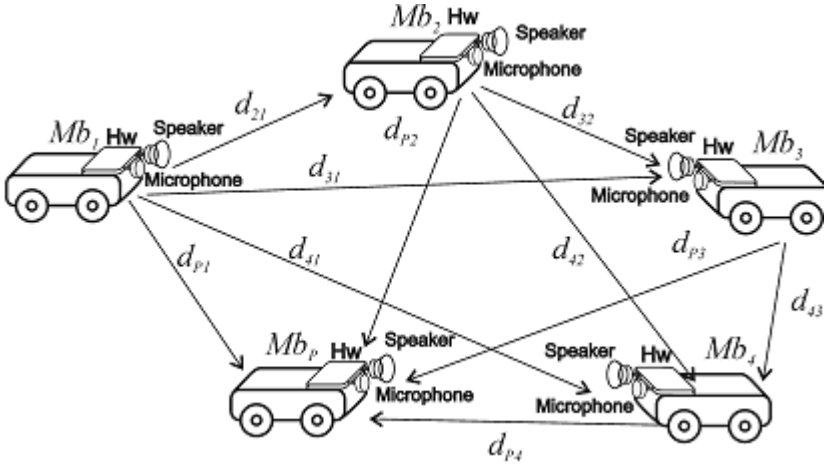

Figure 1: General Scheme of The Proposed System. (Every object of the system is denoted as Mb_p, with $p, q \in \{1, 2, \cdots, P\}$, P is the maximum number of objects and is the distance between object p and object q.)

acoustics emissions are used, so RF or IR connections will not be required for synchronization.

The MultiDimensional Scaling technique (MDS) will be used to determine the positions, with the system determining all the ranges prior to executing the positioning algorithm. These spatial relations will be determined by measuring the propagation time of the emitted acoustic signals by every object. Conventional acoustic emissions can be masked, using a "watermark" technique, in order to be insignificant to humans.

Acoustic signals in the audible band are used to take advantage of their low cost, easy implementation and availability in mobile computer systems. Environmental aspects would affect their performance outdoors and be a drawback, but in indoor spaces these are minimized. Additionally, a non-centralized system is obtained because all nodes are equal in their architecture and functionality, for this reason every node can locally compute all the object positions.

3.1 Metric Multidimensional Scaling Technique

This technique, also known as classic MDS, provides a geometric configuration of the objects, in the smallest possible number of dimensions, when the only thing known is a relation among them; in this case their distances. In [8] an analysis of this technique was made and it is summarized in Figure 2. First, at each node, it is necessary to know all

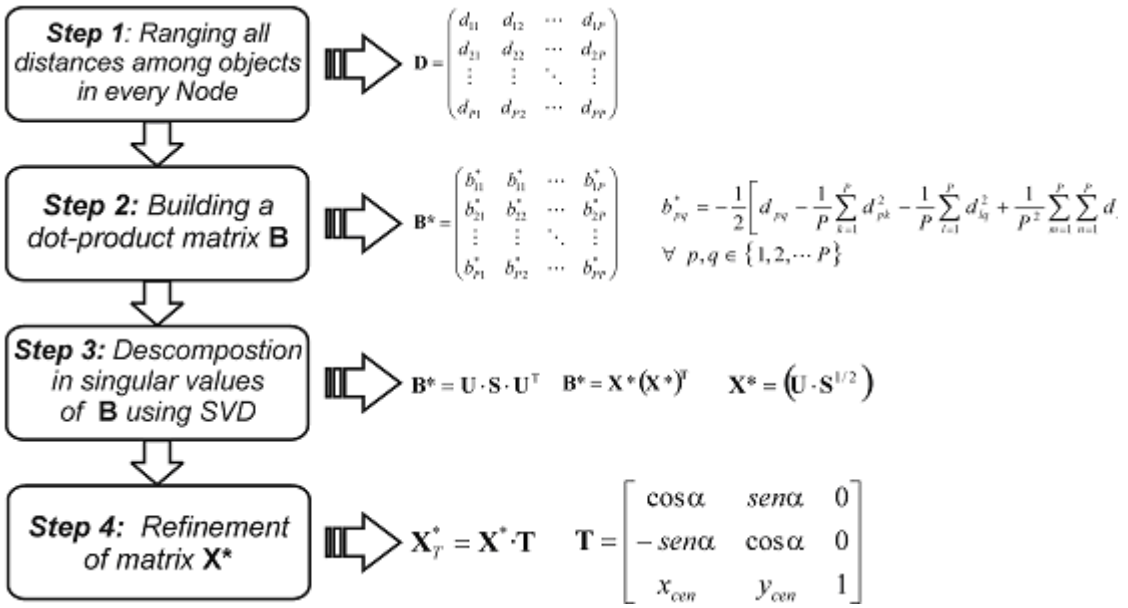

Figure 2: Steps of The MDS Positioning Algorithm. (Every step shows the operations with the aim of obtaining, in every node, the estimated coordinates in a matrix X^*_T of all the objects.)

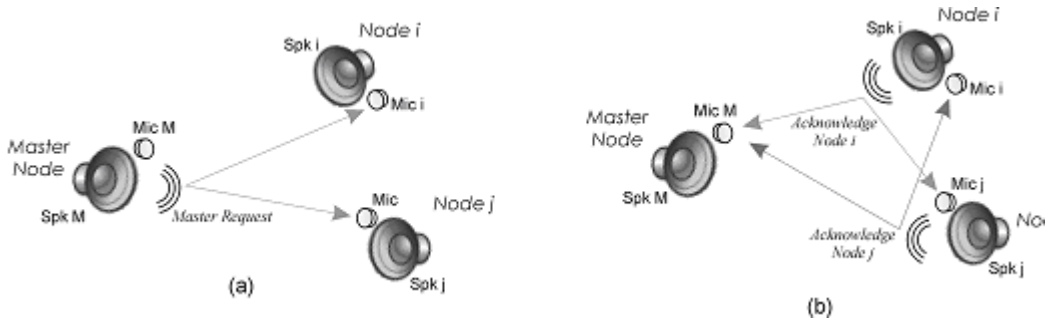

Figure 3: a) Emission of The request from The "Master" Starting The Location Process; b) Acknowledgement from Every Node for Calculating The Distances.

distances before starting the computations of the position, and they are described in a matrix of distances denoted as **D** (step 1).

Once all distances are known the second step is to build a matrix **B***, called the dot-product, that considers the distances among objects from a reference point, the most suitable being the centroid of the figure the objects form in a two or three dimensions system (2D or 3D). The following step is the decomposition in singular values (SVD) of **B*** and considering the properties of the resulting matrixes of eigenvectors and eigenvalues, **U** and **S** respectively, the coordinates of the objects can be obtained by selecting the first two or three columns of matrix **X*** according to the dimensions of the system (Step 3).

In order to fit the obtained results to the reference system of each node it is necessary to consider a process of rotation and translation by means of transformation matrix **T**, because the obtained results are referred to the centroid of the figure formed by the objects. The matrix **T** is built using the object where the calculations are made as the coordinates origin, and selecting another one that forms a line with the previous one. The resulting matrix $\mathbf{X}^*_{\mathbf{T}}$, gives the coordinates according to the system of the object.

3.2 Mechanism of Ranging Distances

One of the goals proposed in the previous section about the architecture is the measurement, in a simultaneous way, of all the distances among objects. This is with the purpose of eliminating all types of additional synchronization connections by RF or IR, reducing the hardware complexity. Also, in indoor spaces, the RF signals can be interfered with by other systems such as 802.11 networks or, in the case of IR, by spurious signals from fluorescent illumination.

Considering this synchronization constraint, the distances are calculated with a similar method to RTOF technique [7] of emitted signals. In this case, taking advantage of the codification properties used on the emissions, the method will be simultaneous in all nodes (see Figure 3) and will be called Simultaneous Round-Trip-Time-of-Flight (S-RTOF) [10]. Because all nodes are equal in their architecture and functionality, any of them can start the location process, by means of multiple access technique (CSMA), and it is called

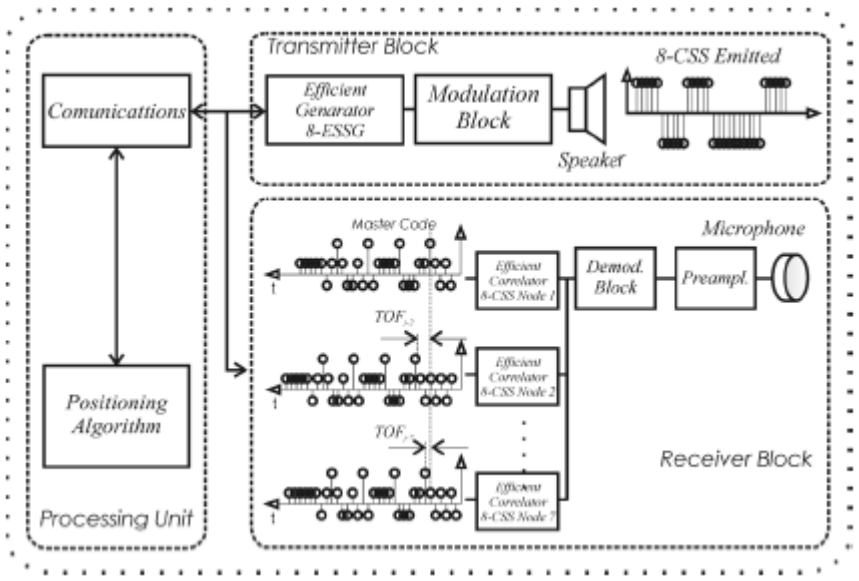

Figure 4: Hardware Architecture of Every Object, Constituted by An Emitting Block. (The receiving blocks contain a set of correlators in order to detect the different codes of the system in a simultaneous way.)

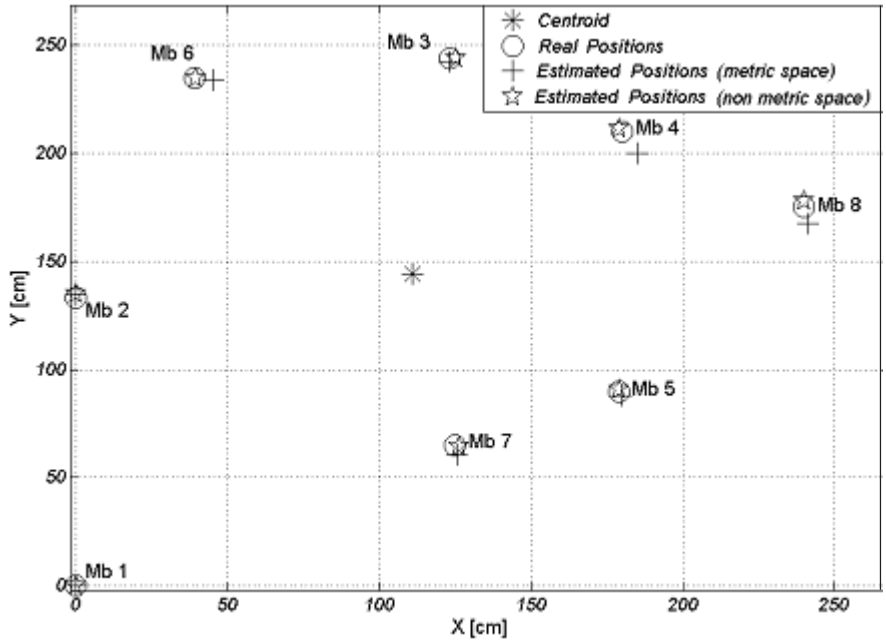

Figure 5: Map of real positions and estimated coordinates considering a 2D system and a Gaussian noise with $\sigma = 3cm$ in the measures of the distances assuming a metric space and non metric space respectively.

"Master". So, at a given instant of time, the node in the *"Master"* object emits its acoustic signal with a particular encoding assigned to it (see Figure 3.a). At this moment, the measuring of TOF's starts.

This emission, called *"Master Request"*, is detected in the every slave node at different times. In answer to this request, each node emits its characteristic code denoted as "*Ack. Node*" which propagates towards the "*Master*" node and also to the other ones (see Figure 3.b). In this way, in the "*Master*" node, the time from when the "*Master Request*" was emitted until the "*Ack. Node*" is detected, can be computed and consequently the distances among the "*Master*" and the slave objects. Also, taking advantage of the emission of every node, it is possible to compute the distances among them by means of similar temporal relations. After computing the temporal relations it is necessary to communicate among the nodes the data collected from every one.

3.3 Acoustic Signals Encoding and Hardware Architecture

Every object emits an acoustic signal codified by means of complementary sets of eight sequences (8-CSS) [9], where the sequence length is a power of the number of sequences of the set, that is $L = 8^N$. These sets allow obtaining the auto-correlation (AC) maximum values of $8 \cdot L \cdot \delta[k]$ for non-time shifted versions, where $\delta[k]$ is a Krönecker function. Also, in ideal conditions, null AC side-lobes for shifted versions of them can be obtained. Additionally, eight mutually orthogonal (MO) sets can be easily obtained, which allows up to eight simultaneous emissions o be made, with no interference among them. In this way, the number of objects to locate simultaneously is based on the number of MO codes that can be obtained, being M in the case of M-CSS, with $M = 2^m$ and m $\mathbf{0} \rceil - \{0\}$. The use of the 8-CSS by means of the algorithm proposed in [9] allows an efficient implementation of their generator and correlador, giving a great reduction in hardware complexity and in the computational load is obtained compared to the straightforward implementation.

The basic hardware architecture of every node is described in Figure 4. There is a block for transmission of acoustic signals, and one for reception. In order for the receiver block to simultaneously detect the codes emitted by the eight different sources it includes a set of efficient correlators. Finally there is a processing unit, that coordinates the communications and computes the algorithm.

4 Simulations and Results of The Positioning Algorithm Used

It is worth comparing the results obtained by the MDS algorithm when there are errors in the measurement of distances. Generally, two sources of errors are considered: "measurement error" arises from the effects on the ranging technique of Gaussian noise, effects of modulation, and non-correct synchronization among nodes because they do not use the same clock; "Non-Line-Of-Sight" (NLOS) error, which strongly affects the estimation of the positions when acoustic transducers are used, is caused by obstructions, solid objects that block the line of sight of the emitted signals. This effect includes the situation where the emitted signals arrive at a given receiver by non-direct ways due to reflections off walls or ceilings. This error is always positive and can be up to several orders of magnitude greater than "measurement error" [11].

In this case, the effect introduced by the "measurement

error" will be analyzed. Considering eight objects distributed in a room in a space up to three meters square (see Figure5); with Mb_1 being the reference of the system with coordinates ($^{x=0, y=0}$) and that Mb_2 forms a line with Mb_2 ($x = 0, y = y_2$). The measurements of TOF are carried out considering a "measurement error" with a Gaussian distribution of $\sigma = 100\mu s$ which implies that errors in the distances are less than.

Because all the distances among the different objects must be known before computing locally the MDS algorithm; two simulations were made. In the first one, it is considered that the matrix of distances **D** is affected assuming a metric space, that is $d_{ij} = d_{ji}$; and another one where the space is non-metric, i.e.d_{ij} ^{1} d_{ji} ,so all the distances have different errors in their measurement. Figure 5 shows the results that were obtained after executing the positioning algorithm described in the previous section with the two conditions.

Table 1 shows the standard deviation and the average of the error in the estimation of the coordinates for each one of the objects that compose the system according to the conditions already described, after executing one hundred times the estimation of coordinates.

From Table 1, it is observed that the standard deviation in the estimated coordinates is larger than the deviation considered in the "measurement error". In addition, it is increased in the case where a non metric space is considered, due to the incongruence introduced for the random error.

5 Conclusions

An architecture of a location system using nodes with acoustic transducers for the relative positioning among different objects is presented. This system is attractive for its use in ubiquitous computing applications where mobile units have available acoustic transducers. The encoding used allows detection of up to eight different codes and consequently it is possible to locate eight objects in a simultaneous way. The positioning algorithm requires knowledge of all the space relations among objects before computing the process, so a communication protocol using acoustic emissions should be developed.

In addition, it is necessary to implement a high level stage in order to transform the estimated positions to the reference system of every object or node where the calculation is to be performed. It is also necessary to apply refinement algorithms in order to eliminate incongruence in the matrix of distances, originating from the incorrect determination of times-of-flight in the location system mainly due to obstructions caused by objects that block the line of sight of the emitted signals.

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Object	Metric space				Non Metric Space			
	Average error x ($\overline{E}_x\ (cm)$)	Standard Deviation $\sigma_{\overline{E}_x}\ (cm)$	Average error y ($\overline{E}_y\ (cm)$)	Standard Deviation $\sigma_{\overline{E}_y}\ (cm)$	Average error x ($\overline{E}_x\ (cm)$)	Standard Deviation $\sigma_{\overline{E}_x}\ (cm)$	Average error y ($\overline{E}_y\ (cm)$)	Standard Deviation $\sigma_{\overline{E}_y}\ (cm)$
Mb_1	0	0	0	0	0	0	0	0
Mb_2	0	0	-0,250	3,155	0	0	0,765	3,298
Mb_3	-0,088	4,462	-0,615	3,754	0,820	5,121	-0,836	4,114
Mb_4	-0,185	4,557	-0,462	5,176	0,540	4,526	-0,538	5,288
Mb_5	0,162	2,206	0,172	4,213	0,423	2,316	-0,407	4,919
Mb_6	-0,096	4,855	-0,272	2,474	1,217	5,666	0,087	2,906
Mb_7	0,055	2,742	-0,047	3,492	-0,225	3,051	-0,217	4,230
Mb_8	-0,253	3,669	-0,187	6,688	0,513	3,793	-0,515	6,492

Table 1: Standard Deviation and Averaged Error in The Estimation of Coordinates Considering A Metric Space and A Non Metric Space when "Measurement Error" with s = *3cm* Exists in The Ranging Method.

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Portable System For Patient Monitoring With Wireless Technologies

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This paper presents a system for monitoring certain physiological variables of a patient outside the hospital environment. The system comprises the following elements: Patient Terminal, a portable electronic system for obtaining the electrocardiographic signal (2 leads), analysing it at a basic level and sending it a short distance on a Bluetooth network; Analysis Module, a system with an analysis and communication capacity (Bluetooth and GPRS - General Packet Radio Service), which automatically analyses the information received and sends it on to the Control Centre and, lastly, the Control Centre, the central supervision unit for a given number of patients.

Keywords: Bluetooth, ECG, GPRS, Microcontroller, Telemedicine.

1 Introduction

Ongoing technological advances have enabled various telemedicine systems to be set up; these can be broken down either by the type of physiological variable or variables they transmit: electrocardiogram (ECG) [1][2][3], medical images [4], blood pressure [1], blood sugar levels [5][6][7], etc, or by the transmission medium used: RF links[8], fixed telephony [7][9], mobile telephony [1][10], satellite communications [11][12], Internet [2][5], etc.

It is generally agreed that telemedicine systems will become increasingly important in the coming years, due to further technological breakthroughs on various fronts (communications, signal analysis, more advanced sensors, integration of electronic systems, etc.) and the inherent advantages of a telemedicine system, including the following:

1. The possibility of monitoring the patient more closely.
2. Savings in healthcare costs and hospital beds.
3. Collaboration of various experts in the diagnosis of special pathologies.
4. The data collected could be useful for further analysis and research into the pathologies.
5. Less nuisance and loss of time for the patients, who are saved hospital trips.

The development of these patient monitoring systems has been favoured by the parallel developments in hardware systems (greater level of integration, reduced consumption levels, etc) and above all by the advances made in various communications systems, such as wireless technology, mobile telephony, Bluetooth, zigbee, etc. The integrated operation of all these elements could provide a useful and practical system such as the one presented in this paper.

A telemedicine system has been designed for monitoring a patient's electrocardiogram with the aim of making a preventive diagnosis of certain pathologies in which the reaction time is crucial. It can also be connected up to various types of personal analysers (glucometers, coagulometers, etc) for sending other information of interest in the monitoring of certain patients. The whole system has a modular structure that can be tailored to the needs of each particular case.

The system is divided into three HW/SW modules, to be explained in the following sections; their general features are:

· Low consumption levels: one of the modules is portable and needs to have sufficient autonomy for all-day operation. This portable module should also be light and ergonomic.

· Low cost: the equipment has to be affordable so that the health administration can use it on the greatest possible number of patients.

· Quick and reliable response: in pathologies of this type early treatment is a crucial factor in saving the patient's life.

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It is important to develop systems for monitoring patients in their normal everyday environments (home, workplace,...), doing so by setting up a Body Area Network (BAN); the patient variables or data that we are interested in obtaining can be broken down into two types, which in turn determine the functionality of the system to be set up:

· Patient body variables to be obtained in real time and if possible continually; the most obvious example is the monitoring of a patient's ECG. We are speaking in this case of a wearable system.

· Variables to be obtained at one-off moments (for example, temperature, blood glucose levels); in many cases this information can be automatically transferred from a personal analyser (thermometer, glucometer, etc.). In this case it suffices for the patients themselves to make the suitable connection.

The Bluetooth protocol could be an advantageous option for setting up a BAN. The main advantage of this protocol is that it is already used by a great number of commercial devices, such as personal computers, PDAs (Personal Digital Assistants), mobile telephones, etc, and can therefore be widely used without problems. Systems with the Bluetooth protocol have mainly been designed for the wireless connection of IT (Information Technology) systems [13], although with time they have also extended to other types of applications, such as home automation [14][15], vehicle electronics [16] or security systems [17], among other possibilities.

Within the medical area the Bluetooth protocol can be used for making the connection between a telephone and a patient's cochlear implant [18] and in many cases for obtaining patient body data on a ubiquitous basis without restricting their movements, such as transmission of the patient's pulse, temperature and GSR (Galvanic Sskin Reflex) [19] or in [20] for obtaining and transmitting the blood oxygen saturation, the heart and respiration rate and the patient's quantity of movement.

A balance needs to be struck between two opposed factors when obtaining and analysing the electrocardiographic signal: on the one hand, the desire to have a high number of leads (in principle the more the better), and on the other, the desire to reduce the level of complexity for the patient (number of electrodes, cables, etc). It was therefore decided to use a 2-lead electrocardiogram to allow analysis of the signal from two different axes. If the depolarisation vector is perpendicular to the exploring electrode, no signal is obtained; the use of a single lead could therefore result in a failure to detect one or several waves of the P-QRS-T (Palliative/Provoking, Quality, Radiation, Severity, Timing) complex. The use of 2 leads will enable us to obtain each one of these waves without making the system too cumbersome for the patient.

The following signal parameters will be analysed:

· detection of the P wave and QRS complex;

· measurement of the duration of the P wave and QRS complex length of the heart cycle (interval between R waves).

The detection of the P wave before the QRS complex enables a rhythm to be defined as auricular, usually a sinus rhythm and therefore normal. The duration of the QRS complex enables the rhythm to be defined as normally conducted by the cardiac conduction system; sudden changes in this value may indicate the following: extrasystoles if they are isolated complexes, bundle branch blocks if they are preceded by a normal P wave or probable ventricular arrhythmias if there is a prolonged QRS complex not preceded by a P wave.

The length of the heart cycle, for its part, enables an assessment to be made of the frequency and its variations (Heart Rate Variability [21]); irregularity beyond certain preset physiological thresholds indicates the existence of arrhythmias.

In short, the obtaining of the ECG and the subsequent automatic analysis of all these parameters means that the system as designed can be applied to a great number of patients eligible for ambulatory monitoring.

This paper has been broken down into the following sections: Section 2 gives a functional description of the system developed; Section 3 gives a detailed account of each one of the three modules making up the system; Section 4 summarises the results so far and then the main conclusions are drawn.

2 Functional Description of The Proposed System

The objective in view was to design a system for monitoring certain physiological variables of a patient on an ubiquitous basis and in conditions similar to in_hospital treatment. On a medical level the following variables are to be monitored:

· **Electrocardiogram: 2 leads**: As already explained, the system has to work with 2 electrocardiogram leads, so 2 independent bioamplifiers will be used, each one with a bandwidth between 0.05 and 300 Hz, CRMM > 100 dB, and input impedance > 10MS, with a sampling frequency of up to 200 Hz per channel and 10-bit resolution. The gain (500 - 2000) and offset of each amplifying stage will be independently programmable from a microcontroller.

· **Connection to personal analysers:** many of these devices (glucometers, coagulometers,....) can store the results of the last analysis in an internal memory and transfer them through an RS232 port; the connector and suitable protocols will therefore be implemented for interacting with several models. The only function of the operator is to connect the device, automating the process and avoiding the possibility of errors. The communications protocol has been designed for various glucometer and coagulometer models. Many of these analysers are likely in the near future to have a Bluetooth communications system, with which our equipment could operate, logically after setting up the suitable communications protocol.

The patient monitoring system developed in this paper comprises the following elements (Figure 1):

Portable Module (PM): this equipment is designed to

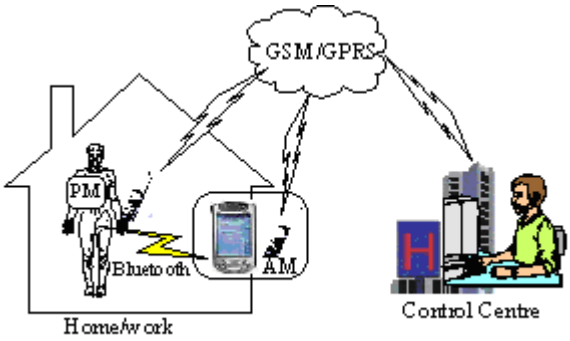

Figure 1: General Diagram of The System.

capture, transmit and, in certain circumstances, make a basic analysis of the ECG. It is basically made up by a microcontroller system, 2 ECG signal amplifiers, a Bluetooth transmission system and an autonomous power supply. Under normal conditions the PM forms a BAN that communicates with an Analysis Module.

Analysis Module (AM): this can be considered as an intermediate unit (gateway) between the PM and the Control Centre set up in the hospital. One of its main function is to provide a top-quality detection of the ECG and pinpoint any abnormalities in a restricted set of possibilities.

It receives the ECG signal sent by Bluetooth from the PM and also communicates with the Control Centre by means of mobile telephony (short telephony messages: SMS or data mode calls as the case may be). It has been set up on a PDA and mobile telephone. A series of algorithms are run in the PDA to analyse the ECG signal received and detect certain anomalies in the patient.

Another possibility is for the AM to be connected up to certain commonly-used personal analysers (glucometers, coagulometers, etc) and download the data stored in them to incorporate this information and send it on to the Control Centre. These devices communicate with each other through RS232 ports using the particular commands of each analyser.

Control Centre (CC): central unit (ideally located in the hospital) for the control of an indeterminate number of monitored patients under the supervision of medical specialists. It can be set up on a personal computer and will carry out the functions of communication by mobile telephony, management of patients, generation of reports, etc.

The above mentioned modules could be used in two different scenarios:

1. The patient wearing the PM is within the range of the AM (*data transmission mode*). In this case the Portable Module basically captures the ECG signals (1 or 2 leads depending on the configuration) and sends on the information to the AM. The latter then runs the signal_analysis algorithms and contacts the Control Centre if it detects any abnormalities. The AM also acts as a gateway between the patient and the Control Centre to request the sending of the signal in real time, statistics obtained, etc.

2. The patient is outside the range of the AM (*data analysis mode*). If Bluetooth communication between the PM and AM is not possible, then it is the PM that analyses the ECG signal; obviously, due to the limitations of the microcontroller of the PM, only very simple analysis algorithms should be used [22]. A prerequisite of this working mode is for patients to carry with them a mobile telephone with Bluetooth communication, for communication with the CC if any problem is detected. It should be pointed out here that it is the PM itself that detects whether or not it is within the AM's range of action; the AM periodically sends certain data to the PM, on the basis of which the PM switches from one working mode to the other.

In either of the two above cases, both the Control Centre and the patients themselves (by pushing a button) can initiate the transfer of the patients' ECG in real time, so that it can be examined in the Control Centre by a specialist.

A data mode call (GPRS - General Packet Radio Service) is used for sending the ECG by mobile telephone and short telephone messages (SMS – Short Message System) for sending data of the personal analysers, configuration, etc, cutting down the cost in each case and optimising the communication bandwidth.

3 HW/SW Architecture of the Various Modules

The modules forming the monitoring system are designed and implemented in view of the restrictions imposed by the application. This is first-need equipment for many cardiovascular patients, so the cost and consumption should both be kept as low as possible, with minimum safety criteria also being ensured.

The hardware design of the Portable Module was based on the guidelines laid down in the European Standard: "*Particular requirements for the safety, including essential performance, of ambulatory electrocardiographic systems*" [23]. At hardware level this standard defines the minimum bandwidth (0.05 _ 40 Hz), input impedance (> 10MS), battery life (> 24 hours), minimum CMRR of the signal amplification (> 60dB @ 50Hz, >45dB @ 100Hz), etc.

If the system offers automatic signal analysis (QRS de-

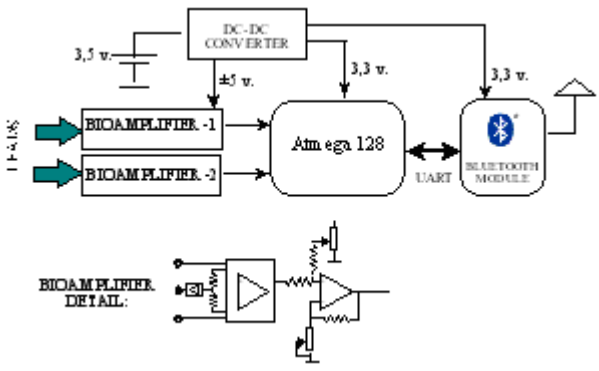

Figure 2: Hardware Block Diagram of The PT.

tection, ventricular ectopic beat detection, etc), the standard indicates the tests and databases to be used for testing the system. In our case, however, this phase has not yet been carried out.

With these restrictions in mind, a description is now given of the HW and SW of each module forming the monitoring system: PM, AM and CC.

3.1 Description of the PM

The PM system has been designed at hardware and software level by the authors. Figure 2 shows its block diagram at hardware level. It is a portable, low-weight, low-volume, low-consumption and ergonomic system. It comprises the following elements:

Microcontroller: PM operation is governed by the ATmega128 microcontroller, with an 8 bit RISC core capable of delivering up to 16 MIPS at a maximum of 16 MHz. Its performance features are the following; in terms of storage capacity it has 128 Kb of FLASH memory (reprogrammable more than 10000 times), 4 Kb of EEPROM and 4 Kb of SRAM. In terms of communications it features IIC, SPI and 2 UARTs. It also has 2 timers of 16 bits and 8 bits, watchdog, eight analog-digital conversion channels, an analog comparator, 8 channels with PWM modulation capacity, low voltage power supply detector, hardware multiplier, internal oscillator, etc.

Programming is done on the electronic board itself through a JTAG (Joint Test Action Group) interface. The main functions of the microcontroller are:

· Initialisation and initial configurations: configuration of the communications port, A/D converters, amplifiers gain and offset, etc.

· Periodic digitalisation of 1 or 2 leads, depending on the configuration. A timer causes a cut-off at an adjustable frequency (40 - 200Hz); in the data transmission mode both signals are sequentially digitalised and sent through the serial port to the Bluetooth module and then to the Analysis Module.

· Reception and attention to commands sent by the AM. At any moment the PM might receive commands from the AM to vary the gain or offset of some of the stages, deactivate/activate the digitalisation of some of the leads, in short, remote configuration of PM parameters.

· Detection of whether or not the PM is within range of the AM. The PM continually and automatically detects whether it is within range of the AM. If so, it works in *data transmission mode*; if not, it switches to *data analysis mode*.

· Basic algorithm for ECG analysis. This algorithm is run when the PM cannot send data to the AM (*data analysis mode*). In this case the :C analyses the ECG signal with the basic aim of ascertaining the patient's heart rate [22]. If this rate strays outside preset levels, it sends the appropriate AT commands to the mobile phone for transmitting an SMS to the Control Centre indicating this possible abnormality. A data mode call will then probably be established from the Control Centre for sending the patient's ECG in real time.

· Reception of commands by mobile telephone. If working in *data analysis mode* it can receive a command by mobile telephone to request, for example, transmission of this patient's ECG, variation of the thresholds or characteristics of the amplification network, etc. In this case the patient's mobile telephone acts as gateway between the PM and the CC.

Bioamplifiers: Two different bioamplifiers have been designed, each one based on an INA 114 instrumentation amplifier, followed by an amplification stage of programmable offset and gain using an operational amplifier (LMC6482AIM) and resistors digitally programmable from the microcontroller (X9C103) for adjusting the gain and offset of this second stage. The bandwidth of each amplifier ranges from 0.05 to 300 Hz, with inclusion of a 50 Hz notch filter.

Communications: The Bluetooth communication is provided by a module based on the CSR BlueCore2_Ext chipset with UART (Universal Asynchronous Receiver-Transmitter) connection to the microcontroller (transport interface). This module, based on BlueCore2_Ext, provides SPI and IIC communications, two widely used communication interfaces. The firmware integrated by this module meets specification 1.1 of Bluetooth, permitting, in the radio interface, asynchronous connectionless links (ACL) of up to 720 kbps (with USB transport) and three synchronous connection-oriented (SCO) links of 64 kbps. It is a class 2 device (4 dBm transmission output) with a typical sensitivity of 80 dBm, with a 15 metre range in an office environment (numerous obstacles) and 45 metres in the open air. The mean power consumption is estimated as 15 mA @ Vdd=1.8 V. in asynchronous transmission of 115 kbps, plunging to 500 microamperes in sniff mode and even further to 20 microamperes in deep sleep mode. A serial port profile (SPP) is used, mainly implemented on Bluetooth devices with data exchange capacity. The Bluetooth module is the slave part while the PDA or mobile telephone (*data analysis mode*) is the master in the SPP profile. The radio interface communications can reach 380 kbps, but the speed used for UART transport is up to 250 kbps. The encryption is 56 bits; the reliability and authentication of the link are guaranteed under the Bluetooth specification 1.1, by establishing a PIN-based link key for authentication and the various control and error correction codes (with retransmission if necessary) implemented in the layers below RFCOMM.

Bluelab SDK is used as the necessary development system for reprogramming the BC02-Ext. This consists of a GCC compiler (GNU licence), a series of utilities (loader, programmer, debugger) and a powerful functions library giving access to all internal modules of the BC02-Ext. Another noteworthy feature is the 64 kBytes user-application space within the Bluetooth module. Furthermore, CSR offers the stack Bluetooth, which implements the different protocol levels specified by the Standard Bluetooth. Two types of stack are possible. One of them offers the application an HCI interface while the other offers stack up to the

RFCOMM level, the latter facilitating access to L2CAP and SDP. The RFCOMM stack is used in the application described in this article. The module based on BC02_Ext thus behaves like a UART once the channel has been set up between said module and the interlocutor device (PDA, smartphone, etc.). In the application presented herein, the microcontroller (ATmega128) controls and communicates with the Bluetooth module through several lines:

· **RESET**. Reset hardware of the communications module run by the main application, resident in the microcontroller.

· **TX** and **RX**. Transmission and reception signals of the microcontroller's UART, used as serial communication lines with the Bluetooth module.

· **S0** and **S1**. Control signals allowing the microcontroller to make petitions to the Bluetooth module.

· **AMB**. Bluetooth module signal used to confirm microcontroller petitions.

The programming of the BC02-Ext with RFCOMM stack is based on a series of calls to an essential component of said stack: the connection manager (CM). Bluelab is equipped with a scheduler for running different tasks. One of these tasks (Task 0) is the CM which is called from another task (Task 1) by means of a series of messages requiring CM functions: messages such as pairing, link key, connect, pin code, error, etc. Finally, once both devices have been paired, a stream connect is set up to connect the data flow from the UART of the BC02_Ext to the RFCOMM channel established by means of calls to the CM.

The sequence of calls starts with initialisation of the CM (CM_INIT_REQ), after which registration is made of the service and device class (CM_SERVICE_ REGISTER_ REQ,CM_WRITE_CODE_REQ), the device pairing (CM_PAIR_REQ) which implies the interchange of the LINK KEY (CM_LINK_KEY_REQ) and the PIN code (CM_PIN_CODE_REQ) and, finally, the establishment of the connection (CM_CONNECT_ AS_SLAVE_REQ). In response to CM_CONNECT_AS_SLAVE_REQ the CM returns a radio_frequency channel (RFCOMM) which connects up to the UART by means of calls to the CM:

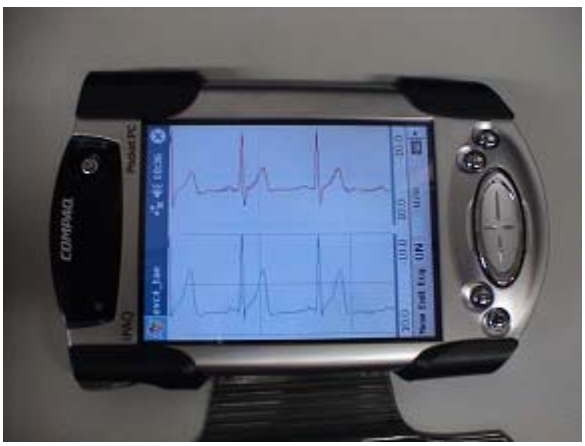

Figure 3: PDA Display with The ECG Signal.

StreamConnect(uart_source, rfcomm_sink);
StreamConnect(rfcomm_source, uart_sink);

Where *uart_source* and *rfcomm_source* are data input streams and *rfcomm_sink* and *uart_sink* are data output streams.

By this time the communication through the Bluetooth device is transparent, acting as a pipe between the UART and the RFCOMM channel set up with the remote device.

The connection established is a slave serial line emulation. This means that once the CM has been initiated, the application and Bluetooth stack wait for the master device to ask for the pairing and the establishment of the RFCOMM channel.

Power supply: Power is supplied from a rechargeable 3.5 volt battery. Values of +3.3 volts are then obtained by means of an MAX1705 step-up converter while the voltage of ±5 volts necessary for the analog part is achieved with a DC/DC NAM0505 converter; this optimises the system's power performance. The microcontroller runs on 3.3 volts; an LC filter has been fitted to ensure that the power supply is as stable as possible and to eliminate any noise associated with the power supply voltage.

3.2. Description of The Analysis Module

The Analysis Module has been implemented on a PDA platform; it is a portable processing system with advanced user interfaces and distance-communication possibilities, whether Bluetooth, Irda or RS232, etc. The model used (iPAQ H3970) does not allow for mobile telephone communications, so these communications are made on a mobile telephone (the same as the one that can be carried by the user in the *data analysis mode*, both communicating through Bluetooth).

A basic feature in the design of the AM is the definition of the user's interface, which must be user friendly and facilitate browsing from one option to another, since it will often have to be used by people with little computing knowledge. Figure 3 shows the AM interface receiving a patient's ECG signals. From this interface the user can easily select the options of "Send to CC", "Record", "Exit", etc.

The following functions have been programmed in the AM:

· Reception of the ECG from the PM and sending a control word so that the Portable Module recognises that it is within the AM's range of action.

· Analysis of the signal received. The parameters to be analysed plus the algorithms to be used in each case can be configured, within the programmed options. As well as the algorithms indicated in [22], wavelet-based algorithms and blind signal separation have also been programmed. These facets are still in research stage.

· Drivers for communication with different types of personal analysers and data capture therefrom glucometers Bayer Esprit® and OneTouch Ultra® (Lifescan) and the coagulometers Coagucheck® (Roche) and HEMOCHRON ® (SIGNATURE).

· Mobile telephone communications by means of calls

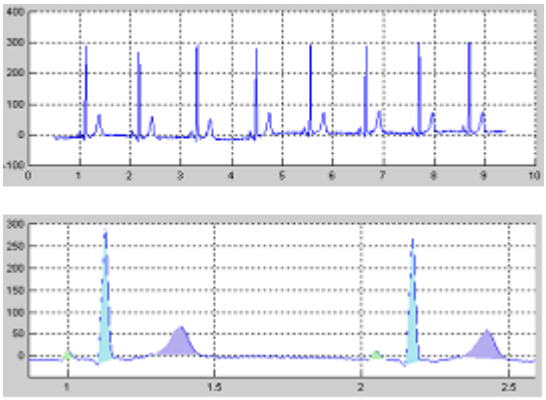

Figure 4: CC Display Showing The ECG, The Areas and The Waves' limits.

(for sending the ECG) and SMS for sending alarms, configurations, etc.

· Database for storing patient information.

It is also possible to carry out the following functions on the AM:

· Storage of the ECG signal, whether ad hoc due to certain events (tachycardia, bradycardia, etc.) or periodically.

· Storage of the data obtained from the personal analysers and display thereof on suitable graphs, even when they have been sent to the Control Centre.

· Possibility of displaying 1 or 2 ECG channels on the PDA screen, for better appreciation of the details.

· Functioning of analysis in "graphic" mode. With this option the PDA screen shows the ECG signal and the algorithm points, making it easy to check whether the running of the ECG analysis algorithms gives the expected result.

3.3 Description of The Control Centre

The Control Centre is based on a personal computer with the following functions: database, mobile telephone communications, printer and a smart module for analysing the information received. It has been implemented using LabWindows language; the function is to centralise the information on possible patients and enable a medical specialist to monitor the state of each patient. Checks can thus be made, for example, on the performance of the automatic analysis algorithms (Figure 4) or the state of each patient; reports can be generated and sent to the patient while the equipment's gain and/or offset can be adjusted, etc.

4 Practical Results

We consider the most innovative part of our system to be the hardware (Figure 5) and software development of the Portable Module. A description is given below of its electrical characteristics, which meet the standard [23]:

· Power consumption: 22,6mA

· Autonomy (750 mAh battery): > 30 hours

· Input impedance: 14,2 MS

· Bandwidth: 0.05 _-250 Hz

· CMRR: > 100 dB.

All sorts of tests have been conducted at functional level to check that the system abides by the indicated specifications, in particular:

· ECG transmission tests (1 and 2 channels) to the CC.

· Tests of the capture and transmission of data from various commercial personal analysers: glucometers, coagulometers,....

· Tests of the system in data analysis mode, using the mobile telephone Nokia 6600

· Tests with the patient moving in an environment with obstacles.

A check has also been made that the ECG analysis algorithms implemented so far work reasonably well, although we understand that further fine tuning is needed until they pass the tests indicated in [23].

5 Conclusions

This paper presents the current state of a system for the monitoring of patients' electrocardiograph signals using different wireless technologies: Bluetooth and mobile telephony. At the moment a hardware platform has been set up for system operation; this will be optimised mainly with the implementation of algorithms that ensure a robust analysis of the ECG signal under diverse operating conditions.

The next stage in this research project will involve tests of the implemented signal analysis algorithms and a check of their performance, in accordance with the specifications laid down in the standard [23]. The aim will be to build up a system that completely meets all relevant standards.

The system is based on an open architecture that allows the system to be configured to meet the needs of each patient; furthermore, the use of standard technology means that new equipment can easily be incorporated as it appears on the market.

Finally we believe that the system can be used for other types of applications, such as telemetry and control of wireless systems.

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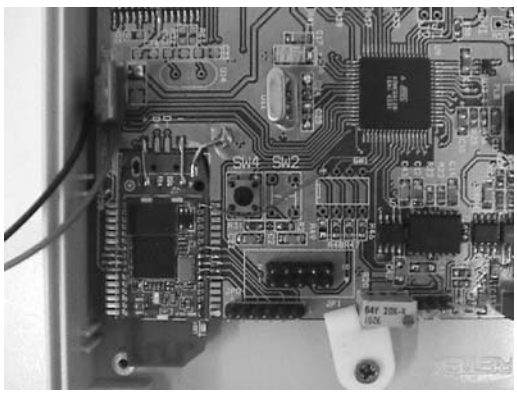

Figure 5: Real implementation of the PT.

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SIGLAS: A Practical Case of The Application of Ubiquitous Computing in Warehouse Management

José-Julio González-Pozo and Manuel Ortega-Cantero

Following the principles of Ubiquitous Computing, we have designed a warehouse management system, hereinafter referred to by its Spanish acronym SIGLAS (standing for Management System for Locating Goods in Warehouses), which we put forward as an example of the application of the Ubiquitous Computing paradigm to business management environments. This article details the processes that need to be undertaken in order to implement a Ubiquitous Computing project in a specific organization, paying special attention to the advantages of such a project.

Keywords: SIGLAS, Ubiquitous Computing, Warehouse Management.

1 Introduction

Since Mark Weiser first defined the Ubiquitous Computing paradigm in 1991 [1], a large number of projects and research initiatives have developed this principle, enabling organizations to address specific problems in their production processes and management thereby stealing a march over other organizations which still consider the paradigm to be too theoretical.

Ubiquitous Computing is an interaction paradigm, making permanent access to information possible not only through personal computers but also through all the electronic devices that people use in their day-to-day lives. This access to information needs to be practically transparent to the user; that is to say, it should require no effort on the part of the user. For this reason, this concept does not apply only to hardware but also to software, by constructing simple user interfaces that focus users' attention on the performance of tasks rather than on how to perform them.

One of the main aspects that has fostered the implementation of Ubiquitous Computing is the development of wireless technology. The most recent 802.11b, g, and i wireless standards together with Bluetooth technology have facilitated connectivity and the access to information from anywhere. This has improved the serviceability, comfort, efficiency, and speed in everyday work and decision making processes. Another important aspect of Ubiquitous Computing has been the technological development of processing capacity per unit of space. As Gordon Moore predicted in 1965, the capacity of the microprocessors has progressively doubled every 18 months, which has enabled the development of ever smaller devices integrated in users' everyday lives.

The CHICO (Computer Human Interaction and Collaboration) research group of the *Universidad de Castilla-La Mancha*, Spain, has developed several Ubiquitous Computing systems based on an architecture called e-CLUB [3]. They allow different experimental disciplines to be taught and learned by using PDAs (Personal Digital Assistants). AULA [4] deserves a special mention in the field of e-Learning.

In this article we introduce the SIGLAS project as an example of the application of Ubiquitous Computing in business management environments. First, we will explain how access to information is achieved in a specific system. Then, we will define the software requirements to accomplish the project. Later, we will detail the advantages that the implementation of SIGLAS has given to a certain environment, before concluding with a presentation of the interface.

2 The SIGLAS Project

The central objective of the project is to integrate Ubiquitous Computing [1] in a typical environment of inventory management in a warehouse. The acronym used, SIGLAS, derives from the Spanish descriptive name *SIstema de Gestión para Localización en Almacenes de Stocks* (Management System for Locating Goods in Warehouses). The purpose of the system is to manage stock in a warehouse, to monitor and organize customers' orders, and to receive and control orders from suppliers.

One of the main difficulties that we encounter when undertaking such a project is the matter of connectivity between the information stored by the organization's general processes and the mobile devices used. In some cases it is the processes, or else the database used as the driver of these processes, that provide the means of achieving connectivity in an easy and rapid manner.

In other cases, such as the one we present here, there may be an inherited information structure which is hard to

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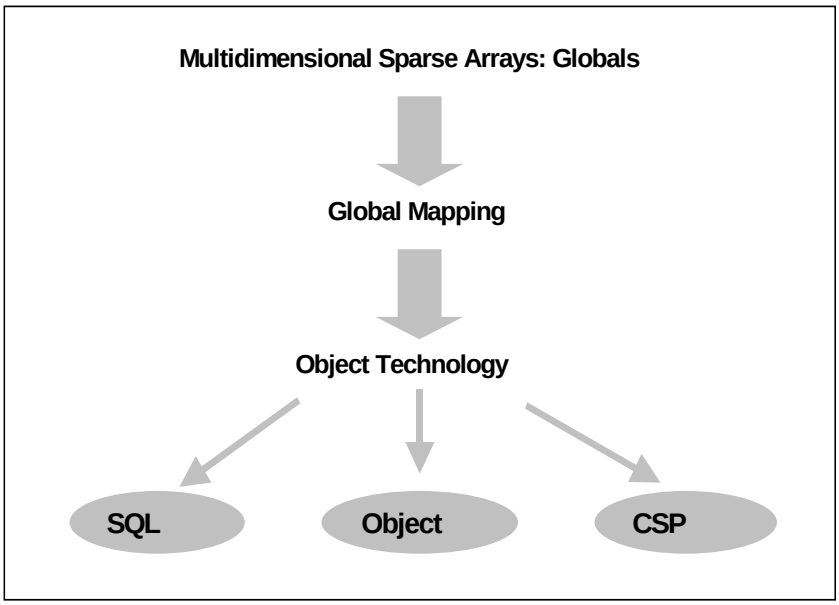

Figure 1: Access to InterSystems Caché.

adapt to current environments requiring, say, the use of objects. For these cases we need to find hardware or procedures that enable connectivity without significantly altering the company's computing structure.

In this project, the database used by the organization is Caché by InterSystems, whose storage model matches a collection of multidimensional sparse arrays called "*globals*" against types and numbers of independent sub-indexes. In order to make these globals accessible to object-oriented technology, aprocess of "*mapping*" was required. This process assigned a structure of classes to each global. Once the information has been made available in a structure of classes, various methods can be used to access the information, such as SQL statements, object-oriented languages, or database-driven languages such as Caché Server Page described below. This process is displayed in Figure 1.

Finally, with regard to physical connectivity there are currently a large number of standards for wireless technology. The standard to be used should allow the system to be evolved to provide more and improved services. This is the case of 802.11b wireless technology, which makes it possible to migrate in the future to 802.11g/i standards or to any faster standards that may emerge.

2.1 Extending the SIGLAS Project

After the feasibility of this project had been verified in a specific organization, the possibility arose of extending the SIGLAS project to a new line of development: the monitoring and controlling of the different components of an automated system.

In the first phase of this project we took the specific situation of a company as our starting point. In this case, the company has an automated system for the receipt and delivery of orders. The system consists of a large number of automatic elements: actuators, light barriers, brakes, engines, conveyor belts, mechanical arms, automatic elevators, etc. All the signals generated by these elements are interpreted and processed by a programmable robot or PLC (Programmable Logic Controller), namely a Simatic S7. The CPU (Central processing Unit) of the PLC is in charge of executing the control program of signals for the management of the warehouse. The program is located in an E-PROM.

The PLC can be monitored through specific programs installed in the PLC. They allow the operation of the robot to be visualized and managed on a personal Computer (PC).

A future extension of the SIGLAS Project could be to enable the PLC to be controlled by any PDA- or Tablet PC-type mobile device. To achieve this, the following aspects need to be developed:

- To analyse and interpret the Simatic S7 protocol that provides information on the state of the robot and the situation of all the devices making up the automated system.
- To create the storage structure required to reflect the different states that the robot can be in and the components that determine these states.
- To enable the storage structure to be queried and interacted with through a Web server. This would involve the design of a simple interface, one which is easy to handle by the workers or operators controlling the automated system.

With this extension, the management of an automated system would be achieved in a fast and simple manner, thereby bringing the Ubiquitous Computing paradigm to the field of automation.

3 Software Requirements

The SIGLAS project's main objective was to meet the needs and expectations of an organization applying Ubiquitous Computing to warehouse management. In this particular project they were:

- Stock control: Access to information related to all items in a warehouse, with their different characteristics of

price, location, and quantity.

- Monitoring the day's orders: Allowing the state of orders to be tracked on a daily basis.
- Organization and planning of customers' orders: Allowing a greater control over order fulfilment, dispatch, and delivery processes.
- Receipt and control of suppliers' orders: Improving the tasks of receiving, storing, replenishing, and locating goods in the warehouse

Before the implementing the software we had to decide which technology and language to use. After considering the multiple possibilities regarding the technology to apply to the SIGLAS project, we decided that the technology should be independent of the mobile devices to be used. For this reason we chose Web technology which allows us to produce designs independently of the end device used to execute them.

Caché has an integrated technology called CSP (Caché Server Pages) [4] for the construction and development of highly scalable, high performance Web applications. CSP allows Web pages to be generated dynamically using data stored in Caché. The content of CSP pages combines HTML (HyperText Markup Language) with Caché ObjectScript language as well as specific CSP tags. These tags allow the embedding of SQL (Structured Query Language) statements.

Although we could have chosen any other Web development language, this database technology helps us to avoid having to use independent gateways such as ODBC. This solution was chosen as it provides greater speed and optimization of the processes to be executed on the server.

4 System Architecture

Once the technology to be used (CSP) had been decided, it was necessary to define the classes required for the SIGLAS system. Figure 2 shows the corresponding diagram of classes detailing the class clients (CLI), laboratories (lab), items (ART), warehouse (ALM), location (UBI), stock (STK), preparation sheets (HPR and HPR1) and purchase orders (FISH); it also shows their attributes and the methods used.

Sequence diagrams were produced for each of the system's functionalities. Figure 3 shows a diagram of the item query functionality.

As seen in Figure 3, the CSP pages required for this functionality were developed. They are:

- SARTCON: This is the entry form of the item identifier
- SARTDAT: This shows information about an item.
- SARTSTK: This displays the situation of different stocks of the item.
- SARTMAS: This shows other information related to the item.

Similarly, the sequence diagrams for the rest of the functionalities were developed: consultation of orders for the day, consultation of customers' orders, and consultation of suppliers' orders.

To close this phase, a Web server was required to connect with the database where the classes and the CSP pages were stored, and to service users' requests.

5 Results

The development of the project led to its actual implementation in a specific organization, COFARCIR (*Cooperativa Farmacéutica de Ciudad Real*), with a 5000 m^2 warehouse. First of all we needed to perform a radio coverage study to adapt the wireless technology to the local conditions. It was also necessary to decide which mobile devices were to be used. Once these decisions had been taken and once the system had been commissioned and started up, we were able to verify the actual feasibility of the project with the following advantages to the user:

- Improved access to information.
- Process integration.

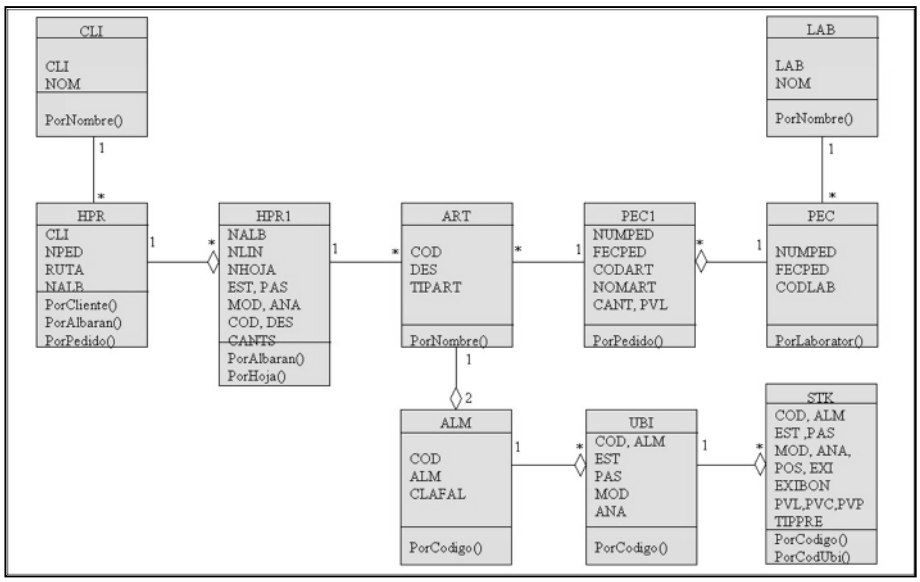

Figure 2: Diagram of Classes.

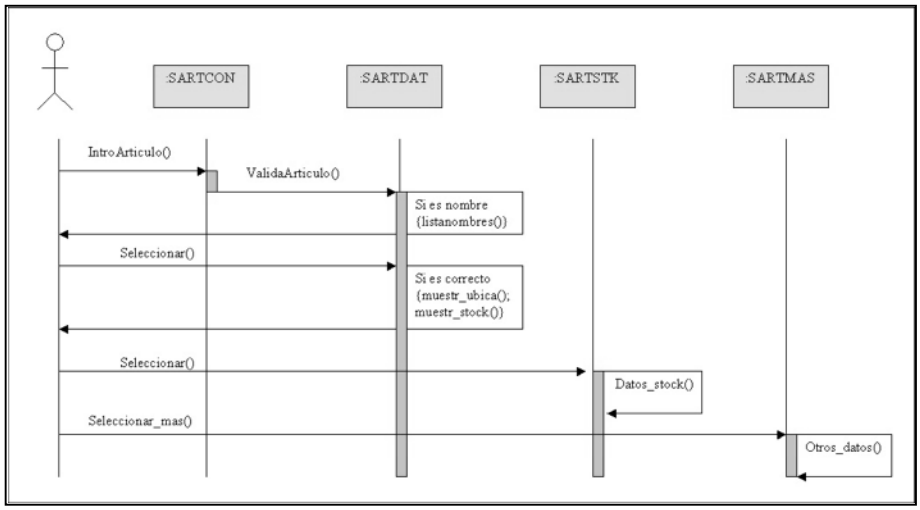

Figure 3: Item Query Sequence Diagram.

- Cost reduction.
- Improved quality of service.
- Optimization of resources.

Finally, a web server was needed to connect with the database in which the classes and the CSP pages were stored, and to service users' requests.

All the above has given the organization a competitive advantage over other companies that have not applied this paradigm to their operations / work system.

As an example, whereas in the past a worker or operator needed time to consult and modify a simple item in the warehouse, now workers have immediate access to information, their access is recorded in a registry, and any corrections needed to avoid mistakes that could alter the quality of service can be made in advance. Although current use is centred on industrial PDA's, the advantage of this development is that in the future any mobile device with a Web browser may be used.

6 User Interface

The importance of user interfaces has been growing in recent years. If the interface is complex, tedious, functionally inadequate, with inconsistent actions and insufficient information for the user, it can cause stress, anxiety and, eventually, loss of productivity [5].

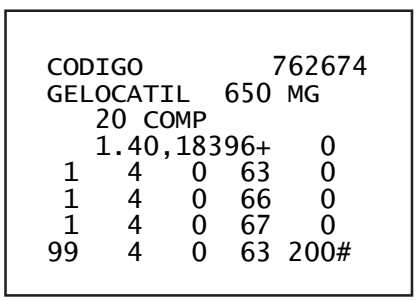

Figure 4: WSS1060 Terminal

Although wireless connectivity allows us to use various types of terminals, the aspect of the user interface is also very important when designing a Ubiquitous Computing project. The interface should be completely intuitive and user-friendly so that the user does not have to spend any extra time or effort in learning how to interact with the system [6]. For a better understanding of this aspect we can take a look at Figures 4 and 5. In Figure 4 the information appears on a radio-frequency terminal, namely a Symbol WS1060. Figure 5 shows the same information on a browser on a mobile device, namely a Symbol PPT8800. The resulting ease of understanding of information underscores the importance of user interface design. The SIGLAS project followed interface design procedures suggested by such authors as Ben Shneiderman [7].

Figure 4 shows information about a certain item, namely Gelocatil. It is possible to see its national code, 762674, its complete name, Gelocatil 650mg 20 comp, where it is stored

Figure 5: PP T8800 PDA

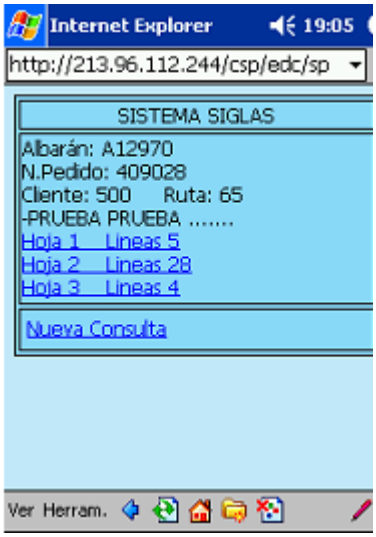

Figure 6: Selection of Order Sheet.

Figure 7: Detail of Order Sheet.

(station, aisle, module, shelf), 1-4-0-63/66/67 and 99-4-0-63, the number of items in stock, 18396, and its price per unit, 1.40.

Figure 5 displays the same information in a clearer way, with the possibility of showing more information about the stock with a simple click on the link.

Figure 6 shows how to access any part of an order simply by selecting one of the preparation sheets making up the order. This figure shows the delivery number and the order number, A12970 409028, the customer's code and name, 500 Prueba, the shipping route associated with this customer, 65, and 3 links to the sheets that make up this order. Figure 7 shows a detail of one of these preparation sheets. In this figure we can see the location of the items to be dispatched, the station or area, the aisle, the module, the shelf, the code, the name of the product, and the quantity to be dispatched.

7 Conclusions

We are at the dawn of a new age in which the application of the Ubiquitous Computing paradigm is beginning to pervade every dimension of our lives. However, it is also true that there are a great many advances yet to be made before the paradigm is fully integrated in our day-to-day lives. In this article we have presented a solution in which the application of Ubiquitous Computing has successfully solved specific problems in business management environments. The advantages, mentioned in previous sections, are causing organizations to consider this type of development as a way of making improvements in several situations arising in their daily business activity. The SIGLAS project was a joint development between the *Universidad de Castilla-La Mancha* and the company COFARCIR which arose out of the close relationship between the academic world and the world of industry. Among the national and international recognition that this project has received we would highlight the 1st International Award for Technological Innovation using the Caché Platform, received at the Worldwide Conference of InterSystems Developers held in Orlando (Florida, USA) in March 2004.

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Ubiquitous E-Management of Indicators

Eladio Domínguez-Murillo, Ángel De Miguel-Artal, Beatriz Pérez-Valle, Áurea Rodríguez-Villanueva, and María-Antonia Zapata-Abad

The goal of this paper is to present a proposal for collaborative management of indicators within a ubiquitous computing context. The scenario we describe assumes that various groups of people, without a common or unique location, need to define and manage a large number of indicators in a collaborative manner. The case we present describes a ubiquitous E-Management Performance Indicators System for Urban Water Services and shows the way in which ubiquitous collaboration can also incorporate aspects of knowledge management. We have used the term E-Management to define the ideas which this notion contains, to refer to the capacity of a tool to allow a user to manage information in a remote and collaborative way.

Keywords: Collaborative Work, E-Management, Performance Indicators System, Ubiquitous Computing, Urban Water Services.

1 Introduction

The ubiquitous collaboration paradigm provides members of a collaborative group with general access in order to share services through a variety of interactive devices, irrespective of the physical location of the members of the group [4].

The goal of this paper is to present a ubiquitous E-Management Performance Indicators System for Urban Water Services. This application is based on the indicator standardization process set up by the IWA (International Water Association) [1] to manage water supply.

The system enables water supply performance indicators to be controlled and periodic measurements taken. As this is the responsibility of a number of different municipal services located in different places, we proposed setting up an Intranet so that the work could be performed collaboratively.

The need to implement this system in a ubiquitous computing context arises from the fact that data on some indicators is collected in remote places. We thought it reasonable to assume that in these cases data could be input and transmitted through devices such as PDAs (Personal Digital Assistant) or mobile phones.

The use of PDAs also allows real time access to the data, irrespective of physical location. In a meeting, for example, the person in charge of municipal water management could show those present the actual values of indicators and their statistics.

In the following section we look at some possible situations in which the system will be used in a ubiquitous way. The next section deals with the hardware architecture that we propose for the system before we go on to describe the most salient features of the system and we introduce the notion of E-Management. To close the paper we summarize the current state of the project.

2 Scenario

We start by describing a typical scenario which shows some of the functionalities related to the ubiquitous use of the system for the management of water supply performance indicators.

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An employee of a certain company, in charge of gathering data related to the indicator that measures the volume of water, is in a water-treatment plant. In order to register this information he accesses the system via his/her mobile phone. Once access is validated, a combobox appears on the screen showing a number of variables. The user selects the desired variable and inputs the value that corresponds to the required reading.

The municipal service, Integral Water Cycle, responsible for the variable Water Supplied decides to change its calculation formula. To perform this change it applies for permission by means of an SMS to the person in charge of the indicators system. The person in charge, who is on a business trip, receives the message and decides to grant permission. S/he does this by accessing the application with his/her mobile phone and transfers a copy of the corresponding variable to the *work environment*. The system automatically sends an SMS to the municipal service, notifying them that they can modify the variable. Once this message is received, one of the people in charge at the municipal service makes the relevant changes. When he has completed the task, he sends another SMS to the person in charge of the system to check whether he considers it appropriate to change the old variable for the new one. Once the person in charge is notified he can visualize the proposed change on the Internet make sure that they still comply with regulations. Next, he gives his/her go ahead to the change and the system sends another SMS to the municipal service, Integral Water Cycle, to record the change that has been made.

Figure 1: Graph Showing Values of A Given Variable (A09).

In another situation, the head of a municipal service is at a work meeting, and they need to know the state of some indicators. So the head of the service accesses the indicators system through his/her PDA. S/he connects it to a projector so that the rest of those present at the meeting can view a statistic about the state of the indicators (Figure 1).

3 Hardware Architecture

For the previous situation we propose the hardware architecture in Figure 2, which shows the hardware elements and mobile devices that will be integrated into the system.

The city council has a database server to manage system performance indicators and their values. The city council also has a Web application server used by the Intranet, thereby providing the city council with a collaborative working environment.

Mobile devices are included in the system to make up a collaborative ubiquitous computing environment as in the scenario previously described.

4 Metadata and E-Management

A number of authors have written about the concept of E-Management [3], but the notion of E-Management that we present is a little different.

Generally speaking, in a collaborative application the participants in the collaboration must be able to create, access, modify, and delete a set of data [2]. In the particular case of water supply performance indicators, the application must allow the value of previously defined indicators to be manipulated. Through this type of application, users can generate reports which include specific values of indicators or results obtained from data analysis (for example, statistical analysis). If the system is equipped only with this type of functionality, it will be a collaborative system orientated towards producing information.

However, another possibility is for the collaborative application to not only allow data to be managed but also to allow the participants in the collaboration to create, access, modify, and delete the definition of indicators. This is the case of the Inagua application, in which users can manage metadata relative to the water supply performance indicators. They can define the indicators, modify the definition of the existing ones, adapt them to new circumstances, or eliminate those that for some reason have been declared obsolete. A system of this type is a system prepared for the generation of knowledge.

The people who can define and manage the water supply performance indicators belong to different services of the city council and have neither a common nor a unique location. We have therefore considered how to enable remote management of the performance indicators through mobile and heterogeneous devices.

The data and the definition of indicators are managed by an organized system of users. Each user has different

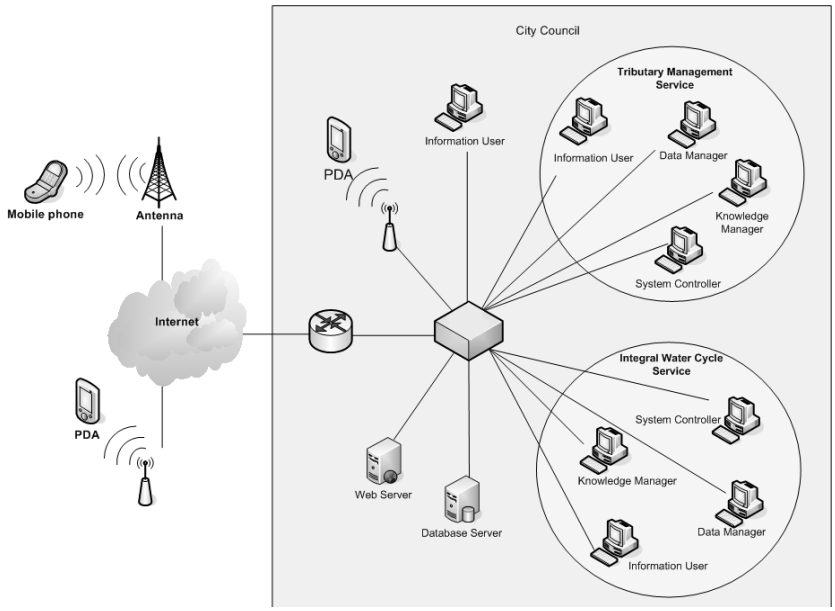

Figure 2: Hardware Architecture.

management responsibilities depending on their role allowing users to collaborate together. The tool controls the responsibility protocols of the real system. One of the metaphors we have used to obtain this characteristic, lies in the existence of two differentiated working environments within the tool: a *production environment* where there is data from performance indicators, and a *work environment* where users with the necessary privileges are able to modify those indicators. Access to the tool is by restricted access over the Internet, and the tool is capable of presenting information dynamically.

We considered that some of the characteristics that we have described make this type of application different from the rest. For this reason, and given the capability of the tool to allow information to be managed remotely and collaboratively, we think it reasonable to consider this idea as *E-Management*.

5 State of The Project

The database storing information on the indicators is implemented in Oracle 9i. An Oracle 10g Application Server(9.0.4) is being used as the Web applications server. The application has been implemented using JSP. Zaragoza City Council (Spain) has already installed all of the above, except for the part referring to the mobile devices.

The abovementioned functionalities to be implemented on mobile devices are currently being implemented.

For related mobile devices, we have chosen .NET to implement functionalities on PDA's and J2ME for mobile phones.

In order to facilitate communication by means of SMS messages between the Web server and a mobile phone, we have opted to use a service provided by a mobile phone operator which will allow us to implement such requests from our application.

We considered that all the elements that comprise the scenario we have described are innovative in the sense that the system behaves like a ubiquitous E-Management environment.

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Computer Algebra Systems

Problems with A Heart-Shaped Curve

Leszek Jankowski and Adam Marlewski

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We examine the work of two computer algebra systems on an ordinary differential equation of the first order. Both systems, DERIVE 5 and Maple 8, yield implicit solutions, and both have problems plotting graphs of integral curves (which may be classified as heart-shaped). These problems are even more serious when, in Maple, we deal with the implicit solution, where the Lambert function is involved.

Keywords: computer algebra Systems, Lambert function

1 Introduction: NOS, SOS, and Errors in SOSes

In the beginning computers handled nothing but numbers, also if represented by letter symbols, later called 'names' or 'identifiers'. And, although very soon they also processed text (usually called 'strings'), by such operation as the deletion of a character and the concatenation, they were designed and used to process numbers. The systems (a.o. BASIC, FORTRAN, Algol, Pascal, C++) intentionally manipulating numbers are called NOSes, i.e. *numerically oriented systems*.

First trials to analytically handle derivatives and integrals on computers were undertaken in 1953 (for more details see e.g. [3] and [11]). First programs intentionally designed to be a direct mathematical aid to scientists in their daily work were released in 1968: MATH-LAB-68 and REDUCE. They both factorized polynomials, calculated indefinite integrals, and solved some differential equations. These two systems (called SOSes, i.e. *symbolically oriented systems*, or CASes, i.e. *computer algebra systems*) were soon followed by such products as MATHSCRIBE (1969, the first WYSIWYG symbolic algebra programs, also showing graphical animation), MACSYMA (1969), SCRATCHPAD (1974) turned into Axiom, MuMath (1979, the first symbolic algebra program to run on microcomputers managed by CP/M, an operating system for 8-bit computers, the predecessor to DOS) and its successor DERIVE (1988), also implemented in hand-held computers TI-89, Maple (1983), and Mathematica (1988). There are many other SOSes, in particular designed to deal within specialised areas (e.g. Cayley, Fermat, GAP, PARI/GP; see [10]), but it was Maple, Mathematica and DERIVE (now from Waterloo Maple Inc. a.k.a. Maplesoft, Wolfram Research, Texas Instruments, respectively) that gained the biggest popularity in education and university research. There are also popular hybrids such as MathCAD and MATLAB (from Mathsoft and MathWorks, resp.); they are basically NOSes, but they can manipulate symbolical transformations if equipped with special packages.

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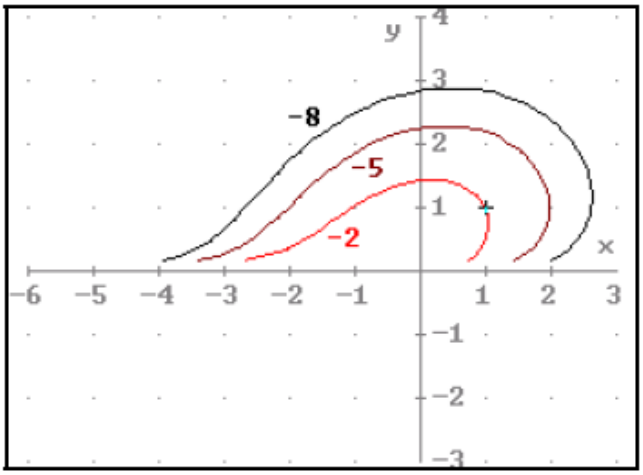

Fig. 1. Graphs of equalities $x \ln y - x^2 - y^2 = c$ for $c = -2, -5, -8$

Obviously, the most important feature of CASes is that thanks to them researchers and students may be freed from laborious, time-consuming transformations and calculations which are performed in an exact mode, i.e. without the rounding which are essentially involved in NOSes. Although intensively developed, CASes are still (and probably they will always be) only assistants to mathematical investigations. This is expressively announced in the full name of DERIVE: *DERIVE. A mathematical assistant*. It is DERIVE, version 5, which is a CAS, we make use of. By the way, in 2001 Derive 5 was voted *Best Budget Buy* of the mathematic section by the English magazine *Computer Shopper* (the didactic use of DERIVE and other CASes is treated in numerous publications, e.g. [1] – [3], [11], [13] – [15], [17] – [18], [20], [21], [23], [24]).

And although today's CASes do much more than their first predecessors, there are still problems which CASes find difficult to deal with and bugs that users find in them. This happened recently to a version of Maple, where the expression 2001!/2000! simplified to 1. DERIVE, which returns a correct result, provides an obviously wrong answer –3/2 when we ask for the value of

$$\int_{-2}^{1} \frac{dx}{x^2}.$$

One easily notices that this error is of a different type from that yielding 2001!/2000! to 1, The former is simply a technical mistake, and the latter is made by an unjustified application of Leibniz's formula for definite integrals. In our paper we discuss difficulties DERIVE and Maple have when an ODE (ordinary differential equation) is to be solved and its solution is to be represented graphically.

2 Heart-Shape Curves

Limaçons of Pascal are covered by the polar equation

$$r = b + 2a\cos\theta$$

and were investigated by Albrecht Dürer (1471–1528) and Étienne Pascal (1588–1651). A special case for $b = 2a$ is a curve traced by a point on the circumference of a circle rolling round the circumference of a circle of an equal radius. In 1741 this epicycloid was named a cardioid by Johann Castillon. He derived this name from Greek word *kardi* (heart), this way he wanted to say that this curve is a heart-shaped. The cardioid is not only a mechanical curve which would make it possible to construct a device which moves a tappet sinusoidally. The cardioid is also the envelope of light beams emitted from a point laying on a circle and reflected from this circle. Its good approximation can be seen on the surface of a mug filled with coffee.

The cardioid, in spite of its name, resembles a heart in a much lesser degree than other lines. For example, we get more natural heart-shaped curves when working with some Bonne projections (see [4]). Other examples of heart-shaped lines are

$$(x^2 + y^2 - 1)^2 - x^2 y^3 = 0,$$

$$x = \sin t \cos t \ln|t|, \quad y = |t|^{0.3} \cos^{0.5} t, \quad t \in [-1, 1],$$

$$(3x^{2/3} - 4y)^2 = 16(1 - x^2),$$

and

$$r = \sin^2\left(\frac{\pi}{8} - \frac{\theta}{4}\right),$$

with θ running from $-\frac{\pi}{2}$ to $\frac{3\pi}{2}$, first two ones proposed in 2003 by Dascanio [9], last two ones listed by K. Eisemann of San Diego University [5], or projections on *Oxy* plane of the surface

$$(x^2 + (1.5)^2 y^2 + z^2 - 1)^3 - x^2 z^3 - \frac{(1.5)^2}{20} y^2 z^3 = 0,$$

worked out 11 years ago by Gabriel Taubin of IBM [22], and

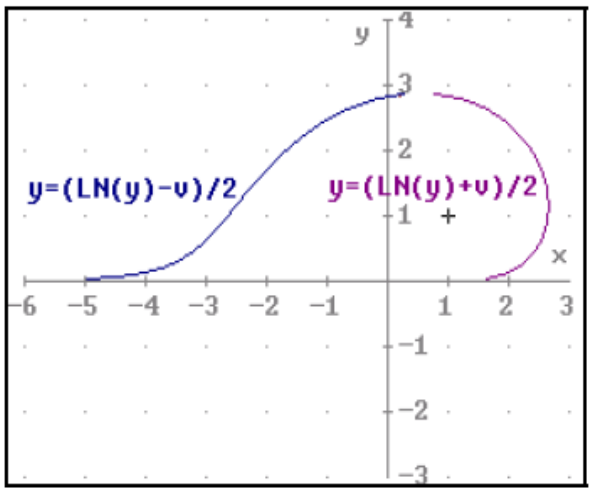

Fig. 2. Graphs of equalities $x = (\ln y - v)/2$ and $x = (\ln y + v)/2$, where $v = \sqrt{u}$ and $u = \ln^2 u - (v^3 - 8)$

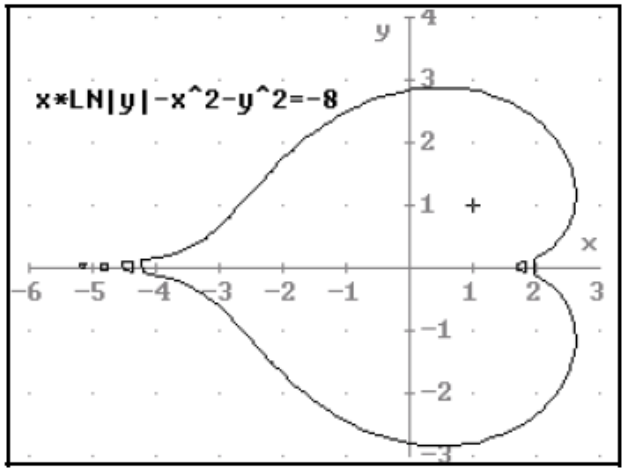

Fig. 3. Graph of the equation (6) with $c = -8$

$$(2x^2 + 2y^2 + z^2 - 1)^3 - \frac{x^2 z^3}{10} - y^2 z^3 = 0,$$

modeled in 1997 by T. P. Nordstrand of Bergen University [19] (see also J. P. Kuska of Leipzig Universitaet [12], [16]). In the next section we find an other heart-shaped curve.

3 Solving an ODE in DERIVE

We look for the solution $y = y(x)$ of the differential equation

$$\ln y - 2x + \left(\frac{x}{y} - 2y\right) y' = 0. \qquad (1)$$

Our equation is an ODE1, i.e. ordinary differential equation of the first order, which has the form $p + qy' = 0$, where p and q are expressions depending eventually on x and y. That's why in DERIVE we can evoke the procedure `DSOLVE1_GEN`. Hence we edit the expression

```
DSOLVE1_GEN(LN(y)-2x,x/y - 2y, x, y, c).  (2)
```

It simplifies to `x·LN(y) - x^2 - y^2 = c,` (3)

where c stands for an arbitrary constant (named an integration constant).

For various values of the constant c we may let DERIVE plot the solution, i.e. we may get the graphs composed of points (x, y) satisfying the final relation (3). In Fig. 1 we see the graphs issued by DERIVE for $c = -2, -5$, and -8.

It is easy to see that these graphs are far from perfection.

The relation (3) is essentially nonlinear with respect to y. But we can easily express x in terms of y. We can let it be done by DERIVE as follows: we simplify the call

```
SOLVE(x·LN(y) - x^2 - y^2 = c, x).  (4)
```

We get the answer saying

```
x = (LN(y) - v)/2 OR x = (LN(y) + v)/2  (5)
```

where $v = \sqrt{u}$, $u = \ln y^2 - 4\,(y^2 + c)$.

In Fig. 2 the resulting equalities for $c = -8$ are plotted. In contrast to Fig. 1, graphs approach the horizontal axis Ox, and there is a gap between left and right branches at the approximity of the point $(x, y) = (0.6, 2.85)$. Should they compose a continuous curve?

Recalling the formula , $\int \frac{dx}{x} = \ln x + c,$ and DERIVE counterpart of this relation, `INT(1/x,x) = LN(x)`, one could suspect that the absolute value sign can be omitted in the yielded answer. In fact it is not forgotten, DERIVE simply does not displays an integral constant. If we assume it is equal to, let's say, $-i\pi + c$ with arbitrary positive c, we have $\ln|x| + c$). It appears that we are right, so we can modify the answer (3) to the form

```
x·LN(|y|) - x^2 c y^2 = c.  (6)
```

The image of this relation with $c = -8$ is shown in Fig. 3. It reveals a "strange" plot close to the horizontal axis Ox. The equation (6) says that this axis has to be the symmetry axis (replacing !y for y changes nothing), so we know that the graph is only a sketchy one (and its quality may be influenced by the screen resolution).

We have produced three graphs and not one of them can be surely accepted. Nevertheless, these graphs show that integral curves may be heart-shaped, that they resemble a stylized heart spread along the horizontal axis. We would like to know if these graphs are really heart-shaped or not. As shown above, we have doubts about the graphs of the solution (5) to the problem (1) when y approaches 0 and when y is close to 2.85 (and $x \approx 0.6$, as it is revealed in Fig. 2). The first question can easily be handled by the limiting procedure which is built-in in DERIVE. We edit the expressions

```
LIM((LN(y) - SQRT(LN(y)^2 - 4A(y^2 +c)))/2, y,
0),LIM((LN(y) + SQRT(LN(y)^2 - 4A(y^2 +c)))/2, y, 0),
```

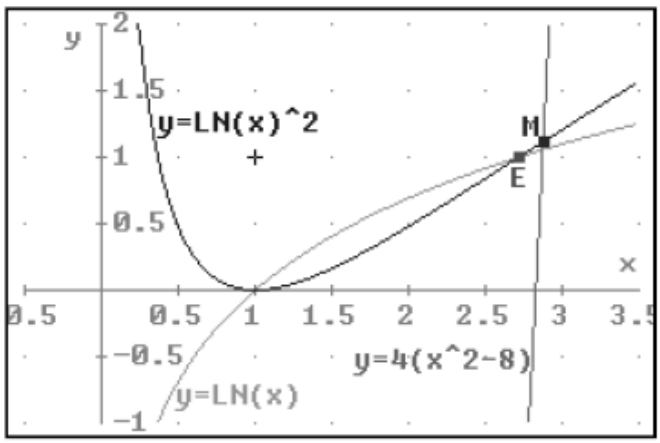

Fig. 4. Graphs of expressions y= ln y, y= $\ln^2 x$, and y= 4(x2 – 8), and points E= (e, 1) and M= (q, $4(q^2 - 8)$), where the last two graphs cross

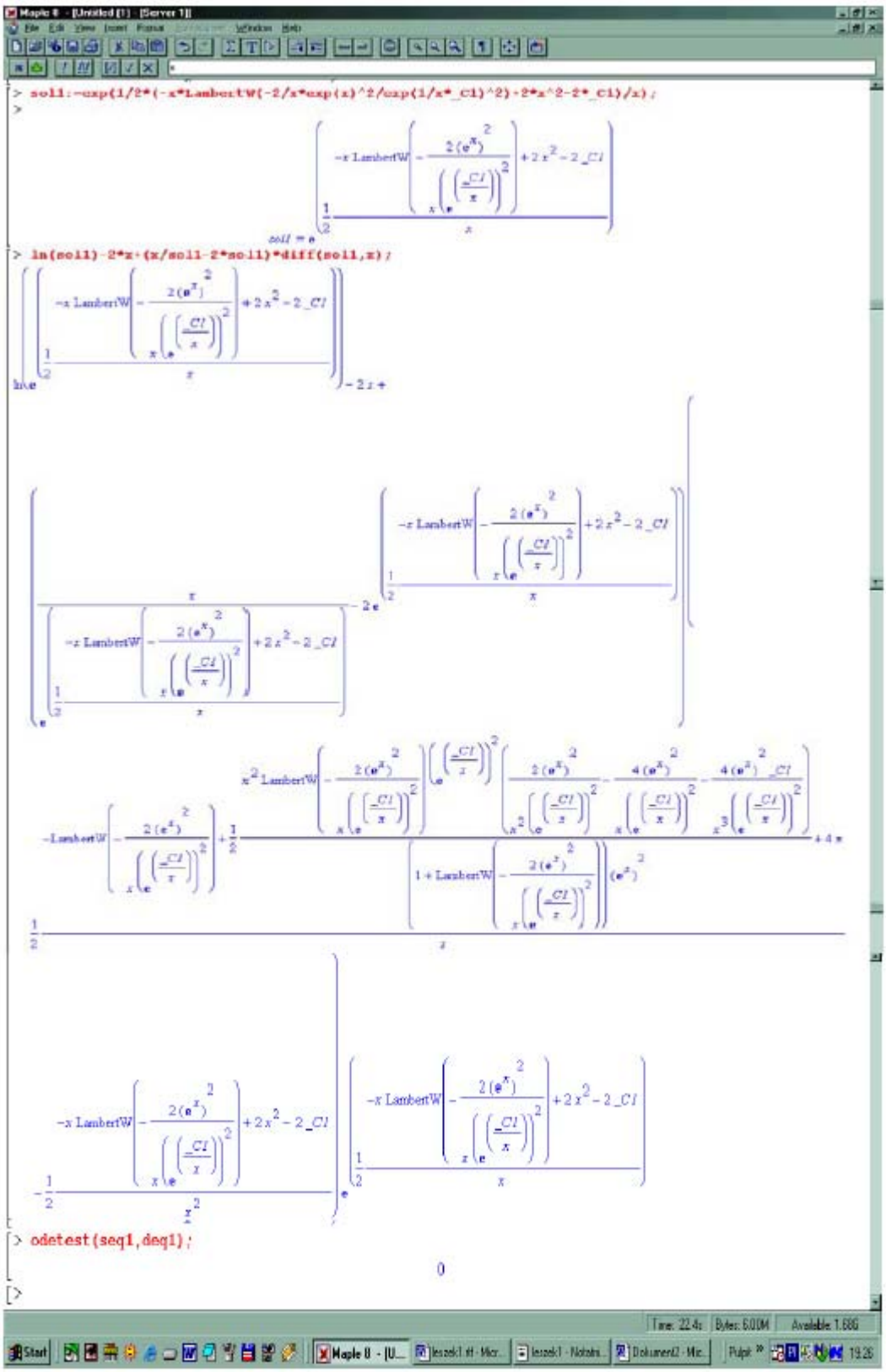

Fig. 5. Screen displayed by Maple: solution to the ODE1 considered and the attempts to check it (the direct one and via the odetest function)

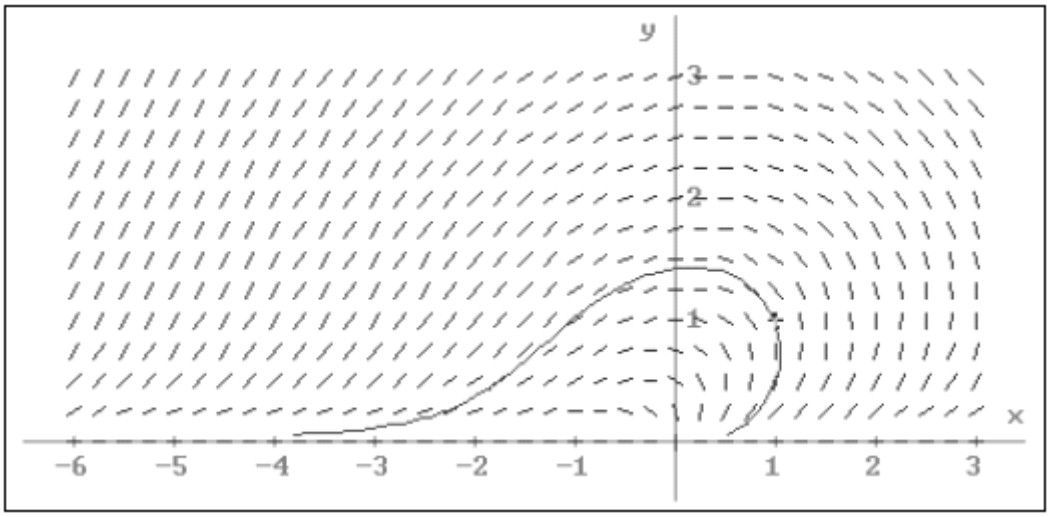

Fig. 6. Direction field of the equation (1) and the graph of one of its solutions plotted in DERIVE

the first call to get the limit for the left branch, and the next call to know the right branch of our solution (5).

Unfortunately, simplifications of both these calls fail as DERIVE does not remove the LIM operator. It does remove it if we command the right-side limiting, or if we replace y by $|y|$. Then the calls

```
LIM((LN( y ) - SQRT(LN( y )^2 - 4A(y^2 +c)))/2, y,
0,1), LIM((LN(|y|) - SQRT(LN(|y|)^2 - 4A(y^2 +c)))/
2, y, 0)
```

simplify to $-\infty$.

If we dare to say that our integral curve is heart-shaped, we have to be aware that this heart has "a tail", that this heart is chained, as if tied by a string spreading along the negative semiaxis Ox.

We are successful if we limit from the right or we limit with y replaced by $|y|$. Unfortunately, an analogical process does not work when we deal with the limit concerning the right branch, DERIVE returns an expression which differs from the given one only by cosmetic changes (and with |y| the outcome is even less clear).

What DERIVE cannot do, we can do. A simple completion of the sum by the difference to have the difference of squares gives

$$\ln y+\sqrt{\ln^2 y-4(y^2+c)}$$
$$=\left(\ln y+\sqrt{\ln^2 y-4(y^2+c)}\right)\frac{\ln y-\sqrt{\ln^2 y-4(y^2+c)}}{\ln y-\sqrt{\ln^2 y-4(y^2+c)}}$$
$$=\frac{4(y^2+c)}{\ln y-\sqrt{\ln^2 y-4(y^2+c)}}.$$

If $y \to 0+$, the nominator approaches the value $4c$ and the denominator $-\infty$. Hence

$$\ln y+\sqrt{\ln^2 y-4(y^2+c)} \to 0.$$

This proves that the right branch approaches 0 when y decreases to 0 (and it runs to 0 by positive values if $c < 0$). So our "heart" has a deep indentation, which it reaches the origin O.

At last, we discuss do both branches touch or are they disjoint curves. By their definition it has to be

$$y > 0 \text{ and } \ln^2 y - 4(y^2 + c) \geq 0.$$

The last inequality cannot be solved in an exact way, because the equation

$$\ln^2 y - 4(y^2 + c) = 0$$

is transcendent. It determines a number, let's call it q, such that both expressions

$$\ln y-\sqrt{\ln^2 y-4(y^2+c)}$$

and

$$\ln y+\sqrt{\ln^2 y-4(y^2+c)}$$

are defined for $y \in (0, q]$. Putting $y = q$ in both these expression we get the same value $\ln q$. This proves that left and right branches meet. Fig. 4 illustrates the situation for $c = -8$. The value of q, $y = 2.87736$, is returned by the simplification of the call

```
NSOLVE(LN(y)^2-4*(y^2-8),y).
```

4 Explicit Form of the Solution

The Lambert function, also called the omega function, and denoted here by the letter W, is defined to be the multivalued inverse of the function $z \to z \exp z$. This means that W satisfies the equation

$$W(z) \exp(W(z)) = z \qquad (7)$$

For $z < 0$ the W function has only two real-valued branches. The branch with values greater than –1 is called the principal one. This function was named after Johann Heinrich Lambert (1728 –1777) who was the first to pro-

vide, in 1761, a rigorous proof that π is irrational[1]. In some of his works he dealt with the expressions satisfying the relation (7), but a real interest concerning it exploded only some years ago, and recently many applications of this function have been shown, see e.g. [6], [7], and [8].

By means of the *W* function we can provide an explicit form of the solution of our equation (1). For this purpose let us take a new variable $t = \ln y$. Then the solution (3) takes the form

$$xt - x^2 - \exp(2t) = c, \text{ i.e. } 1 = (xt - x^2 - c)\exp(-2t).$$

That is why $vu \exp u$, where

$$v = -\frac{2}{x}\exp\left(2x + \frac{2c}{x}\right), \quad u = -2t + 2x + \frac{2c}{x}.$$

Thus, by the definition of the Lambert *W* function,
$u = W(v)$
i.e.

$$-2t + 2x + \frac{2c}{x} = W\left(-\frac{B}{x}\right),$$

where

$$B = 2\exp\left(2x + \frac{2c}{x}\right).$$

Finally,

$$t = x + \frac{c}{x} - \frac{1}{2}W\left(-\frac{B}{x}\right),$$

and so, if

$$A = xW\left(-\frac{B}{x}\right) - 2x^2 + 2c,$$

then the explicit form of the solution to (1) is

$$y = \exp\left(-\frac{A}{2x}\right). \qquad (8)$$

[1] 121 years later C. L. F. von Lindemann established that π is transcendental.

In DERIVE the Lambert function is not implemented, whereas in Maple it is identified by `LambertW`.

5 Looking for a Solution in Maple

As we have already said, the Lambert function is implemented in Maple 8, and it is identified by LambertW. The simplification of the call

```
dsolve(iod)
```

where `iod` stores the considered equation, i.e.

```
iod := ln(y(x))-2*x+(x/y(x)-2*y(x))
*diff(y(x),x),
```

yields the expression of the form (8), the only difference being that instead of *c*, the integration constant is –_C1. One can see it in Fig. 5, where the attempts to check whether the output expression really solves the equation (1) are also reproduced. The direct checking, consisting in the substitution of the obtained result into the equation (1), is not satisfactory as we get a lengthy and illegible expression, and we can even suspect that (8) does not solve (1). The confirmation that (8) solves (1) is provided by the call of the built-in Maple function called `odetest`, intentionally designed to be applied in such situations.

As we can see in Fig.7, the graph, produced in Maple, of the solution satisfying the condition $y(x = 1) = 1$, is incomplete: it does not pass through the point $(x, y) = (1, 1)$ nor does it pass in its neighborhood. The graph of the relation (3), providing the implicit solution to (1), however passes through this point. We see it in Fig. 6, produced in DERIVE, where the direction field of (1) is shown. The result is surprising: despite the enrichment of the system (Maple with the function `LambertW`) we get a result which confuses us.

This conclusion once again confirms that CASes are only mathematical assistants. It stays valid also when, in DERIVE, instead of the call

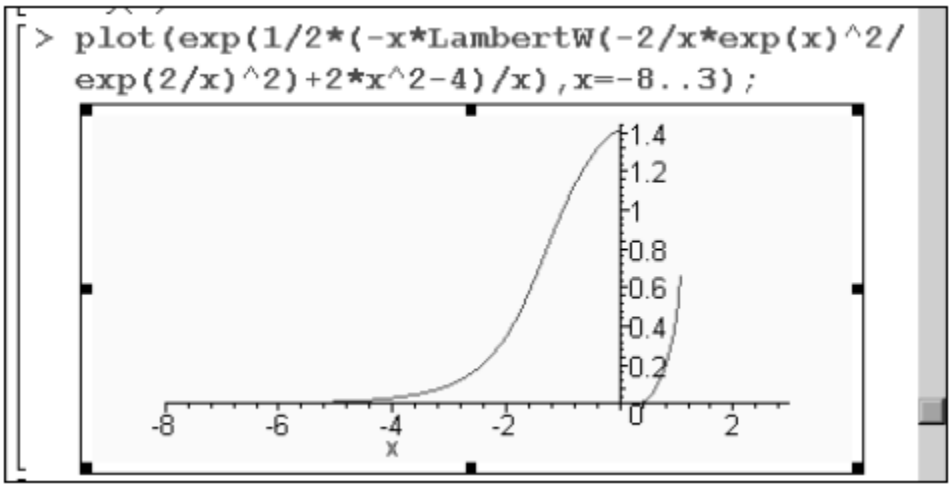

Fig. 7. Graph produced in Maple


```
DSOLVE1(LN(y) - 2·x, x/y - 2·y, x, y, 1, 1)
```

we simplfy the expression

```
DSOLVE1( -(LN(y) - 2·x)/(x/y - 2·y),1, x, y, 1, 1).
```

The first call refers to the equation (1), the second one to the equation

$$-(\ln y - 2x)\left(\frac{x}{y} - 2y\right) + y' = 0.$$

It is different from (1) only on the curve $x = 2y^2$ which, obviously, is not a solution to the Cauchy problem (1) or (2) with $y(x = 1) = 1$. As we know, DERIVE provides the solution (3) in the first case. The simplification in the second case fails, as the program displays the information: `inapplicable`.

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Web Engineering

A Quality Model for Websites

Roberto Polillo

This paper was first published, in its original Italian version, under the title "*Un modello di qualità per i siti web*", by ***Mondo Digitale*** (issue no. 2, Giugno 2005, pp. 32-44, available at <http://www.mondodigitale.net/>). ***Mondo Digitale***, a founding member of **UP**ENET, is the digital journal of the CEPIS Italian society AICA (*Associazione Italiana per l'Informatica ed il Calcolo Automatico*, <http://www.aicanet.it/>.)

The quality of a website is a product of the activity of many actors: web designers, graphic designers, software developers, content writers, webmasters, and web managers. The result of the work of each specialist must integrate correctly with the work of the others. In order to evaluate the quality of a website, a "quality model" is very useful, since it reminds us of the principal factors involved in achieving it. This article describes a simple quality model for websites, which has been used widely.

Keywords: Quality Model, Software Quality, Web Assessment, Web Evaluation, Web Quality.

1 Introduction

Even if web technologies allow users with little experience in Computer Science to quickly create elementary websites, designing professional websites is a very complex process. In fact, there are many different aspects to keep in mind. The website must be in line with the communication style of the organization it represents, it must present the characteristics and the products or services in an accurate way. More and more often it is necessary for the visitor to be able to do complex operations, such as purchases, reservations, access to databases, which require a close integration with company information systems. Also during the functioning of the website, it is important to manage complex problems. For example, to make sure that the informative contents are always and timely updated, that the technological infrastructures used guarantee acceptable service and run correctly and continuously, or that information requests from visitors are answered.

All the above require the use of personnel with specific professional skills which up to a few years ago did not even exist. Furthermore, the range of competences needed to create a quality website is large. The contribution of different people is therefore necessary; experts in marketing, communication, software, and above all experts in the specific business of the company that owns the website. The overall quality of a website depends on the harmonious cooperation of all the professionals involved: the results of the work of each much integrate correctly with the results of the work of all the others. No contribution can be ignored: because, like in a chain, global quality is equal to the quality of the weakest link. These needs are normally underestimated today: in the implementation of projects, or the improvement of a website, the focus is only on some of the aspects involved, neglecting others, equally important to the eyes of the final user. It is precisely the final user who ultimately determines the success or failure of a website.

To evaluate the quality of an existing website, or to correctly plan a new one, it can therefore be very useful to use a simple quality model which reminds us of the principal factors involved and that allows us to keep them under control. This article synthetically describes a quality model explicitly designed for websites, which was used successfully on websites of every kind and complexity, both for making a rapid *check-up* and also for in-deth *assessments*. The model, which is described in depth in a recent book by the author of this article [5], takes into account, above all, the quality perceived by the users of the website; in other words, the so-called *external quality and quality in use*, according to the ISO (International Organization for Standardization) [2] terminology, leaving aside the aspects of the internal structure of the software used in the website (*internal quality)*.

A quality model can be defined in many ways. However, it is very convenient - as we will see in the following - to start from the analysis of the activities involved in the design, the creation and management of a website, and of the various types of actors involved. Therefore, in Section 2, the logical phases that occur in the creation and operation of a website are briefly described. Starting from this, in Section 3, the quality model is introduced, which will be further analyzed in Section 4. In Section 5 we describe how the model can be used in the evaluation of websites. Following is a brief conclusion (Section 6), and an essential bibliography of the issues discussed.

2 How A Website Is Built

Web engineering is a recent sub-

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ject and is not yet consolidated, and in practice there are varied approaches and methodologies, normally not very structured, for planning and creating websites. A universally adopted model of processes does not exist. Also because, for example, the creation of a large portal is very different (it can involve a project group with tens of people) from that of an institutional website of a small company (which could be created and managed by a single person, who can take care of all the aspects).

Without pretending to be dealing with a universal model, we briefly describe the general phases which need to be followed from the conception, implementation and management of a website in order to identify the type of actors involved in each phase and the contributions that each member gives to the overall quality of the website.

This schema deals mainly with websites having a certain level of complexity, which therefore require the involvement of many people: e-commerce websites, *internet banking*, public administration websites, and other similar types of websites. In the case of simpler websites, the model is still valid if the necessary simplifications are made: the roles which are described will not necessarily be taken care of by different people. In a simpler website, is not unusual to have only one person in charge of everything.

The various phases that appear in Figure 1 show the principal activities which must occur for creating and running a website, as well as the logical relationships between them, and the professional skills required for each activity.

For example, the web design phase receives its input from the definition of the strategy; the visual design requires that the structure of the website has already been defined in the web design phase; the management of contents requires that a software container be already available, and so on.

Using Figure 1 as a reference, the process begins at the planning of the general **strategy and requirements**, which consists of defining the objectives associated to the website, identifying the target audience, the requirements and the constraints that must be met, the services that the website must provide to users, the context of use and possibly the technological architecture to be used. Typically, in this phase, an analysis of competitors' websites singles out the best practice in the business area and allows for the definition of an appropriate differentiation policy. Usually this preliminary phase is handled by the company's top management with the help of consultants specialized in this field. The output of this phase is a document specifying the general requirements, often used by third parties in order to build technical and economic proposals for the execution of the following phases.

The next phase shown in the figure is **web design**. In this case the general information architecture of the website is designed, and, most of all, the navigational structure, defining the interaction modalities between the website and the users, and sketching the general characteristics of the visual appearance of the pages. Web designers are protagonists of this phase, *architects* of the web who often work in organizations called *web agencies*.

Next comes **visual design,** in which the graphics of the website are detailed, on the base of the planning made in the previous phase. Sometimes various prototypes are built, in order to be able to choose the best solution. This phase is carried out by the *visual designer*, designers with a strong graphics and visual communications background who work closely with the *web designer*.

The **software development** of the website is the next phase, where standard software products are used often. This is the activity which is closest to "classic" information systems development and, in the case of less complex websites, can be carried out by the same *web agency* that intervened in the previous phases. Instead, for more complex websites these activities are normally led by companies specialized in system integration. They assemble the standard software products and develop specific software components when necessary, and normally take over the project, in cooperation with the *web agency* (if one has been also involved in the project). The software development activities prepare, so to say, an "empty" website (without information contents). *Content editors* work on the contents aspect in the next logical phase, **contents management**. Basically it involves editors who are

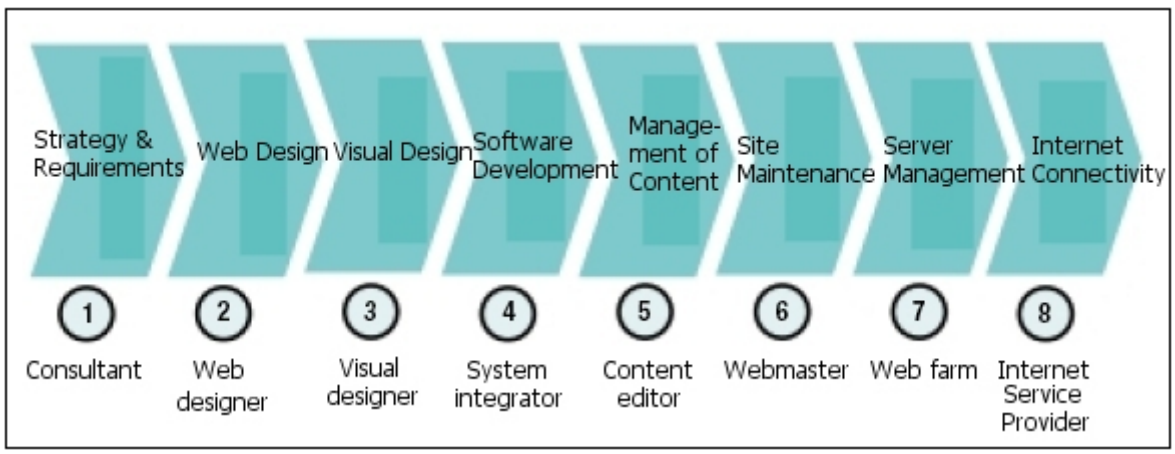

Figure 1: Activities and Professional Skills Involved in The Creation and Management of A Website.

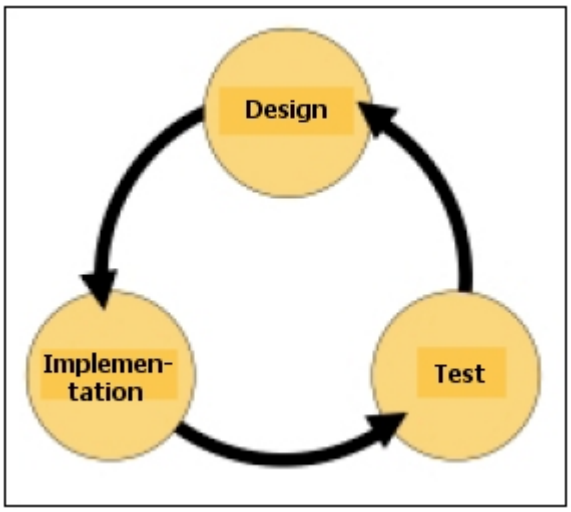

Figure 2: The Construction of A Website Is An Iterative Process.

expert in the business domain the website belongs to, and carry out their work not only in this phase but also when the website is on line.

When the website is online, it is necessary to manage and supervise its operation. This task is performed by *webmasters*, who have the responsibility of making numerous and frequent technical interventions in order to keep the website running and updated, preventing interruptions in service. In the case of websites which offer complex services, it is also necessary to manage the information systems the website cooperates with for the execution of the service. For example, in an e-commerce website, the application software for the management of warehouse, accounting, and any functions related to the sale and shipping of goods. In these cases, the webmaster should receive support from specialists in the applications involved.

Next in Figure 1 diagram comes the **management of the server** which hosts the website. This activity can be done internally by the company that owns the website of by an external *web farm*, if the decision of delegating via an outsourcing contract has been made. There are firms who manage large quantities of *web servers* for various clients. They have the appropriate infrastructure for this task, allowing significant savings to their customers in fields like management and maintenance of computers operations, security and continuity of service.

The last actor present in the diagram is the *Internet Access Provider* (IAP), which is the organization which supplies **Internet connectivity** to the *web farm*: an IAP is basically a telecommunications operator who provides access to the Internet and the services associated to this access.

We have identified all the activities relative to the planning and management of a website, their interrelations and the key actors. These must work together, each one playing its own role, in order to guarantee proper operation of the website. Their activities are very different from each other and are led by professionals from different areas, with very different work methods, languages, professional cultures and values.

The logical sequence of the different activities does not necessarily always coincide with the time sequence; in fact, the process of creation of a website, as in every complex software system, rarely follows a linear path. Often changes to decisions already taken occur, which produces modifications to the work already done, in an iterative process which converges, so to speak, through subsequent approximations (Figure 2). In any case, the basic structure of the website is planned, created, presented to the customer and tested with real or simulated users, customers' and users information is collected, and the project is refined with this information, improving the unsatisfactory parts. When the website becomes operational, its evolution is not finished yet, but continues for the rest of its life span. A website which is "alive" is improved continuously and is adapted to new needs, not only updating and enriching it with new

	Characteristic	Sub-characteristics
1	Rooms	Comfort, size, elegance, cleanliness
2	Public areas	Comfort, size, elegance, cleanliness
3	Service	Reception, room service, staff courtesy
4	Restaurants	Food quality, environment, service, food variety
5	Swimming Pool	Comfort, size, environment, equipment, cleanliness
6	Beach	Distance from hotel, equipment, landscape
7	Surroundings	Possibility of excursions, distance from city
8	Sports facilities	Tennis, golf, fitness, other
9	Children	Nursery, playing areas

Table 1: A Tentative Quality Model for Hotels.

contents, but also making modifications and improving the software "container" and the hardware infrastructure which hosts it.

3 A Quality Model for Websites

Having described the different phases and activities which must take place in the creation and management of a website via a global schema, we will now introduce the basic elements for the quality model which is the subject of this article.

It is useful, above all, to define what is intended for quality model. When the quality of something needs to be evaluated, it is necessary to decide which criteria have to be used. For example, in order to evaluate the quality of a hotel, a given level of importance must be assigned to the elements which are considered important, for example: rooms, public areas, service, restaurants, swimming pool, beach, surroundings, sports facilities, children's' areas, and so on. The same technique must be used in order to define the criteria for evaluating every single element. For example, the quality of the rooms could be evaluated on the basis of comfort, size, elegance and cleanliness. A set of criteria is shown in Table 1, which is a tentative quality model for hotels. The nine basic elements chosen are called *characteristics*, the others, *sub-characteristics*.

It is evident that the characteristics and sub-characteristics of any quality model can be defined in many different ways, according to the point of view that is chosen. In the case of hotels, for example, we may adopt the point of view of the company that provides maintenance services, or the tour operator who sells the service to the public, or the client. Depending on the point of view, the model will be different.

For example, the system engineer may be interested in the technologies used for the systems to comply with legal regulations, in the accessibility to the control settings, and so on. The system engineer is not interested in the surrounding environment, nor in the weather conditions: s/he is, above all, interested in how the hotel "works inside" or, more precisely, in its internal quality.

The tour operator takes for granted that the hotel works but will care instead about the aspects which characterize the hotel services at the market: location, price, number of rooms, the aesthetic aspects of the swimming pool, etc. It is interested on how the hotel "is externally" or, more precisely, in its external quality.

The customer, when s/he uses actually the hotel services, is interested in other aspects. Probably s/he chose the hotel because of its price, location and appearance. However, once in the hotel, these aspects do not interest her/him too much: they are factual evidences. Instead, the customer wants the hotel to be adequate for the use s/he wants to make of it. If s/he likes to read in bed, s/he wants there to be sufficient lighting. If s/he gets up late, s/he wants to be able to have breakfast, and then to find a sun bed at the pool. In other words, s/he is no longer interested in the general characteristics of the hotel: s/he wants it to be adequate for his/her specific uses. S/he is interested, so to speak, in the *quality in use* (or usability) of the hotel.

Internal quality, external quality and quality in use are general concepts that can be applied to any system: hotels, automobiles, or websites. In fact, a website can also be considered from an internal point of view, i.e. from the structure of the code it is made of, and this aspect is essential for those who created or maintain it. It can also be contemplated from the point of view of its external specifications, and this is what the person who evaluate the website is interested in when has to decide if it can go online. Finally, it can be considered from the user's point of view, when s/he uses it in a specific context to satisfy personal needs.

These simple examples suggest that the definition of a quality model is not a simple matter. In the particular case of software, the characteristics of a quality model have been discussed for more than thirty years. An ISO standard exists which aims to define precisely the characteristics and sub-characteristics of software quality, and the way they can be measured. Even if we have been inspired by this ISO standard in some aspects, it is not the model adopted in this article because it is very complex, and not particularly adapted for websites, which are software systems with very peculiar characteristics. In particular, our model does not looks into the internal quality (i.e. the internal technical aspects of a website are not evaluated), but only into the external quality and the quality in use.

To introduce the quality model we return now to the diagram in Figure 1, which shows the actors involved in the production and management of a website. The first phase is very important because it is where the objectives of a website are established; obviously its quality can be evaluated only in relation to these objectives. Once the objectives are defined, every phase of the work and the actors involved contribute to the final quality of the website for specific aspects. Figure 3 presents the 7 macro-characteristics on which the proposed quality model is based (architecture, communication, functionality, content, management, accessibility and usability), shown beside the activities which contribute the most to each characteristic.

The first characteristic, **architecture,** is about the general structure of the website, and the navigation modality which is available to its users. It this context it is applied here exclusively to the informative architecture of the website, which is how a website is structured in relation to its informational contents, and not to its internal software architecture. Internal quality aspects are not of interest here, since they do not deal with the model, as explained previously. A website has good architecture if its page organizations is consistent with its contents and if navigation is easy. This characteristic has been indicated in Figure 3 next to the *web design* phase, since it is here that principal decisions are made which determine the general organization of the website.

The second characteristic, **communication,** unites many aspects: the clarity of the website for communicating its message, the consistency with the corporate image of the website's owner, the appeal of the graphics, the "relationship" established with the user. The *visual design* phase above all (but

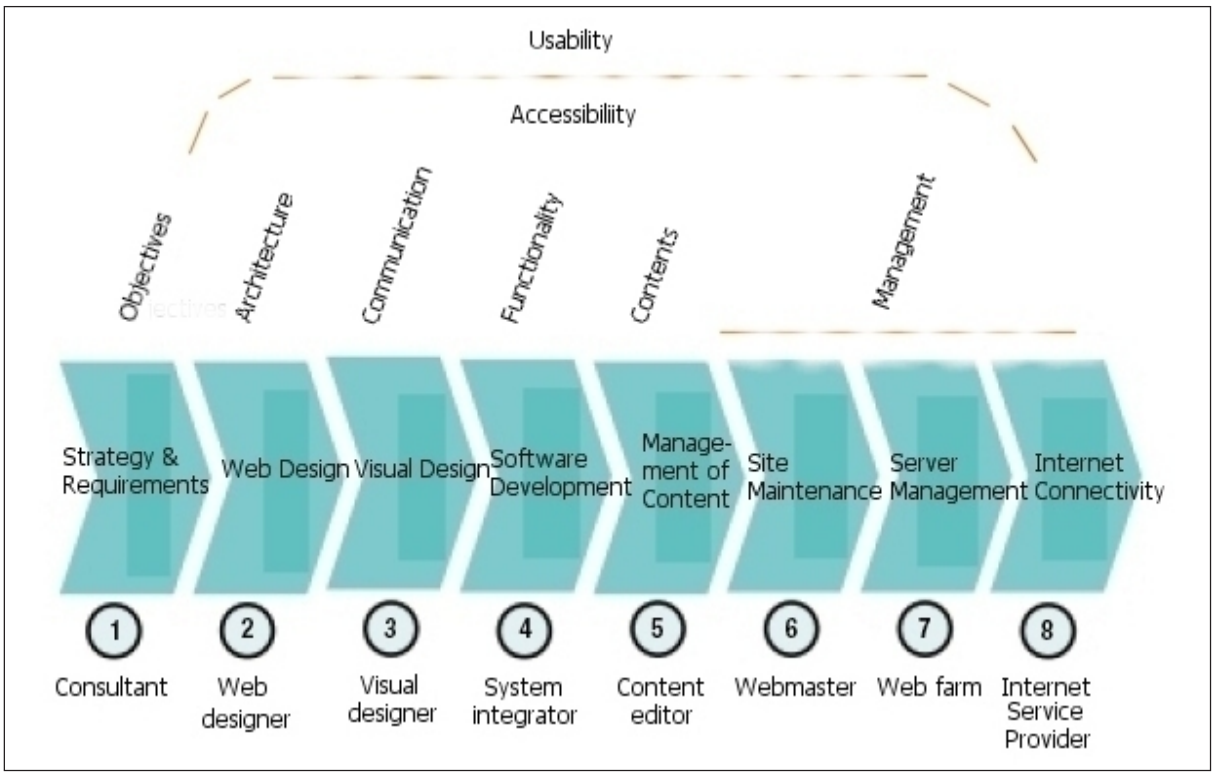

Figure 3: Macro-characteristics of The Proposed Quality Model, including Their Main Activities.

not only) determines the communicational quality of the website, as shown in Figure 3.

Functionality is the third characteristic considered in the model, and consists in the set of functions the website makes available for its users. From this point of view, a website is a good one when it provides the user with the functions s/he requires, all the functions work correctly as far as software is concerned, i.e. is is error-free. To provide a good evaluation of functionality, the main functions of the website must be examined in detail and rated for adequacy and correctness. Good functionality derives principally from the correctness of the software development activities, and therefore this characteristic has been placed in this area of the figure.

The fourth characteristic is relative to the quality of the informative **contents** of the website, considering all points of view: reliability, updating, comprehension of the contents, and so on. The quality of the contents, as indicated in Figure 3, essentially results from the accuracy of the work done by content editors.

The fifth characteristic regards to **management** and measures the total quality of the management work of the website during its operations: a quality website must me managed permanently in order to guarantee its correct operation around the clock. It examines therefore the work quality of the webmaster, of the professionals in the web farm and also of the *Internet Access Provider*, since all of them must directly or indirectly guarantee the permanent operation of the website.

The sixth characteristic is **accessibility,** which covers the aspects which allow everyone to rapidly access the website without problems. The Web, in the vision of the *World Wide Web Consortium* (W3C), intends to guarantee universal accessibility (including users with disabilities), regardless of the type of hardware or software being used, of the network infrastructure, of the language, culture, geographic location, ... Therefore accessibility has many facets. In order to correctly evaluate accessibility, the following aspects must be considered: access time to the website (which depends not only on server efficiency and on the infrastructures of the available networks, but also on the size and "weight" of its pages), easy retrieving of information, and ability to access information through a variety of devices, including those which allow for comprehension by disabled users. The accessibility of a website is so a product of the work done of many actors and this is the reason why it it has not been linked to any particular phase in Figure 3.

Finally, the seventh and last characteristic of the model is the **usability** of a website, a term which encompasses all the elements that make a website easy and pleasant to use. From the point of view of the user, it is perhaps the most important characteristic. It does not have its roots in any specific activity but is the result of the contribution from all the actors involved in the development and management of a website. Because of this in Figure 3 no particular activity has been associated to it: all the activities contribute to create usability. It is not independent of the other characteristics: in a certain sense, it summarizes and completes them all. The other characteristics are necessary but not sufficient to guarantee a good level of usability. For

example, if the access time of a website is very long, the usability factor will certainly be modest. But it does not mean that a website with bad access time is usable. Likewise, a set of complete and correct functions guarantees good operation of a website, but not necessarily good usability. Usability will be tested during access by users in their specific context: each one has specific traits and needs. Usability is also, probably, the most neglected web characteristic in practice, because creating usable systems is difficult, and requires paying particular attention to the users' needs. The culture of usability is not adequately diffused yet among computer scientists, and websites today often have serious shortcomings from this point of view.

Figure 4 represents the proposed quality model. In order to underline the particular role of usability with respect to other characteristics, it has been represented in the center of the schema.

In the evaluation of the quality of a website, it is possible to assign a mark to each characteristic, and therefore visualize in a synthetic form the "quality profile" of a website using a star diagram. An example is represented in Figure 5, where the merits and defects of a website can be immediately seen, even if roughly. It is, so to speak, its "report card". It is particularly advantageous for its simplicity, with a scale from 0 (which means very poor) to 4 (which means very good).

Representation through star diagrams can be very useful to compare the quality characteristics of two websites: it is enough to overlap their diagrams, as in Figure 6.

4 The Sub-Characteristics of The Quality Model

As already observed, the macro-characteristics of the model have many components. In order to evaluate and assign a mark to each characteristic it is useful to further detail the model and to decompose each characteristic into simpler sub-characteristics, that can be examined singularly. In this way, the mark attributed to each macro-characteristic can be calculated starting from the mark attributed to each sub-characteristic. In this case there are also different possible choices. Experience shows that about twenty sub-characteristics are sufficient to keep the main quality aspects of a website under control, at least from the point of view of the user.

It is a choice which shows in practice to be simple and at the same time complete enough, as is represented in Table 2. Here, each sub-characteristic has been associated to a simple question, which is answered during the evaluation of the website.

As seen in the table, the sub-characteristics express rather macroscopic properties of the website, which can be further decomposed into lower level properties. For example, Tables 3 and 4 show the decomposition into sub-sub-characteristics of two composite sub-characteristics: **Adequacy** of the **Functionality,** and **Graphics** of the **Communication.**

The complete model cannot be presented here, for space reasons. Overall it has about seventy questions [5], which supply a very detailed guide to the process of evaluation of a website. These questions are used for every type of website, independently of their scope or complexity. If necessary other more specific questions relative to the specific applicative domain can be added to these questions. For example, for e-commerce websites, the question "Are the functions to make the needed transactions adequate?" can be further articulated as follows:

- Are the functions to select products to purchase adequate?
- Are the functions for the insertion or modification of payment or shipping data adequate?
- Are the functions to confirm the order adequate?
- Are the functions available for the user to monitor personal information and orders adequate?
- Is the security of the transactions managed in an adequate manner?
- Are the processes for user registration simple?
- Is the personal information required from users proportional to the type of transaction?

5 Using The Quality Model

The quality model which has been briefly presented in the previous pages can be used in many ways. It can be useful for performing a rapid check-up of a website to find the principal areas which need improvement, with the purpose of setting up an action plan. In this case, it is not necessary to perform

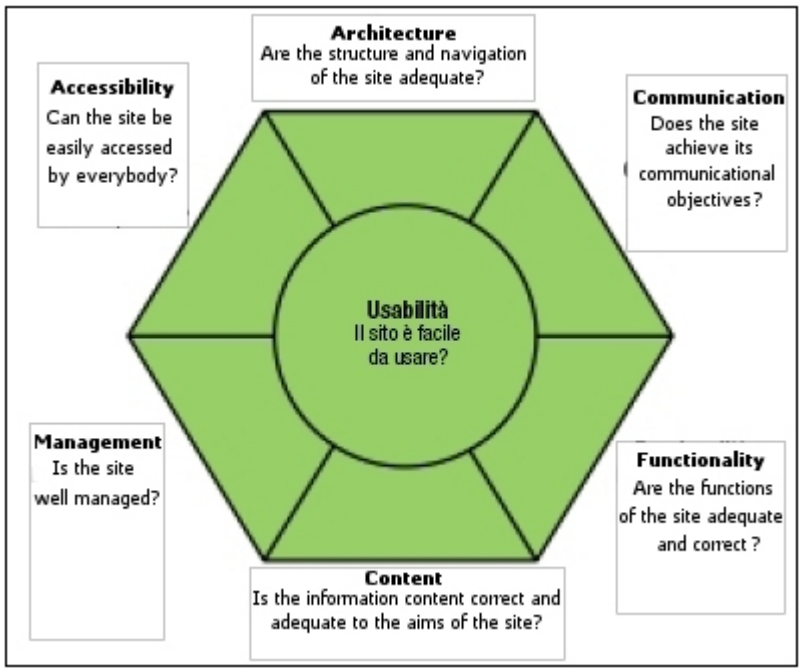

Figure 4: Macro-characteristics of Our Quality Model for Websites.

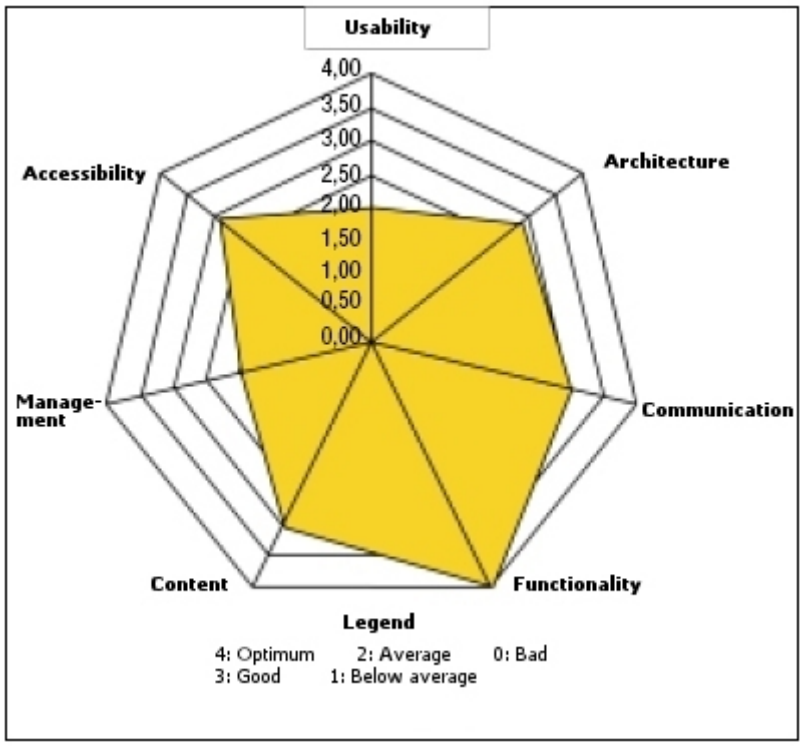

Figure 5: Star Diagram Which Shows The Quality Profile of A Website in A Glimpse.

a detailed analysis of individual sections of the website since it will probably be heavily restructured: it would be a useless waste of time and money. In other cases, the model can be used to perform an in-depth evaluation of the website, which examines in detail all its principal sections. For example, this can be useful following a *restyling* of the website, or various maintenance interventions in an already stable and mature website, to verify that the overall quality has not degraded. Sometimes the model can also be used to compare the website to other competitors' websites, to identify respective strong and weak points.

In all cases, it is necessary to initially define our goals with accuracy, to decide how to proceed and how long and how many resources will be used for this task. An evaluation done without a clear definition of the methodology would in fact have the risk of producing results which are not very significant.

The final result of the evaluation of a website is usually a document called "evaluation report". Briefly speaking, it contains a description of the objectives of the work done and the methodology used. It then presents an analysis of the quality characteristics of the website, and the synthesis of the results obtained: the strong and weak points of the website. Finally, the document concludes with a series of proposals for improvement, inspired and motivated by the analysis. The document does not need to be very long, in practice what actually matters is that it covers all the necessary material to justify and adequately support the improvement actions proposed.

The definition of the metrics to be used for the evaluation of the different characteristics is an important aspect. Usually in the evaluation of a specific website not all the sub-characteristics of the model are given the same importance. Some characteristics could even be considered irrelevant, as for example the localization of a website which is intended only for a single country. Therefore in function of the website objectives, it is useful to assign a weight to each sub-characteristic, showing the importance assigned to it in the evaluation. This way, the value of each characteristic can be calculated as "weighted average" of the values assigned to for each sub-characteristic.

The example in Table 5 explains the method. Each sub-characteristic has been assigned a weight, expressed with a number between 0 and 1. The value 0 is associated to the sub-characteristics irrelevant for the website being analyzed, and therefore they do not contribute to the final value. Instead the

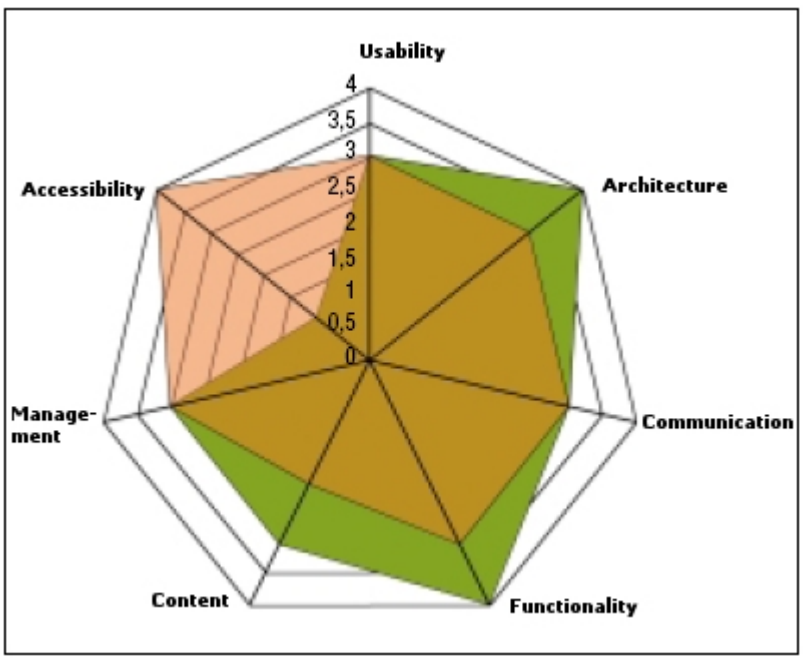

Figure 6: Star Diagram Which Allows for The Comparison of Quality Profiles between Two or More Websites.

Characteristic	Sub-characteristic	What we should we ask?
Architecture	Structure	Is the informative structure of the website adequate?
	Site map	Is there a site map of the website which clearly represents its structure?
	Navigation	Is the navigation of the website adequate?
Communication	Home page	Does the home page clearly communicate the objectives of the website?
	Brand image	Is the website consistent with the brand image?
	Graphics	Are the graphics of the website adequate?
Functionality	Adequacy	Are the functions of the website adequate?
	Correctness	Are the functions of the website correct?
Contents	Categorization/labeling	Is the information classified in an adequate manner?
	Style	Is the style of adequate for the website?
	Information	Is the information adequate, pertinent, reliable, and updated?
	Localization	Is the website correctly localized?[1]
Management	Availability	Is the website always on and available?
	Monitoring	Is the use of the website adequately monitored?
	Updating	Is the website constantly updated and improved?
	Relationship with users	Is the relationship with users adequately supported?
Accessibility	Access time	Is the access time adequate?
	Easiness to be found	Is the website easy to find?[2]
	Browser independence	Is the website accessible with every browser?
	Accessibilty by disabled people	Is the website usable by users with disabilities?
Usability[3]	Effectiveness	Can the user obtain the desired result in an accurate and complete way?
	Efficiency	Is the effort requested from the user to obtain the desired result acceptable?
	User satisfaction	Is the website comfortable and well accepted well by the user?

[1] This sub-characteristic examines multi-language websites, and deals with the correct translation of the informational contents, taking into account not only the linguistic differences between different countries (currency, measurement system, different conventions, etc.).

[2] This sub-characteristic summarizes essentially three very important aspects which can contribute decisively to the success of a website, and therefore should be managed carefully: the mnemonics of the URL of a website (Is the name of the website easy to remember?); the ranking in search motors (Is the website easy to find with the most popular search engines?); the popularity of the website (Is the website adequately referenced by other websites?).

[3] The sub-characteristics for usability have been identified according to the ISO 9241 standard, which defines usability as "*the effectiveness, efficiency and satisfaction necessary for users to reach precise objectives in a precise use context*". In this definition, effectiveness means "*the accuracy and completeness necessary for users to obtain the desired results*"; efficiency it means "*the resources spent to obtain this result*", and satisfaction is "*the comfort and acceptance of the system by the user*" [3].

Table 2: Characteristics and Sub-characteristics of The Proposed Quality Model.

value 1 is associated to the most important characteristics. For example, in the evaluation of the Architecture, we have given the highest importance (1) to Structure and Navigation, and an average importance (0.5) to the site map. Since the values attributed to Structure, Site map and Navigation are respectively 3. 2 and 3 (on a scale from 0 to 4, like we did for the macro-characteristics), the total value (weighted) for the Architecture will be obtained from the following calculation:

$$(3 * 1 + 2 * 0.5 + 3 * 1)/2.5 = 2.80$$

The value is higher than the simple arithmetic mean of the values of the sub-characteristics (2.67). In fact, the site map, which received a rather low value (2), has a lower weight than the other sub-characteristics.

As seen previously, the overall evaluation of the website can be represented by a star diagram, like in Figure 5, which is relative to the example in Table 5. It can be also worthwhile to see the evaluation of the sub-characteristics with a star diagram. For example, the diagram in Figure 7 represents the evaluation in Table 5.

The diagrams in Figures 5 and 7 give a fairly precise vision of the physiognomy of the website, of its strong and weak points even if we do not know anything about it. They are somewhat like the

Sub-characteristic	Sub-sub-characteristic	What we should ask
Adequacy Are the functions of the site adequate?	**Content management**	Are the functions available for website editors for the insertion and updating of the informative contents during its life adequate?
	Transactions	Are the transaction functions adequate?
	Search	Are the tools for searching information adequate?
	Error management	Are user errors handled adequately?
	Communication	Can the user contact the website manager adequately?

Table 3: Decomposition of Sub-characteristic **Functional Adequacy** into Sub-sub-characteristics.

results of the analysis of a clinical check-up, when the doctor reaches his conclusions without knowing anything about the patient's life.

In order to demonstrate our claim, let us try to analyze the data in the example. We can see from Figures 5 and 7 that the website being observed is excellent from a functional point of view, it has good contents (but it could be improved in classification and labelling), it has good graphics (but the coherence with the brand could be improved). The management is only satisfactory: in fact the availability of the website could be improved (perhaps the servers are unstable) and also the quality of the updates (Is there obsolete information?), and access monitoring tools are not used. The website is not accessible by the disabled, but this was not an objective (the weight attributed to this characteristic is only 0,25). The overall usability could be improved (the value of effectiveness, efficiency and user satisfaction is only a mediocre 2). This does not seem to be caused by important structural problems (the structure and the navigation are good), but is probably due to a series of *microfactors* which together make the total value lower.

These factors must be identified carefully by analyzing the usability problems which emerged during the evaluation in order to discover where users had the most difficulty. It seems that these most critical points are likely concentrated in the labelling (which has a low evaluation). Perhaps the low importance given to the site map (only 0,5) should be reconsidered, as it could be improved.

These numbers seem to tell us that we are dealing with a website with several positive characteristics, with weak points from the point of view of usability, which nevertheless could be improved without big structural changes or functional additions, and whose management we definitely need to improve. The brand consistency problem must presumably be further analyzed by communication department of the company. When the final synthesis, the evaluators obviously must not go forward blindly as in the

Sub-characteristic	Sub-sub-characteristic	What we should ask
Adequacy Are the functions of the site adequate?	Content management	Are the functions available for website editors for the insertion and updating of the informative contents during its life adequate?
	Transactions	Are the transaction functions adequate?
	Search	Are the tools for searching information adequate?
	Error management	Are user errors handled adequately?
	Communication	Can the user contact the website manager adequately?

Table 4: Decomposition of Sub-characteristic **Graphics** into Sub-sub-characteristics.

Characteristic	Mark	Weight	Weighted value
Architecture	2.67	2.50	2.80
Structure	3	1	3
Site map	2	0.5	1
Navigation	3	1	3
Communication	3.00	3.00	3.00
Home page	4	1	4
Brand image	2	1	2
Graphics	3	1	3
Functionality	4.00	2.00	4.00
Adequacy	4	1	4
Correctness	4	1	4
Contents	3.00	4.00	3.00
Categorization/labeling	2	1	2
Style	4	1	4
Information	3	1	3
Localization	3	1	3
Management	2.67	4.00	2.00
Availability	2	1	2
Monitoring	1	1	1
Updating	2	1	2
Relationship with users	3	1	3
Accessibility	2.50	3.00	2.92
Access time	3	1	3
Easiness to be found	4	1	4
Browser independence	2	0.75	0.25
Accessibility by disabled people	1	0.25	0.25
Usability	2.00	3.00	2.00
Effectiveness	2	1	2
Efficiency	2	1	2
Satisfaction	2	1	2

Table 5: Example of Evaluation of A Website. (The evaluation of each characteristic corresponds to the average weight of the evaluation of its sub-characteristics on a scale from 0 to 4.)

example just examined, where we have only considered the numbers. They will arrive at their conclusions after carefully analyzing the website in detail, and having discussed it with a sample of users. Even if the values attributed by them to the many characteristics will be subjective by nature, they will know very well the defects and merits of the websit. The resulting diagnosis will therefore be rather reliable.

5 Conclusions

This article has presented, though very synthetically, a quality model for websites, which evaluate both external quality and quality in use. This model has been experimented and improved on over several years, initially and essentially for educational purposes, to help students in university courses taught by the author to develop a global ability of critical analysis. In particular it has been used in order to do rapid check-ups and in-depth evaluations of the quality of numerous websites of every level of complexity, ranging from simple informational websites to e-commerce websites and large portals.

The main merit of the model consists in the fact that it is based on a vision of the development and management process of a website, as depicted in Figure 3. In this way the improvement proposals which arise from the evaluation of a website can be easily sent to the different categories of participants involved. Another significant merit is its simplicity: it can also be used by people who do not have particular technical competencies about web technologies. Furthermore, the methodology can be easily upgraded: it can be used to do quick informal check-ups of a website (in a very limited amount of time: a few work days) or in-depth evaluations, which involve sophisticated analysis and usability tests.

Numerous examples of the use, by

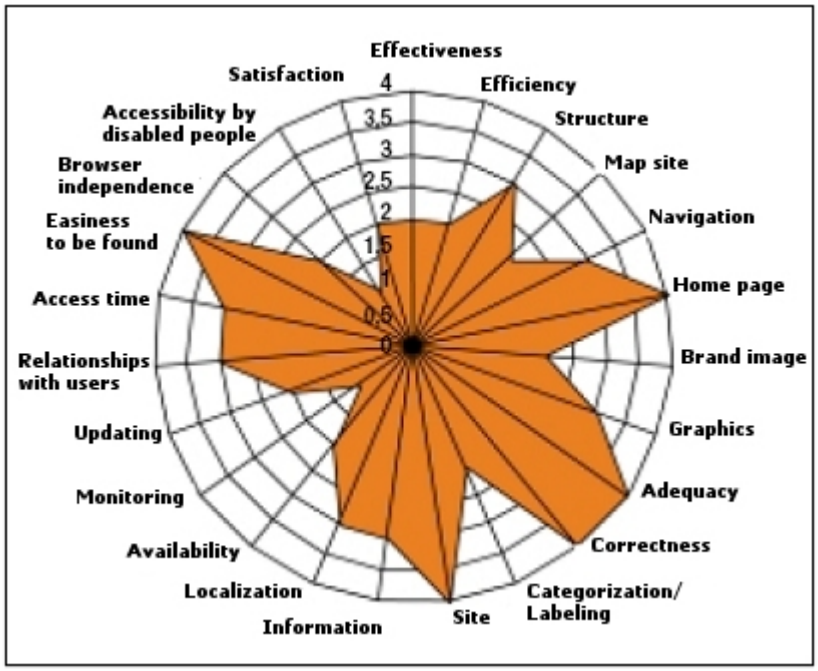

Figure 7: Star Diagram of The Values Attributed to The Sub-Characteristics of The Example in Table 5.

computer science university students, of this methodology for the evaluation of Italian websites are available at <http://www.ilcheckupdeisitiweb.it>, a website managed by the author.

Translation by ***Julia Weekes***

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