Pervasive Computers and the GRID: the Birth of a Computational Exoskeleton for Augmented Reality

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ABSTRACT

In the near future, the "computer" as we know it will disappear. It will be hidden in everything around us to improve our sensorial and perceptive skills (reality augmentation). Pervasive computing (also known as "ubiquitous computing") is about distributed computing devices in the physical world: wearable computers, devices embedded in everyday objects, sensors located everywhere in our environment. In this vision, Pervasive computing is about both the devices and the infrastructures (de-centralized High Performance Computers and communication channels) needed to support ubiquitous applications such as the so-called "pervasive GRID". In the near future, the pervasive GRID infrastructure, which I prefer to define as a "computational exoskeleton", will be extended to many human activities and will represent an ideal starting point for the creation of a future class of applications and services [1]. The development of these applications and services can be boosted and accelerated by the use of powerful tools like Eclipse, SODA and Java. These tools are the result of a new collective and collaborative approach in software development that is currently emerging in the software community, and whose drivers are the "open source" movement and the web 2.0 technologies.

Categories and Subject Descriptors

C.2.1 COMPUTER-COMMUNICATION NETWORKS: Network Architecture and Design - *Distributed networks*

General Terms: Design, Human Factors, Standardization

Keywords: Invited talk, pervasive computing, grid, wearable computers, sensor networks, mest compression, cyberspace, exoskeleton, soda, eclipse, java

The framework is changing now. The Internet is redefining software. The Internet is redefining the role of computing and communication .. I still don't understand the framework. I don't think any of us really do. But some aspects of it are pretty clear. It's proven not to be computing based but communication based

Andy Grove former INTEL CEO

"Decisions Don't Wait", Harvard Management Update, 2003

ESEC/FSE'07, September 3-7, 2007, Cavtat near Dubrovnik, Croatia.

1. INTRODUCTION

In the near future, the computer as we know it will disappear. It will be hidden in all the things that surround us, in order to improve our sensorial and perceptive abilities. We are currently moving from a computer-centric world to a network-centric world, in which humans (not technology) will achieve a central position, and benefit from the interesting side-effect of virtual ubiquity. Before we move forward to discussing this vision and its software implications, let me start with some background observations on technology trends and innovations.

2. CYBERSPACE VS. COMPUTATIONAL EXOSKELETON

If we observe the progress of computing technology, it is not hard to see a clear meta-trend, going from one computer for many people (the mainframe) to one computer for a single person (the PC), and finally to many interconnected computers for everyone. Yesterday's computers filled whole rooms because of their size; tomorrow's computers will do the same because of their number.

The three associated "laws" underlying this meta-trend are Moore's law on the exponential growth of transistors at constant cost (processing speed and storage capacity double every 18 months: "cheaper, smaller, faster"), Metcalfe's law on the square value of a network (the usefulness, or utility, of a network equals the square of the number of users or nodes) and Gilder's law on bandwidth growth (the total bandwidth of communication systems triples every twelve months) [2].

The combination of these three laws has given birth to the cyberspace [3] and to a new economy called "digital economy", where value has shifted from atoms to bits. As Negroponte says, "it is not about computers anymore. It is about living." [4] The cyberspace is composed of networks of networks of networks of … platforms of different size and granularity. These networks connect a multiplicity of intelligent devices, they can amplify our human perceptions and capabilities, acting as an exoskeleton.

From the perspective of applications and services, I find it more convenient to think in terms of exoskeleton rather than in terms of cyberspace, because the exoskeleton conveys an amplified reality, and thus it concerns our real lives. It is not just virtual reality as the word Cyberspace suggests.

3. MEST COMPRESSION

But how can we expand and improve this exoskeleton, which today is still in its infancy? To answer this question, we must first identify the drivers of the technological innovation process.

In 1938, Buckminster Fuller coined the term “Ephemeralization”, positing that in nature "all progressions are from material to abstract" [5]. Later he called it "the principle of doing ever more with ever less weight, time and energy per each given level of functional performance” [6]. This is the principle of innovation: it is based on the compression of physical variables like Matter, Energy, Space and Time. But if we take a closer look, we can see that this compression is associated with the simultaneous expansion of another variable: Information. This process of MEST compression and Information expansion has no “practical” physical limits, as demonstrated by Seth Lloyd [7]: “A 1-kg computer that has been compressed to the black-hole limit .. can perform 10^50 operations per second on its .. ~ 10^16 bits, and store about 10^31 bits”. At today’s pace, according to Moore’s law, it would take about 250 years for technology to reach these limits. To say it with the words of Buckminster Fuller, we are moving toward an Ephemeralization of the Earth: we will be increasingly able to do much more with much less. This is an unstoppable technological process, and it is not only true of information technology; it is true of any industrial process where “less is more”. This process is responsible for the current trend toward pervasive and ubiquitous computation, which will associate with the equally powerful trend of data bandwidth increase to give birth to the computational exoskeleton. In this society of knowledge, the value lies in ideas, not in atoms, and the economy is based on use, not on property. This paradigm shift explains the “open source” movement and the Web 2.0 revolution that is leading to a collaborative environment in which users can participate, sharing resources and opinions [8]. The trend of this evolution follows John Smart’s third Law of Technology, according to which technology moves through three phases[9]: a first phase in which technology appears de-humanizing, a second phase in which it is indifferent to humanity and a third phase in which technology (hopefully) becomes network-humanizing. Evidence that this law is correct can be found in the analysis of ITC development (and pervasive computation): instead of de-humanizing the world, this trend is revealing itself as network-humanizing.

4. PERVASIVE COMPUTING & THE GRID

The Pervasive Computing Grid is just an extension of the way in which we can use computers and infrastructure: computers of variable size (i.e.: mobile computers, wearable computers and sensors embedded in everyday objects and in the environment) and High Performance Computers (HPCs) interconnected through a scalable communication infrastructure (PAN, LAN, WAN). This is the new environment (i.e.: computational exoskeleton) which we have to explore and which can support a new class of services and applications.

If we go back to the definition of the “Grid” in computer technology, we find that the word was coined in the mid-‘90s to signify a distributed computational infrastructure, and was used at first in the field of advanced science and engineering. Foster, who created the term, describes a computational Grid as “a hardware and software infrastructure that provides dependable, consistent, pervasive and inexpensive access to high-end computational capabilities” [10]. With the pervasive computing Grid, we are moving away from the sole function of sharing computational resources. The new Grid has become a multi-purpose platform for the sharing of any kind of networked resource.

Figure 1 – Zypad, a wrist worn wearable Computer. Main Features: Touch screen, GPS, WiFi, Bluetooth. Optional functions: Zigbee or RFID reader. Operating systems: Linux or Win CE.

Using a more recent quote from Foster, the Grid is now seen as a system that “coordinates resources that are not subject to centralized control . . . using standard, open, general-purpose protocols and interfaces . . . to deliver non-trivial qualities of service”. That’s why, in the near future, the Grid concept will be extended to many other human activities. That’s why Grid technology is the ideal starting point for developing and facilitating the deployment of pervasive & ubiquitous computing scenarios[11]. The following discussion does not deal with the computational Grid in its first definition, but is aimed at understanding the potential benefits coming from the interaction between the pervasive Grid and humans: a challenging playground for new software protocols, middleware and applications.

5. THE BUILDING BLOCKS

The computational exoskeleton is taking form: it is made of all the intelligent devices and computers which, thanks to wireless communications, are no longer seen as distinct computers, but as parts of a much larger computer that surrounds planet Earth. We will not use computers as distinct devices anymore: they will be sophisticated gates that give us the means to amplify the external reality and our own ubiquity through the net and through the computational grid. The progress will be such that we will no longer see computers as computers, but as an integral part of our world, as an extension of ourselves: this is what we mean when we talk about the disappearance or invisibility of computers, that they will become an unnoticed part of our background.

It is before our eyes that computers are in telephones, doors, TV sets, DVDs, DVRs, microwave ovens, refrigerators, cash registers, motorcycles, cars, and in a multitude of everyday devices and appliances. However, this ubiquitous presence is not enough: we do not have just to make our devices more intelligent, we have to provide them with the capability to “sense” the world. The pervasive computing Grid must be fed with data coming from sensors, and the wireless sensor networks are the missing link to augmented reality. When this gap is filled, we will finally have an exoskeleton that functions as an extension of our five senses. We will be able to extend ourselves from a computational semi-rich and sensors-poor body to a super-body that is sensors-rich and

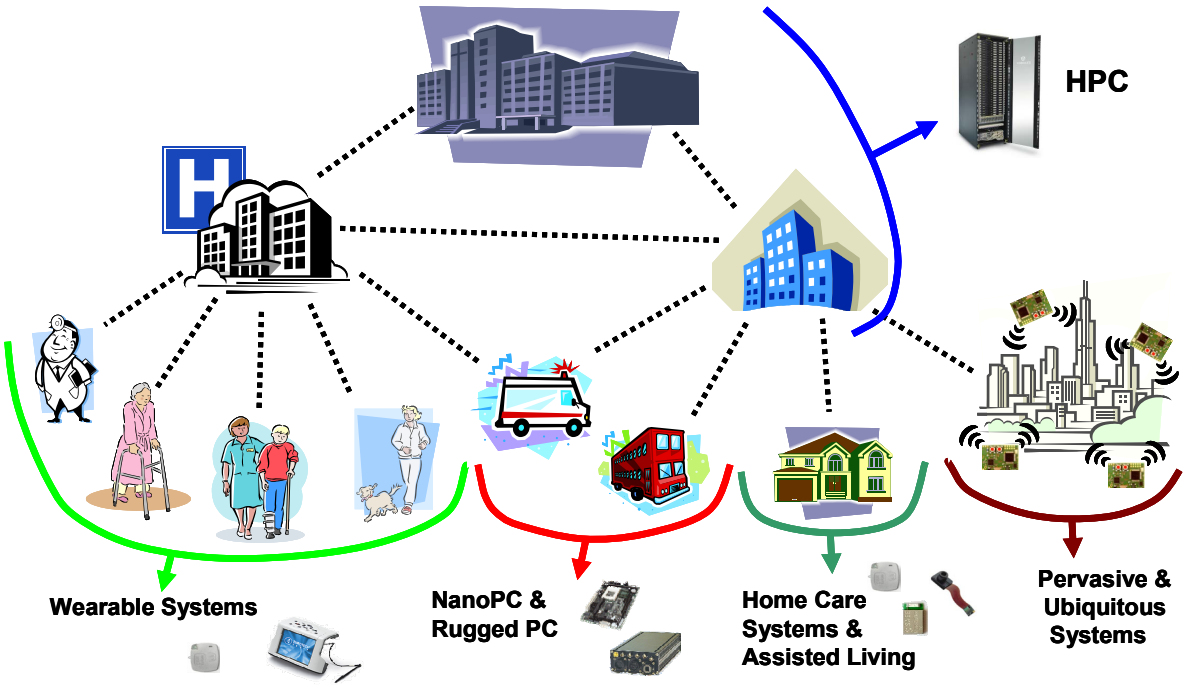

Figure 3.- Pervasive Computing scenario for health care

computation-rich, and we will have a better capability to understand the world around us (and the whole universe).

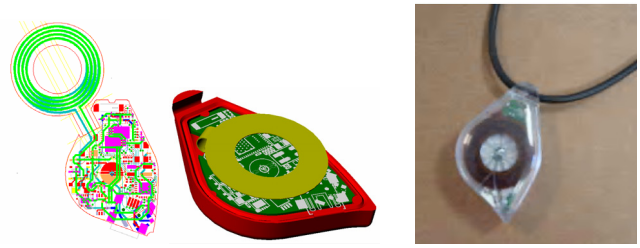

Figure 2 – SOLO, a wearable smart thing. Pendant-like device for personal affinity matching and personal data management. Features: Zigbee and contactless power supply.

Ultimately, the pervasive computing Grid will give to humans a sort of ubiquity of the mind and senses (not yet of the physical body) and we will be where we want to be. To attain all this, what we need most is a seamless interface to computers, because everything depends on a good human-computer interaction, on a really effective human-machine conversational interface. Today this interface is too complex and cumbersome, and greater efforts need to be made in this direction.

6. A SEAMLESS INTERFACE

We are living in the Information Technology age, but further evolutions lay ahead. Very soon, humankind will enter the Symbiotic age [12], when we will feel naked without our wearable computers (fig.1), real gates to bidirectional ubiquity (telepresence [13] and context aware scenarios). This is our future framework, and for this framework we will have to build new classes of applications and services. This is the scenario envisioned by Mark Weiser at the end of the '80s and early '90s, while he was at the Xerox PARC (Palo Alto Research Centre), and summarized here by three statements taken from his publications:

The Disappearing Computer: "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."

Ubiquitous Computing: "In the 21st century, the technology revolution will move into the everyday, the small and the invisible…"

Calm Technology: "As technology becomes more embedded and invisible, it calms our lives by removing the annoyances while keeping us connected with what is truly important" [14,15]

When the exoskeleton is complete, we will be able to explore different kinds of interactions: people to augmented reality, people to people, people to machine, machine to machine, machine to people and machine to reality. With these new pictures in mind, we can create a world totally different from what it is today. Just imagine how much the Calm Technology can deliver in terms of background assistance to all of us: children, patients and the elderly (fig.3). Specialized, invisible computers will become an integral part of the natural human environment, and we will do "computing without computers".

We are entering a new world of cooperating smart things. Things are smart because they embed small, cheap, lightweight processors, and they are cooperative thanks to wireless communications that allow the creation of spontaneous networks

(fig.2). Compared to traditional objects, these smart things have totally different properties: they can remember selected events, they have a memory, they show context-sensitive behavior, they may have sensors, they have location/situation awareness, they are responsive, they communicate with their environment and they are networked with other smart objects and with everyone on the Grid. We are nowadays at the frontline of this creation and, as Gordon Bell has stated, "everything that is cyberizable will be in cyberspace", a "fractal cyberspace" of "networks of networks of networks… of platforms" [16].

7. THE TOOLS

Which software tools can we use to forge this new era? Our time is characterized by the birth of the "open source" movement and of the Web 2.0 technology. Both have in common a collaborative environment. Thanks to the net, we are no longer alone and we can share anything, to maximize results while saving time. New and powerful tools are available to the software community, among them an IDE (Integrated Development Environment) like Eclipse [17], an OSGi (Open Service Gateway Initiative) [18] middleware framework like SODA (Service Oriented Device Architecture) [19] and a language like Java (with its embedded extension, the Java Micro Edition or J2ME). The Web 2.0 is offering Mash-ups, a powerful technology of content creation/reuse which allows users and programmers to integrate multiple sources of information.

7.1 Billion Cell Phones Can't be wrong!

I would like to spend a few words on Java, before I conclude, because it is a paradigmatic example of technological progress and at the same time of counterintuitive industrial choices. Java is widely used in the cell phone industry, and cell phones represent one of the most ubiquitous examples of pervasive computing appliances; as a matter of fact, cell phones have totally disappeared into our daily routine. One of the primary technologies used to accomplish this was the Embedded Java. However, even though the cell phone industry has embraced Java as a core component, the embedded computer industry as a whole is strangely slow in accepting it. From a practical point of view, Java allows you to write only once, it runs anywhere because it is a virtual machine, it has a memory management and a built-in thread support, it allows rapid code development because of a large repository of existing code and it is fast enough. Most important of all, it is network- and Web-centric. Java is the language we are looking for, and if we consider that there are a middleware like SODA and a powerful open-source collaborative development environment like Eclipse available, we have all the right tools to start our exploration of the pervasive computing territory.

8. CONCLUSION

In conclusion, the exponential progress in computing speed, communication bandwidth, material sciences, miniaturization and sensor technology is leading to a New Era, the Era of real augmented reality. Pervasive and ubiquitous computing technologies will have a major economic, social and cultural impact on our society and on the world where we live. We need a paradigm shift in order to fully understand and appreciate the opportunities that this intelligent infrastructure can offer, and we will have to face many challenges on security, privacy, dependability. But an exciting new era is coming our way: the era when we can have a new external "body": the computational exoskeleton.

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10. REFERENCES

[1] D. De Roure, Semantic Grid and Pervasive Computing, GGF9 Semantic Grid Workshop, 2003

[2] W. Webb, "laying down the law", IEE Communications Engineer, February/March 2006

[3] W.Gibson, Neuromancer, July 1984, pp. 4-5

[4] N. Negroponte "Being Digital" , Vintage – 1996 ISBN 0-679-76290-6

[5] R. B. Fuller "Nine Chains to the Moon", DoubleDay – 2000 ISBN 0385011490

[6] R. B. Fuller Synergetics 2 Macmillan Publishing Co. 1983 ISBN 0024418807

[7] S. Lloyd, "Ultimate physical limits to computation", Nature 406:1047-1054 , Aug. 2000

[8] T.O'Reilly, www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/ 30/ what-is-web-20.html

[9] J. Smart http://www.accelerationwatch.com/laws.html

[10] I. Foster C. Kesselman, eds.: The Grid: Blueprint for a New Computing Infrastructure. Morgan Kaufmann Pub., Jul. 1998.

[11] O. Storz, A.Friday, N. Davies: Towards 'Ubiquitous' Ubiquitous Computing: an alliance with 'the Grid', Ubisys 2003, Seattle, Washington, Oct. 2003.

[12] R. Kurzweil, The age of spiritual machines: when computers exceed human intelligence, Penguin, Jan. 2000 0140282025

[13] G. Bell, Live on line "Telepresence Discussion" at Washington Post, May 2000. http://research.microsoft.com/~gbell/Pubs.htm

[14] M. Weiser: The Computer for the 21st Century. Scientific American, pp. 94–104, Sep. 1991.

[15] M. Weiser and J. Brown: Designing Calm Technology. P. Denning and R. Metcalfe, eds., Beyond Calculation – The Next Fifty Years of Computing, chap. 6 – The Coming Age of Calm Technology. Copernicus Books, Mar. 1997.

[16] G. Bell, J. Gray, The revolution yet to happen, 50th anniversary of ACM, http://research.microsoft.com/~gbell/acm2047.doc

[17] R. Day, Eclipse unites the embedded and enterprise environments, Embedded System Design, Jan 2007

[18] The OSGi Alliance mission is to specify, create, advance, and promote an open service platform . www.osgi.org

[19] S. de Deugd, R. Carroll, K. E. Kelly, B. Millett and J. Ricke, SODA: Service-Oriented Device Architecture, IEEE Pervasive Computing –July-Sept. 2006.