# The Web of Things as an Infrastructure for Improving Users' Health and Wellbeing

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***Abstract.*** *This position paper outlines the authors' vision on how the Web of Things, using interconnected devices, including sensor nodes, mobile phones and conventional computers can help improve the overall health and wellbeing of its users. We describe ongoing work being carried by our research group both at PUC-Rio and at Lancaster University as well as the motivating background.*

## 1. Introduction

In recent years, the world has witnessed a significant shift in how the World Wide Web and computing itself are perceived and engaged by its users. While the Web has seized being just a means for information presentation to become a much richer platform for user collaboration, computing has come out of the box that we would normally call a computer to be embedded in all sorts of everyday devices, in what Mark Weiser, a pioneer of the area, called Ubiquitous Computing (UbiComp) [Weiser 1991]. When these two technology advances meet, we have the Web of Things, where embedded computers on common objects disseminate information and communicate among themselves over the Web.

In this scenario, devices are seamlessly integrated and collaborate in order to proactively make users' life easier. Interaction is often implicit, meaning that actions that are not primarily used to interact with a computer system are also used as inputs for the system [Schmidt 1999].

An important component of Weiser's vision on UbiComp was the idea of proactive computing [Tennenhouse 2000], where the computer would make inferences on our needs and intentions in order to act on our behalf. Although proactive computing has been criticized in other works [Rogers 2006], trying to use context information, i.e. any information that can be used to characterize the situation of an entity [Dey 2000] to provide relevant information and services to the user is still a way in which the UbiComp reality can make our lives easier.

Context information can be gathered by physical or hard sensors embedded in devices, such as accelerometers, pressure pads and thermometers; virtual or soft sensors, such as an electronic schedule and websites; or a combination of them. Types of context information can be the user's location, the current time, environmental conditions and the user's activity.

At first, context-aware systems focused on location as their primary form of context [Want 1992], [Cheverst 2000], but as sensor technologies evolved, systems could build a much richer model of context [Davies 2008]. Therefore, Activity Recognition plays an important part in Context-Aware Systems and emerges as a research area of its own.

Alongside with these sensors, objects are also embedded with actual processing and communication capabilities. This enables them to communicate over a network and even have a Web presence [Kindberg 2000].

In a previous paper [Velloso 2010], we described our research group's vision on the Web of Things. In this one, we describe our current approaches to tackle actual problems by taking advantage of this infrastructure. We claim that by using networked sensors and actuators embedded in everyday objects, we can recognize qualitatively activities and actually improve users' health and wellbeing.

## 2. Web of Things Support for Health and Wellbeing

In the previous session, we characterized the UbiComp vision and made a point for using context information in order to recognize activities. But how can the Web of Things offer support to actually improve our health and wellbeing?

To begin with, a computational infrastructure can help keeping people away from hospitals. Studies have shown that most patients prefer home health care rather than being in hospital environments and that there are significant differences in recovery of patients in hospitals or at home [Clarkson 2010]. Computer assisted environments, such as Ambient Assisted Living (AAL) [Mulvenna 2011] and health environments are used to provide assistance for recovery and chronic patients in their own homes. For instance, a solution based on Internet of things, combining software, physiological sensors, and environmental sensors, has been developed to assist diabetes patients [Jara 2011]. AALs also aim to improve patients and elderly's quality of life and safety at home, providing services such as emergency incidents detection [Doukas 2009].

A variety of biomedical information, such as respiration, pulse, electrocardiogram, blood pressure, and temperature can be measured in/on the human body. Ubiquitous biomedical information sensing system [Imai 2011], wearable devices [Chen 2011] and wireless body area network (BAN) [Jovanov 2009], [Yang 2006] are some of the technologies used for monitoring multiple physiological signals at a distance (telemonitoring) and for providing information to alert systems that detect or predict emergency health situation.

In the area of using interconnected sensors for physical activities monitoring, there has been work on using sensors on clothes to record physiological data from children playing sports [Knight 2004], combing data from the user's trainers with music on his iPod [Apple 2011], combining GPS, acceleration and heart rate data to provide motivation through a 3D agent in a mobile device [Butussi 2008].

## 3. Ongoing Work

Considering that the Web of Things can be of use of for health-related systems, our research group aims at using this approach to develop novel applications. In this session we describe two projects in which we use an interconnected sensors infrastructure to tackle real world problems, namely giving support to elder care at their homes and monitoring weight lifting performance.

### 3.1 UbiLife

UbiComp and health technology propose the use of sensors and actuators in home-based tangibles and wearable computers to provide assess of their own health and that of the ones who are taking care of [Mynatt 2005]. UbiComp has already shown that health indicators typically monitored in clinical settings can be successfully deployed for home tracking (eg, [Bratan 2005], [Korhonen 2001]). In this way, commercial systems have been developing sensors for health tracking for elders living alone [Doughty 1996].

We are investigating how to create UbiComp environments for supporting elders in their activities of daily living (ADLs). This project, entitled Ubilife, proposes the prototyping of UbiComp systems for monitoring and measuring vital signals, and for providing healthcare in their own houses. Ubilife makes use of wearable computers, tangibles and virtual reality in a way that do not disturb the elders' routine, making no interference with theirs ADLs, preserving their autonomy and self-esteem, and also providing information when and where decisions and actions should be made. A multi-agent approach was used for modeling Ubilife.

One of the challenges of this project is to infer ADLs from sensor data by a context-aware system. Context-aware algorithms must recognize patterns of elders' routines and vital signals for detecting changes in their activities, which could be early indicators of emerging health problems. Behavior profiling will be inferred by applying machine learning techniques to the data set gathered from the sensors.

In order to get a reliable data set, trust issues raised by highly instrumented responsive environments are taking into account. Researchers must test the reliability and acceptance of home-based wearable monitoring systems such as blood pressure and body temperature devices. All the UbiComp devices including their sensors, actuators and power supplies must always be available and running.

Moreover, privacy issues must be considered in the development of healthcare systems. Hence, it was decided not to use a video streaming for presenting the elders' activities, and instead to use an avatar representation in a virtual world environment. This environment works as a real-time mirror of their activities. So, this environment not only preserves elders' privacy, but on the top of it, it could activate some physical actuators in the "real world". For instance, audio warnings could be played whenever emergency incidents are detected.

## 3.2 PerActive

Physical activity has been linked to a better and longer life in several studies and official recommendations over the years [O'Donovan 2010], [Blair 2009], [NHS 2011]. Weight lifting, in particular, is recommended for all healthy adults, since it can lower blood pressure, improve glucose metabolism and reduce cardiovascular disease risk, among several other health benefits [O'Donovan 2010].

These activities, however, must be performed correctly in order to offer the desired outcomes. If performed with the incorrect technique, they can result in severe training injuries [Gallagher 1996]. Free weights exercises are especially susceptible to cause training-related injuries, corresponding to 90,4% of weight training injuries [Kerr 2010].

Very few projects, however, address the issue of activity recognition for weights training activities. [Chang 2007] used sensors in the user's glove and waist to do exercise recognition and repetition counting, but they didn't use the gathered information to provide feedback to the user.

Moreover, whereas most of related work in the field of Activity Recognition has focused on determining in which activity the user is engaged, we take a more qualitative approach. Our goal in this project is to provide pervasive computing support for weight lifting activities by not only recognizing the exercise, but assessing how well the user is doing it. Work in this area include [Fothergill 2011] and [Heinz 2006], that used qualitative analysis for rowing and martial arts. In our system, information on the user's performance is gathered via IMU's (inertial measurement units) installed on the weights, and on the user's body, and is combined with information from his personal exercise routine. These sensors are wirelessly interconnected and contain an accelerometer, a gyroscope and a magnetometer.

Following the principle of augmenting everyday objects rather than making the user wear new equipment, the sensors will be installed in common gym accessories such as training gloves and lumbar belts.

Using machine learning, data fusion and activity recognition algorithms, our intention is to use qualitative analysis not only to discover which exercise he is doing but also to gauge whether the user is doing the exercise correctly and how he can improve his technique. Feedback would be available online, via audio and vibration and offline, in an exercise report. This could be used by the user himself in order to improve his technique or by a personal trainer to keep track of the user's performance.

Data flow and synchronization are maintained by the Context Recognition Network Toolbox (CRNT) [Bannach 2006], [Bannach 2008].

The final system should be able to run on an Android mobile phone that contains all his personal and exercises information, processes all data and provides feedback. We'd also like to explore how we can use a mobile phone as a standalone sensor to monitor his performance.

Challenges in this project include how to provide an accurate qualitative analysis, how to perform activity recognition in real time and how to achieve these goals using as few sensors as possible.

## 4. Conclusion

In this paper, we outlined our vision on how the Web of Things can play a part in improving our health and wellbeing. We described ongoing work comprised of UbiLife, that aims at providing computational support to elder care and PerActive, that aims at aiding weight lifters in correcting their technique by providing qualitative activity recognition assessment.

Both projects use an infrastructure of interconnected sensors to make assumptions on the current state and activities of its users in order to provide valuable feedback to the user and to health professionals, such as nurses, doctors and personal trainers.

Further insights will be obtained as we mature our work and conduct thorough system evaluations.


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