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# Web of Things: The Collaborative Interaction Designer Point of View

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***Abstract.** This position paper describes the authors' vision of the future of computing. Once Ubiquitous Computing matures as a new paradigm for computing three major issues arise: how can these systems interact with people, environments and other systems, how can all the information collected by the system be smartly represented so it can be useful and how can the system use this information to make intelligent inferences over context. Non-traditional interfaces, Semantic Web technologies and Multi-Agent systems are discussed as possible solutions for these problems.*

## 1. Computing in the 21<sup>st</sup> Century

Computers are everywhere. Recent data from [The Economist 2008] magazine estimates that in 2009 there was, on average, more than one personal computer for every five people in the world. This estimate, however, only considers what we nowadays call a computer.

The truth is we are all surrounded by computers, but these are located inside things we wouldn't normally call a computer. The mass production of electronic circuitry enabled the augmentation of everyday appliances, such as mobile phones, video game consoles, vehicle control systems, television sets, household appliances, etc. In order to improve user experience, these devices come with low cost, low power, multi-functional embedded sensors, actuators and microcontrollers that collect information from the user and the environment, process it, and give some feedback.

If we take into account that [Barr 2006] states that less than 1% of the 9 billions of microprocessors manufactured each year find their way into multi-application programmable computers, one can only image what sorts of devices might ship with some kind of embedded system in the near future.

Once sensors become available in a wide spectrum of devices, there will also be a trend in tagging objects for them to control. One of the most promising technologies in this sense is Radio Frequency Identification (RFID). [Glover 2007] defines it as any identification system in which an electronic device that uses radio frequencies or magnetic field variations to communicate is attached to an item. [Roussos 2008] adds to that the ability to automatically identify objects, locations and individuals to computing systems without any need of human intervention. An RFID tag costs less than a dollar and with new production technologies (such as nanotechnology) these prices tend to get even cheaper. Nowadays, bar codes tag classes of products (like a milk carton), but

RFID will enable item level tagging (like the specific milk carton you bought yesterday), carrying information specific to that item (like when it was produced, when it expires, from which farm does it come, even from which cows!).

According to the situation, devices will be interconnected, forming a dense network of all sorts of appliances. The technology to enable the addressing of all these nodes is the Internet Protocol version 6 (IPv6). This new implementation will include 128 bits long addresses (4 times longer than IPv4 addresses, which are 32 bits long). Hence, the IPv6 address spaces supports  $2^{128}$  addresses (approximately  $3.4 \times 10^{38}$  addresses), which will permit every object around us to have its own IP address, forming the Internet of Things.

There is also a movement towards empowering people to design and implement devices themselves. Low cost prototyping kits such as Arduino and Wiring enable people from different backgrounds other than engineering to build electronic circuits and create functional devices. According to their website ([www.arduino.cc](http://www.arduino.cc)), Arduino is 'an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software and it's intended for artists, designers, hobbyists and everyone interested in creating interactive objects or environments.' Similarly, in their website ([www.wiring.org.co](http://www.wiring.org.co)), Wiring is defined as 'an open source programming environment and electronics I/O board for exploring the electronic arts, tangible media, teaching and learning computer programming and prototyping with electronics.' Supporting this movement there is also a huge community of do-it-yourself enthusiasts that gather around websites like [Instructables.com](http://Instructables.com) and [Makezine.com](http://Makezine.com) and offer tutorials and blueprints for all kinds of projects. We should expect to see very interesting devices created by people from otherwise unexpected backgrounds.

All this technological movement is in accordance to Mark Weiser's vision of the major trends in computing. According to [Weiser 1996], the computing history can be divided into four eras. First, the Mainframe Era, when *many* people used to share one computer, which was mostly run by experts behind closed doors. After that the Personal Computer Era took place, when each person had his own computer. Then, we entered into the transition from this era to the next: The Internet and Distributed Computing Era, when computers were still personal, but were connected with each other. We are now stepping into the next one, the Ubiquitous Computing Era, when *many* computers will share each one of us.

As [Weiser 1993] defines it, Ubiquitous Computing (in short, UbiComp) is the method of enhancing computer usage by making *many* computers available throughout the physical environment, but making them effectively invisible to the user. [Poslad 2009] defines it as information and communication technology systems that enable information and tasks to be made available everywhere and to support intuitive human usage, appearing invisible to the user.

This new paradigm of computing will evoke new forms of interactions. In the next section, we will show some of the current research directions in the area.

## 2. Post Desktop Interaction

In the current model of Human Computer Interaction (HCI), the Interaction Designer only has to deal with the user and the system. However when computing becomes situated, a new dimension is added to the equation: the environment.

[Poslad 2009] lists several types of interaction in this framework: human-to-human interaction (HHI), human-computer interaction (HCI), human-physical world interaction (HPI) and computer-physical world interaction (CPI).

As soon as everyday devices become augmented and interconnected, new interfaces will arise, exploring all of our senses. [Kortum 2008] lists some of them: haptic, gesture, locomotion, auditory, speech, interactive voice response, olfactory, taste.

Haptic interfaces provide feedback through the sensation of touch. Such type of interface use a manipulator, like the PHANToM desktop haptic interface, to control a virtual or physical environment and the device provides the user with realistic touch sensations [Gupta 2008].

Gesture interfaces use face expressions and hand movements as input and can be implemented by mechanical, tactile and computer vision technologies [Nielsen 2008].

Locomotion interfaces enable users to move virtual spaces while sensing that they are moving in the physical world. They involve large scale movement and navigation, in contrast to gesture interfaces, that involve small scale movements [Whitton 2008].

Auditory interfaces involve sounds as means of feedback. They have been used for a long time, but new challenges have appeared. Some of them are how to present information to visually impaired people, how to provide an additional information channel for people whose eyes are busy with a different task, how to alert people to error or emergencies, how to provide information with limited capacity to display visual information. All of these must be achieved trying to minimize problems like annoyance, privacy, auditory overload, interference, low resolution, impermanence and lack of familiarity [Peres 2008].

Speech interfaces use voice recognition systems as means of input. It must capture what the user has said and decode it to machine understandable data [Hura 2008]. On the other side of the interaction are interactive voice response interfaces, in which a pre-recorded or machine generated voice is the means of feedback to the user.

Olfactory interfaces involve scent as input or output. They involve devices that provide users with information through smell. These smells can be generated vaporizing and blending odours [Yanagida 2008]. Also, they can sense smells to make inferences over the environment.

Taste interfaces simulate tastes like sweetness, bitterness, sourness, saltiness and the least known umami taste. Challenges in designing this type of interfaces include how to sense the perceived taste by the tongue and how to simulate food textures [Iwata 2008].

With these types of interfaces, input can be combined with output, like in touch screens (where the position of contact of the finger or pen with the screen can be

detected and used as input and the image displayed on the screen is used as output); tangible interfaces (interfaces that augment physical devices to receive input and provide feedback); wearable computer interaction (clothes, garments and accessories with embedded systems), and others.

As important as designing new types of interfaces is combining them to enhance user experience. Any one of these interfaces won't be adequate for all situations alone, so the skilful designer will know when and where to use and combine any of them.

While we were stuck with the GUI paradigm, interaction designers used to struggle to fit functionality in WIMP (window, icon, menu, pointing device) format, lots of times achieving a poor result. In the near future, we should expect to see more natural, implicit and adequate interfaces (the right tool for the job).

Since new ways to interact will start to appear, how can the amount of input and output involved in the interactive process not overload the user's attention and cognitive capacity?

### **3. Information to Empower, not Overwhelm**

Naturally, one can imagine the amount of information to be generated by an UbiComp infrastructure. Sensors will be everywhere acquiring and sending data, microcontrollers will be processing and distributing this data, actuators will be responding by generating audio, sound, text, and others. Moreover, people will be inside this loop, adding content, manifesting themselves, downloading and uploading data and receiving feedback from actuators.

However, the amount of information can be rather overwhelming. There could be an unbearable amount of buzzing sounds and electronic displays overloading our senses. Try searching for a simple word like "house" in Google and expect to get over a billion results. How can one go through all this information?

The current model for Human Computer Interaction involves the explicit control of the user. This model might work well for a single device, but as they become interconnected, users will need to access services across several different devices to accomplish their goals. Hence, if each individual device requires the user to provide explicit input, the user might become overwhelmed. The same goes for the system's response, since not every device being used will need to provide feedback to the user, but to the environment and other devices.

Observing how humans interact, one can notice that much of the communication happens implicitly, through body language, tone of voice, eye movement, pupils' dilatation, etc. [Schmidt 2000] takes that to define a new model for HCI: the implicit Human Computer Interaction (iHCI). He defines it as 'an action performed by the user that is not primarily aimed to interact with a computer system but which a system understands as input'. To achieve iHCI it is necessary for systems to perceive its usage, to perceive what the environment and circumstances are like, to understand what sensors detect and how to make use of this information.

Therefore, an UbiComp system must be context aware. [Schmidt 1999] structures the concept of context stating that context describes a situation and the environment a device or user is in, it is identified by a unique name, for each context a set of features is relevant and for each relevant feature a range of values is determined

by the context. Context shape users' behaviour, so UbiComp systems must understand the context to better interact with the user. For a system to be context aware, it must include several sensors. As [Gellersen 2002] concludes, integrating information collected by sensors is a viable way to obtain context representing real-world situations and context that captures interaction with everyday artefacts.

[McCullough 2005] lists a situational typology to reduce the complexity of understanding context. Hence, the system must behave differently when the user is at work (deliberating, presenting, collaborating, dealing, documenting, officiating, crafting, associating, learning, cultivating, watching); at home (sheltering, recharging, idling, confining, servicing, metering); on the town (eating, drinking, talking, gathering, cruising, belonging, shopping, sporting, attending, commemorating) and on the road (gazing, staying, adventuring, driving, walking).

In short, UbiComp systems must understand the users' context in order to interact with them adequately and not overwhelm them with information. But how can an UbiComp application store this context information in such a way that it is useful for the system? Besides that, once the information is stored, how can the system access it?

#### **4. Semantic Web and Ubiquitous Computing**

As stated earlier, context will be fundamentally important and not many current data models are prepared to represent this data. As [McCullough 2005] puts it, representing scenes and situations becomes the essential challenge. Hence, knowledge representation and sharing becomes central issues in developing UbiComp Applications. The Semantic Web might well be the answer to that problem.

According to [Berners-Lee 2001], 'the Semantic Web will bring structure to meaningful content of Web pages, creating an environment where software agents roaming from page to page can readily carry out sophisticated tasks for users'. If we think not only about a Semantic Web, but of a Semantic Web of Things, we can imagine agents roaming devices and environments to achieve their goals.

Current Semantic Web technologies include the Resource Description Framework (RDF), which is a standard model for data interchange on the Web; RDF Schema, which is an extensible knowledge representation language, providing the basic elements for the description of ontologies; the Web Ontology Language (OWL), which is a family of knowledge representation languages for authoring ontologies.

[Gruber 1993] defines ontology as a specification of a representational vocabulary for a shared domain of discourse - definitions of classes, relations, functions, and other objects. [Noy 2001] lists several reasons for using ontologies that can aid UbiComp Systems, including to share common understanding of the structure of information among software agents and to analyze domain knowledge.

Semantic Web technologies are already being used to tackle UbiComp research issues. [Chen 2004] proposed an agent-oriented architecture that uses Semantic Web languages to model ontologies of context, to reason with context in a smart space, and to define a policy language for users to control the sharing of their contextual information.

While Semantic Web technologies appear as a solution to context representation, Multi-Agents systems appear as a solution to embed intelligence to UbiComp systems.

## 5. Multi-Agents Systems and Ubiquitous Computing

Artificial Intelligence has been used for quite some time to solve a variety of problems in Computer Science, but since 1985, a new trend has emerged inside this field: agent based systems. According to [Acampora 2006], an agent is ‘an entity capable of carrying out goals as a component of a wider community of agents that interact and cooperate with each other.’

The UbiComp vision of a network of embedded devices leads to the research into embedded agents to provide useful intelligence to embedded systems. [Kaelbling 1990] says that and ‘embedded agent is a computer system that sense and act on their environment, monitoring complex dynamic conditions and affecting the environment in goal-directed ways.’ As [Serrano 2008] points out, the scientific community has reached little consensus about how to tackle the problems of UbiComp, but the Multi-Agent System design and development paradigm is appropriated to be used in ubiquitous contexts.

[Garcia 2004] lists some properties of agents: interaction, adaptation, autonomy, learning, mobility and collaboration which are also requirements for UbiComp systems. [Poslad 2009] lists several properties of UbiComp systems. These two sets of properties fit rather adequately.

Interaction means that agents use sensors and effectors to communicate with the environment. These are part of the UbiComp system infrastructure, so the agent might be implemented in a device to enrich its interaction with people, nature and other devices.

Adaptation means that, by receiving messages from the environment, the agent adapts and modifies its mental state. UbiComp systems actively adapt to changes, instead of just presenting these changes to the user. In a networked mesh of devices, messages will be exchanged between them to create a consistent environment and interaction.

Autonomy means that an agent is capable of acting without direct external intervention. In UbiComp, while some control over the system is always necessary, the system cannot depend on human interaction. [Poslad 2009] gives some reasons why not, including the fact that human interaction might become a bottleneck, the amount of information might overload the cognitive and haptic capabilities of humans and it may not be feasible to make some or much machine interaction intelligible to some humans in some situations. Therefore, the system must be able to make decisions on its own.

Learning means the agent uses previous experience to learn how to react and interact with the environment. Ubiquitous systems must be designed to improve their performance after it acknowledges information from people, devices and its environment. As the system is in execution, it gathers information that can be stored and queried to discover personal preferences, behavioural patterns, and others.

Mobility means that an agent is able to transport itself from one environment in a network to another. Since UbiComp comprises networked embedded systems in everything, wireless and ad-hoc networks will be everywhere, so users, services, data and code may be mobile.

Collaborative means that agent can collaborate with other agents in order to achieve its goals and the system's goals. Many devices in an UbiComp environment will have to exchange and share tasks, information, sensor data, etc, to organize themselves in order to achieve the same goal.

Software agents will communicate by sharing domain ontologies. As the Semantic Web evolves, each website or organization will have its own ontology. Hence, the web of the future will comprise several small ontologies that will be used by many software agents to communicate. [Breitman 2006] states that the challenge in developing ontologies is not in the construction of ontologies, but in having software agents communicating. In the context of UbiComp this will be crucial, because agents need to collaborate in order to reduce complexity.

Therefore, it is possible to see how software agents can act as tools for UbiComp systems.

## **6. Conclusion**

There is an observable trend towards the formation of a pervasive, interconnected and localized computing infrastructure. This infrastructure will comprise networked sensors, actuators, microcontrollers embedded in devices and environments, in order to provide more natural, non-traditional interfaces. This infrastructure will also generate a massive amount of data which must be available online, everywhere. This data must be smartly stored using technologies related to the Semantic Web, such as ontologies, RDF, RDFS and OWL and it will be retrieved using intelligent multi-agent solutions.

Our research group strongly believe that the richness of this new paradigm of computing is not only in the new smart devices or environment, but in how they interact among themselves and with people. Moreover, the richness of the process really blossoms when fixed environments can interact with mobile devices, when virtual avatars can collaborate with real people, when form meets behaviour.

We take this vision of the future of computing to direct our research interests. We want to look at how will people collaborate in an environment where they can't see the computer, how can tangible interaction improve the user's experience and how can devices embedded in clothes enhance the user's ability to complete tasks. On a lower level of abstraction, we want to see how can we embed circuitry in clothes in a comfortable fashion for the user, how can we interconnect devices of different nature and how to create ergonomic tangible interaction devices.

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