Embedded WiSeNts

Information Society Technologies

Cooperating objects and wireless sensors: the impact of the technical visions on society

A framework for discussion

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Embedded Wisents is a EU-funded project aimed at creating a roadmap that will accelerate European research in the area of wireless sensor networks and cooperating objects. An important part of the roadmapping is to identify appropriate directions that fully recognise and address the social and ethical impact of these technologies.

1. Cooperating Objects: The Technical Vision

Two technical developments support the notion that systems based on very small communicating computers are likely to have important social and economic impacts in the next decades.

Ubiquitous computing

Ubiquitous computing aims to develop systems that sense and interpret the state of the world and human activities in order to enhance the human experience. Current ubiquitous systems range from the nearly imperceptible ones that control lighting, heating, ventilation and physical security in indoor environments to hand-held interactive devices that automatically provide relevant information to visitors as they move around a museum.

Some more extensive applications developed in laboratories now working in ubiquitous systems indicate the potential benefits of ubiquitous computing. Such systems are constructed from networks of computers that can be carried, worn and installed pervasively in indoor and outdoor spaces together with sensors that enable them to detect their location and observe the state of their environment and actuators that interact with environment and with human beings.
Sensors may measure force, sound, light, temperature and most other physical and chemical parameters. These measurements can be used, for example to detect human presence and activity, monitor air quality or determine vital signs and other parameters in healthcare. Sensors that acquire visual images are not excluded although their analysis and interpretation is currently limited by the image processing required and its resource costs.

Actuators control devices interact with human users. For example, managing indoor and outdoor environments by controlling access to a building according to a security policy or controlling traffic to maintain air quality.

The GAIA project at the University of Illinois gives this perspective for the future technical infrastructure of ubiquitous computing:
Physical spaces become interactive systems, or in other terms, Active Spaces. Such environments are analogous to traditional computing systems; just as a computer is viewed as one object, composed of input/output devices, resources and peripherals, so is an Active Space. However, the heterogeneity, mobility and sheer number of devices makes the system vastly more complex. Applications may have the choice of a number of input devices such as location sensing system, mouse, pen, or finger and output devices, such as an everywhere display, monitor, PDA screen, wall-mounted display, speakers, or phone. [*GAIA project web page, University of Illinois, Urbana, IL. http://gaia.cs.uiuc.edu/]*

'Mote' computers

Even current handheld and other mobile computers are at least an order of magnitude too large for most of the scenarios envisaged for ubiquitous systems. And even if they were smaller, their cost, management demands and power consumption are incompatible with their deployment in the extremely large numbers required by many of the scenarios.

Several research projects initiated around the year 2000 have developed extremely small, low cost and energy-efficient freestanding computers with a wireless networking capability suitable for deployment in large numbers. The most important of these was the 'mote' concept originated at the University of California at Berkeley. The name was coined to indicate that they can be regarded as a sort of 'smart dust' (dictionary definition: mote = something, especially a bit of dust, that is so small it is almost impossible to see). The products to date from these projects should be regarded as large-scale prototypes for the much tinier versions that can be expected in the coming years. Miniaturization is advancing with the goal of producing complete devices with dimensions of a few millimetres - small enough to embedded in everyday objects or distributed throughout the environment with cost of 0.5 Euros or less.

MICA mote is a commercially available product that has been used widely by researchers and developers. It has all of the typical features of a mote and therefore can help you understand what this technology makes possible today. MICA motes are available to the general public through a company called Crossbow. These motes come in two form factors:

- Rectangular, measuring 2.25 x 1.25 by 0.25 inches (5.7 x 3.18 x.64

centimeters), it is sized to fit on top of two AA batteries that provide it with power.

- Circular, measuring 1.0 by 0.25 inches (2.5 x .64 centimeters), it is sized to fit on top of a 3 volt button cell battery.

The MICA mote uses an Atmel ATmega 128L processor running at 4 megahertz. The 128L is an 8-bit microcontroller that has 128 kilobytes of onboard flash memory to store the mote's program. This CPU is about as powerful as the 8088 CPU found in the original IBM PC (circa 1982). The big difference is that the ATmega consumes only 8 milliamps when it is running, and only 15 microamps in sleep mode.

This low power consumption allows a MICA mote to run for more than a year with two AA batteries. A typical AA battery can produce about 1,000 milliamp-hours. At 8 milliamps, the ATmega would operate for about 120 hours if it operated constantly. However, the programmer will typically write his/her code so that the CPU is asleep much of the time, allowing it to extend battery life considerably. For example, the mote might sleep for 10 seconds, wake up and check status for a few microseconds, and then go back to sleep.

MICA motes come with 512 kilobytes of flash memory to hold data. They also have a 10-bit A/D converter so that sensor data can be digitized. Separate sensors on a daughter card can connect to the mote. Sensors available include temperature, acceleration, light, sound and magnetic. Advanced sensors for things like GPS signals are under development. The final component of a MICA mote is the radio. It has a range of several hundred feet and can transmit (depending on the radio technology) approximately between 40 and 250 kilo bits per second. When it is off, the radio consumes less than one microamp. When receiving data, it consumes 10 milliamps. When transmitting, it consumes 25 milliamps. Conserving radio power is key to long battery life. *[http://computer.howstuffworks.com/mote4.htm]*

2. Cooperating Objects: Application Visions

In this section, we report a selection of visions for applications of sentient systems that have been constructed by researchers in the field and others. They come from two sources, where further details and full attributions can be found:

EW Study 3.2 M. Pias, G. Coulouris & Embedded Wisents Consortium, 2006, Study 3.2: Visions for Innovative Applications - Version 1, (downloadable from http://www.embedded-wisents.org/studies/studies_wp3.html)

Pister K. Pister UC Berkeley, 2001, sensor networks in 2010, (http://robotics.eecs.berkeley.edu/~pister/SmartDust/)

In the next decade, the majority of goods and even some services sold in the market will be trackable from their production line to the delivery. Sentient systems will track the product throughout its life, sensing or reading data about its producers, the production methods used and the environment. It adds further information to each product including the identity of the main producers with their hourly wages, work required for the production and also any airborne sprays detected during the process. The food industry is expected to benefit from sentient systems in monitoring the quality of food.

Fair trading could then be realised and verified for products produced by people in third world countries to ensure that producers receive fair reward for their labour and investment (see the Validated Fairtrade scenario). To work properly, this scenario ought to have the right type of incentives otherwise entities in the chain can circumvent the validation system (e.g. switching off the sensors). *EW Study 3.2*

Utilities will be differentiated by placing low cost wireless sensors into taps, lights, switches, heating systems and appliances. Utility companies could provide itemised billing and a whole host of value added services, well-being monitoring and remote control that might even allow the utilities to remotely enable/disable selected devices for whatever reason (please see the Smarter Utilities scenario). *EW Study 3.2*

In the next decade, everything you own that is worth more than a few dollars will know that it's yours, and you'll be able to find it whenever you want it. Stealing cars, furniture, stereos, or other valuables will be unusual, because any of your valuables that leave your house will check in on their way out the door, and scream like a troll's magic purse if removed without permission (they may scream at 2.4 GHz rather than in audio). *Pister*

In the next decade, ubiquitous devices will present a reality enhanced with added textual and visual information to assist our daily activities (see the Agnostic Algorithms of Creation). *EW Study 3.2*

In the next decades, people will know more about the personality type of other people through the cooperation of embedded sensory systems in our clothes and other accessories. Our social behaviour in a given situation and context will be profiled (see the Personality Sensors scenario). Our eyes and face expressions will be tracked and understood (see Ambient Intelligence by Collaborative Eye Tracking). People will tend to interact more with other people. *EW Study 3.2*

In the next decade, thousands of square kilometers of geographical area will be supervised and duration of this can be years. Networked sensors will measure vegetation growth and air/water quality (see Pearl sensors) and cooperating objects will obtain localised measurements and cooperate (statistical sampling and data filtering) to create a big picture of natural spaces. Because of the large-scale aspect, natural disasters such as prominent flooding and earthquakes will be anticipated through improved models of the global environment. Authorities will be alerted and actions taken quickly to respond to natural disasters. More sensors will tell accurately what the weather will look like. *EW Study 3.2*

In the next decade, plantation swarms will be monitored individually or as a group and controlled to prevent outbreaks and disastrous economical losses that follow in the trail of, for instance, the desert locust in Africa and western Asia (see the LocuSent scenario). Invasive insects will be controlled in regions where they have no natural predators. *EW Study 3.2*

In the next decade, the management of the population's waste will be efficient and sustainable leading to higher life quality and less costs for the city authorities. Financial incentives will be employed to encourage the correct disposal (see BIN IT! The Intelligent Waste Management System). Carbon emissions and absorption will be measured or estimated in order to charge/ration citizens according to their consumption. Individuals can receive carbon debits for their use of energy and other carbon-emitting activities and carbon credits for 'clean' energy that they generate, for example, by investing in wind farms and for carbon-absorption activities including trees and other vegetation planted or invested in. Carbon debits are converted to a tax on the individual. The direct benefits are increased environmental and public health gains. There is the risk, however,of privacy loss and fraudulent interference with sensor systems (see Zero Carbon City scenario). *EW Study 3.2*

In the next decades, your house and office will be aware of your presence, and even orientation, in a given room. Lighting, heating, and other comforts will be adjusted accordingly. If you and a colleague are looking for a conference room, you will know which is the nearest available . If you're in an unfamiliar building, lighting will guide you, with a ribbon of arrows on the floor or the walls, annotated with the name of the room they are pointing to, and color coded if there are two lost souls whose paths may cross. Sensors are easy to defeat though, so security of these systems is a major roadblock here. *Pister*

In the next decades, million of computers will be embedded in our everyday lives providing ambient intelligence at our house or work. The scenario of Ambient Intelligence by Collaborative Eye Tracking gives some technical insights on subconscious social interactions and indicates directions when other communication is inappropriate. Integration of eye tracking and sentient technology will create a powerful paradigm to control and navigate applications. *EW Study 3.2*

In the next decade, scanning 3 color laser projection systems will be no larger than a grain of rice, and cost under a dollar. They will be in augmented reality displays that appear to others as regular glasses. They will be in laser pointers, turning any wall into an electronic whiteboard. They will be in large arrays on walls, forming a truly staggering 3D display with brightness, contrast, and viewing angle unparalleled by any technology available or predicted today. *Pister*

In the next decades, infants will not die of SIDs, or suffocate, or drown, without an alert being sent to the parents. How will society change when your neighbors pool calls your cell phone to tell you that Johnny is drowning and you're the closest adult that could be located? *Pister*

In the next decade, your car will know the freeway conditions on your favorite route home, not at the level of some traffic announcer telling you that it's slow on I5, but with detail of the instantaneous speed and history of every vehicle between you and your destination, as well as the ones that are likely to get on the freeway, should you choose to look at that detail. Most likely your software will just tell you which route to take, and how many minutes it will take. Your spouse will know too, if you so choose. *Pister*

In the next decades, cars will be aware of dangers and pro-active in making semi-autonomous decisions. Vehicles will cooperate and exchange information to determine and avoid dangerous situations ahead of time. Proactive safety systems will be in place in every car. The cooperation will allow sensors in each vehicle to monitor the environment conditon with in-loco air quality measurements (e.g. nitric oxide, carbon monoxide, etc). The Kyoto protocol will be supported by extensive monitoring of gas emissions - a required task to make our enviroment more sustainable. *EW Study 3.2*

In the next decade, traffic congestion in urban areas will be mitigated by advanced congestion-based charging which will be supported by pervasive distributed traffic monitoring system. A few non-critical applications will emerge allowing people to exchange their favourite audio tune with other vehicles travelling together. The Supportive Road scenario put forward a scenario where sensors installed on the roads assist in various traffic applications including road congestion avoidance and safety of drivers. Significant investiment in technology and infrastructure is required. The cost of instrumenting road infrastrucure may be apportioned by governments and private organisations such as insurance companies for keeping information on drivers driving history. Privacy may be a major concern here. *EW Study 3.2*

In the next decades, technological systems will not decay at the same rate as today. Technology will become sustainable, whereas today we throw them away and purchase new ones. People will re-use technology in a modular way - combining pieces of existing systems. Once sensors and cooperating objects are installed, it will be difficult to replace them. Sensors to measure trees health (see Zero Carbon City) will not be replaced. *EW Study 3.2*

In the next decade, MEMS sensors will be everywhere, and sensing virtually everything. Scavenging power from sunlight, vibration, thermal gradients, and background RF, sensors motes will be immortal, completely self contained, single chip computers with sensing, communication, and power supply built in. Entirely solid state, and with no natural decay processes, they may well survive the human race. Descendants of dolphins may mine them from arctic ice and marvel at the extinct technology. *Pister*

In the next decades, there will be no unanticipated illness. Chronic sensor implants will monitor all of the major circulator systems in the human body, and provide you with early warning of an impending flu, or save your life by catching cancer early enough that it can be completely removed surgically. *Pister*

In the next decades, critical diseases will be diagnosed by means of telemonitoring of individuals with specialised biosensors (some of them will be implanted). Benefits of this will be clear, although short-comings are expected too. Employers can demote employees based on analysis of bio-medical data (bio-sensors and genetics information). *EW Study 3.2*

In the next decade, a speck of dust on each of your fingernails will continuously transmit fingertip motion to your computer. Your computer will understand when you type, point, click, gesture, sculpt, or play air guitar. *Pister*

In the next decades, small sensors embedded in our clothes (e.g. smart fabrics) will sense our physiological signals and movements in order to gather and understand our health conditions. Computers will understand when we perform a physical activity (e.g. walk or run). Enhanced experience in fitness exercises will be achieved with useful feedback systems from tiny computers embedded in sports clothes and equipment. Entertainment systems for audio and video ubiquitous in mobile phones will be the basis for such systems. *UCAM-CL*

Wireless sensors and actuators embedded in smart fabrics will make life much easier for doctors, disable people and patients. Sensors will monitor patients to provide historical data to the diagnosis process. Patients and doctors will be easily located inside hospitals. Biodegradable materials and new biosensors will be available. Energy harvesting from the body heat seems conceivable. *EW Study 3.2*

Physiological signals will be constantly taken from various points of a child's body. This is intended to make sure small children are thermally comfortable and healthy. (see Body area sensor network for small children scenario). *EW Study 3.2*

We request the help of researchers to update the visions in order to identify plausible scenarios and to add social, ethical and legal impact evaluations of them.

3. Questions

Privacy

How do we achieve privacy within a distributed pervasive system of sensing actuating entities? Do people really care about privacy?

For instance, people do seem to care about CCTV systems constantly monitoring them literately anywhere in the UK. On the other hand, in the future data will be stored in large databases, perhaps in the next generations people will be more aware of privacy issues. If the CCTV cameras could immediately recognise who they are and store this information in the database, people would be more concerned.

Someone in the age between 20-25 years old might be turned down in job interviews by companies who simply decide to hire a man instead because of a likely maternity leave. In the medical issue, we may end up legislating against the use of information by employers in their staff promoting decisions. It only takes a high profile case for the legislation to change.

Who can monitor this data (e.g medical records)? Who should have access to it? Gmail is an example of an entity who controls a lot of data about people and it seems that there isn't any specific legislation to control such an access.
If my car communicates with other cars to get and send information about the road traffic conditions, can other vehicles track my whereabouts?

There are two sides for the data privacy issue: technical and social? How do people perceive privacy? Are they willing to trade privacy for useful sensor-based services?

Will ever be possible to have the trade-off between privacy and benefits of technology? Example: collecting medical information and fitness training will be a good thing for an individual. But this is likely to be disclosed to my employer, for example. But since it's important to my health, I will allow the disclosure of this information. For example, not to give an employer access to your medical data is as bad as giving him information about diseases.

Digital Divide

Will the use of distributed sensor systems in applications accentuate the problem of digital divide? Some of the visions may reduce the division if the society can adapt to the technology. Can you just introduce technology in these societies?

- low-cost systems
- educational requirement: is the system too complicated for a normal user (see below)?
- The educational problem for using technology maybe can change with the 100 dollars laptop?

Usability

Complexity is believed to arise from the distributed nature of the system. The Ambient Intelligence scenario, for instance, allows the detailed management of an environment - but how long will this take? Will that be an hour when I come to a new hotel room? What about people who are not used to the technology? Will it be so easy that even a child or elderly people can still use it? Or would some people be excluded from the technology (see Digital divide)? A couple of related issues:

- implication for such a system design in hiding this complexity
- how's the user exposed to the system? Should they have a representative (proxy system) that hides/handles the underlying complexity?
- Some scenarios take too much control of the user. For instance, pro-active vehicles that take (semi-)autonomous decisions. Many people drive a car because of the driving fun. The question is how much control are people loosing?
- technical outcome: guidelines on the design of these systems such that they can be easily understood. Systems should provide sensor errors for reliability.

Roles of Government and Private Sector

What's the role of the government and private sector in offering such services? For instance, medical applications may still be partially provided by the government in some countries. Who are the sponsors of such services?

Legislation can be done to change the design of systems. But we do not have the right type of legislation.

- What's the involvement of government and private sector in legislation, law enforcement, regulation (eg. UK Ofcom, Oftel)? What's the policy on data availability to interested/suitable parties? How should issues like data protection be dealt with?
- For instance, Germany is very strong on privacy. They have something like small databases, where the flow of data among them is the one controlled by the government.
- To write an application, you need data. How does the sharing of information work between countries? How much information of myself is delivered to other countries? For instance, UK send 54 entries of UK passport data to the US.
- Medical records are owned by insurance companies in the US.

Ethical issues

What's ethics in this context?

Moral principles for equal treatment among businesses and people (level playing field). See cases such as Apple/iTunes being judged by the European Commission.

The Personality Sensors scenario (EW Study 3.2) is a good example of extreme privacy invasion. There are basic feelings and actions that human beings should have the freedom to exercise. For example, sometimes people want to pretend doing things for whatever reasons. This may be impossible to do with such a monitoring system. People are degraded to things which are constantly monitored - even their deepest feelings. Should we push the technology that far?

Big picture

What can we do with these visions? Are they simply visions or do they guide our research in any way?

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