From Smart Devices to Smart Everyday Objects*
(Extended Abstract)

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Abstract

Microelectronic devices are becoming so small and inexpensive that they can soon be embedded in almost everything, rendering everyday objects "smart". These smart objects may communicate by wireless means and form spontaneous networks, giving rise to a world-wide distributed system several orders of magnitude larger than today's Internet. The prospects of a world of smart things that virtually talk to each other are fascinating, leading to many new applications and opportunities. In our presentation we will summarize the technology trends behind the ubiquitous computing idea and then discuss means to render everyday objects smart. We will also mention some non-technical issues such as privacy aspects.

1. Technology Trends

The driving force behind the continuing technological progress in the field of ubiquitous computing is the long-term trend in microelectronics: Moore's Law, drawn up in the late 1960s by Gordon Moore, and which states that the power of microprocessors doubles about every 18 months, has held true with astonishing accuracy and consistency. A similarly high increase in cost-efficiency can be observed for some other technological parameters such as storage capacity and communications bandwidth. This trend, which will continue for at least 10 years, means that computer processors and storage components will become much more powerful, smaller, and cheaper in the future, so that there will be an almost unlimited supply of them.

It is not only microelectronics that is contributing to the ubiquitous nature of computers, and simultaneously to their disappearance. Recent developments in the field of materials science could give computers of the future a completely different shape, or even mean that computers will no longer be recognizable as such because they will completely blend into their surroundings. Amongst other things, light-emitting polymers ("illuminating plastic") should be mentioned in this context. This innovation enables displays to be created from thin, highly flexible plastic foils. Research is also taking place into "electronic ink" and "smart paper," which will enable pen and paper to become fully functional interactive and truly mobile input/output media, with a tried and tested user interface. If paper can be transformed into a computer or, conversely, computers into paper, the practical significance of such a development cannot be overestimated.

Even more important are the results of microsystem technology and nanotechnology. These could lead to tiny sensors, for example, which could record a wide variety of environmental parameters. More recent sensors are able not only to react to light, acceleration, temperature etc., but also to analyze gases and liquids or generally preprocess sensor input and therefore recognize certain patterns. One interesting development in this regard is radio sensors that can report their readings within a few meters distance without an explicit energy supply – such sensors obtain the necessary energy from the environment or directly from the measuring process itself.

Electronic labels (so-called "smart labels" or RFID tags) also operate without their own energy supply. Depending on their construction, these are less than a square millimeter in area and thinner than a piece of paper. In the form of flexible self-adhesive labels, they cost between 0.10 euro and 1 euro each, with prices falling all the time. In some ways, this is a further development of the well-known anti-theft technology involving security gates in department stores. However, this is not just about the binary information "paid/ stolen"; within milliseconds, several hundred characters could be read and written "wirelessly" up to a distance of about two meters.

What is interesting about such remote-inquiry electronic markers is that they enable objects to be clearly identified and recognized, and therefore linked in real time to an associated data record held on the Internet or in a remote database. This ultimately means that specific data can be associated with any kind of object. If everyday objects can be uniquely identified from a distance and furnished with information, this opens up application possibilities that go far beyond the original purpose of automated warehousing.

Significant advances have also been made in the field of wireless communications. Especially interesting are recent short-range communications technologies that require very little energy, making it possible to produce designs that are much smaller and cheaper than today's mobile phones. Communications modules of this type are currently about the size of half a matchbox. Further integration will soon result in even smaller dimensions; the price is only a few euros, and is expected to fall rapidly. Intensive research is also being carried out on improved options for indicating the position of mobile objects. As well as increased accuracy (currently around ten meters for the GPS system), the aim is also to make the devices much smaller.

2. Smart Objects

If you summarize the technology trends and developments mentioned above it becomes clear that the technological basis for a strange new world has been created: everyday objects

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that are in some respects "smart," and with which we can even communicate under certain circumstances.

For implementing such communication with things, imagine everyday objects such as furniture, packaged food, medication, clothing, or toys being equipped with an electronic label containing a specific Internet address as digital information. If you can then read this Internet address with a portable device just by pointing it at the object, this device can, independently and with no further assistance from the object in question, access and display the associated information from the Internet via the mobile phone network.

The user has the impression that the object itself has "transmitted" the information, although in fact it has been supplied by the display device via the Internet. The information could be, for example, operating instructions, or cooking instructions for a ready-to-serve meal, or the information leaflet for medication. The details of what is displayed may depend on the "context" – for example, whether the user is a good customer and paid a lot of money for the product, whether he is over 18 years of age, what language he speaks, or his current location, – but also maybe whether he has paid his taxes on time…

In the future, this display device might even be a piece of electronic paper or a special pair of spectacles used in conjunction with a wireless pointing device. Furthermore, it will not only be human users who are interested in the additional information on objects, but also other "smart" objects. A trash can, for example, may be very curious about the recycling characteristics of its contents, and a medicine cabinet may be concerned about its medication's possible side effects and best-before date.

The foreseeable technological developments will therefore add an additional new quality to everyday objects – these might be able not only to communicate with people and other "smart" objects, but also to discover where they are, which other objects are in their vicinity, and what has happened to them in the past, for example. Objects and devices could thus behave in a context-sensitive manner and appear to be "smart," without actually being "intelligent."

3. Social and Political Issues

If information is attached to "electronically enhanced" objects, in other words physical objects effectively become media, who can or should determine their content? If objects are equipped with information or a means of identification that enables a personal digital assistant, maybe located in a pair of spectacles, to explain the world ("Computer, what's that?"), can real-world objects then be interpreted by the manufacturer of the smart spectacles in any way he likes? World views have often been the cause of disputes. Given a situation where cyberspace is approaching reality, partially overlaying or even merging into it, there are some things we must be prepared for – ultimately, some political questions of a fairly explosive nature must be asked.

Many other questions are generated by the "informatization" of the world, only a few of which are touched on here: if many objects can only function properly if they have access to the Internet or a similar infrastructure, this results in a far-reaching dependency on those systems and their underlying technology. If these fail, for whatever reason – design errors, material defects, sabotage, overloading, natural disasters etc. – then it could have catastrophic consequences on a global scale. If the correct functioning of the information technology infrastructure is vitally important to society and individuals, not only do we have to have appropriate security mechanisms, but the systems have to be designed from the outset with this in mind.

Another set of questions relates to the socially acceptable design of the technologies outlined and their applications. Using the most important functions should, of course, be simple and straightforward in order to prevent a "digital divide" in society reaching deep into our everyday lives. It is equally important to bear in mind that cartels, monopolies, or power concentrations could develop due to the expansion of the Internet into our everyday world, and how this could be moderated in a democratic society.

Last but not least, we should pay particular attention to the protection of privacy. Whereas the Web surveillance of a person has previously been clearly limited to computer usage, there will often be no distinction between "online" and "offline" in a world full of smart everyday objects. As a result, this ubiquitous data will become more valuable. Whereas until now only a relatively limited view of a person could be obtained by rummaging around in data, a much more comprehensive picture can be painted of this person and his day-to-day behavior in the ubiquitous vision.

It seems clear that, without effective data protection measures, the technology of ubiquitous computing could be used to create a surveillance infrastructure that would render ineffective many existing laws and privacy protection mechanisms. Therefore basic legal considerations and new technical approaches, as well as much social and organizational effort, will be required in order to prevent this brave new world of smart, interconnected objects becoming an Orwellian nightmare where Big Brother will be joined by lots of little brothers.

4. Consequences?

The technology trend is pointing quite clearly towards a continued informatization of the world – for example through embedding more and more processors into everyday objects and through the increasing connection of all kinds of devices to the Internet.

If technical progress means more and more everyday objects are becoming "smart" and therefore behaving unconventionally towards humans, then this will ultimately lead to a totally different world from that to which we are accustomed. The changes won't happen overnight; instead, this process will be more of a creeping revolution. Taken to its logical conclusion, a world which is literally permeated by information technology will sooner or later bring with it major social and economic consequences, adding a political dimension to ubiquitous computing and the associated future direction of the Internet.

Dynamic development in microelectronics and computer science is continuing unabated, and its effects are increasingly influencing everyday life. It is therefore clear that the 21st century will be characterized less by major technological structures such as moon colonies, underwater cities, and atomic cars (as suggested by earlier popular futurologists), than by the application of tiny, practically invisible technology that is therefore easy to replicate and distribute.

It is worth thinking about the economic and social prospects and the social and legal consequences this all could have!