Chapter 1

Ambient Intelligence: Science or Fad?

1.1. Ambient intelligence: still young at 20 years

Ambient intelligence concerns the use of emerging technologies for computing, sensing, displaying, communicating, and interacting to provide services in ordinary human environments. Different facets of this problem have been addressed under a variety of names, including ubiquitous computing, pervasive computing, disappearing computing, and internet of things. Whatever the name, the field is defined by its core aim: to provide services and devices that can adapt to individuals' needs and the social context. This includes diverse applications such as aiding people to adopt more energy-efficient lifestyles, improving the quality of life for the disabled, helping senior citizens remain independent, and aiding families with services for security, entertainment, and with tools for managing the cost of living.

Comment [E1]: Handicapped is used in the U .S. but is deemed an almost offensive term in the U.K.

Ambient intelligence is not a new concept. In 1988, only a few years after the introduction of the Macintosh computer and the French Minitel, Mark Weiser [WEI 91] identified the principal challenges under the name "ubiquitous computing". Weiser stated that technologies centered around daily activities would inevitably fade from view while becoming an imperceptible but ubiquitous component of ordinary life. Weiser contended that, although increasingly widespread, personal computing was the first of many steps in this process.

During 1990s, researchers at IBM proposed the term *pervasive computing*. With this approach, emphasis was placed on technical challenges such as developing hardware and software techniques necessary for bringing computing into ordinary

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human environments. At around the same time, the European IST Advisory Group (ISTAG) put forth its vision of *ambient intelligence* [STA 03], leading to the creation of the *Disappearing Computer* program within the European Union's Fifth Framework Programme for Research and Technological Development. This period also saw the emergence of the Philips Research "Vision of the Future" [PHI 96] program and the creation of the Philips *HomeLab* designed to stimulate creativity through experimentation, to explore new opportunities for combining different technologies, to identify the socio-cultural significance of these innovations, and to make these concepts tangible, useful, and accessible to all.

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During this period, a number of conferences, workshops, and journals were organized. The Ubicomp[1] conference, created from the mobile computing and smart environment communities, focuses primarily on user experience. The IEEE Pervasive and Percom[2] conferences have arisen from the "distributed computing" community, to focus on the challenges and technical solutions in distributed systems and networks. Within Europe, the EUSAI (*European Symposium on Ambient Intelligence*), later renamed AmI – *Ambient Intelligence*[3], was launched in 2002 with support from Philips Research. A scientific community has also emerged to address the topic of *context-aware computing*. While the concept of context is not new in computer science (nor in other fields), bringing computing into ordinary human environments raises a rich, new set of problems. Other aspects of this problem have also been explored, including collectives of artificial agents for ambient intelligence[4], the internet of things[5] and *Machine-to-Machine* (M2M), communicating objects, mobile computing, wearable computing[6], social computing, intelligent habitats and environments (towns, housing, roads, transport, architecture, etc.), *tangible and embedded interaction*[7], affective computing, human–robot interaction[8], and embedded systems.

In summary, Weiser's vision has been used to justify and define new research within an extremely diverse collection of fields. It is increasingly evident that such research cannot be carried out in isolation. Research in this area is fundamentally multi-disciplinary, requiring the assimilation of problems and concepts from a variety of specializations. From our perspective, in its current state, ambient intelligence is only the latest stage in the evolution of informatics as a scientific discipline. In the following chapters, we will provide an overview of the field in its current state.

1 www.ubicomp.org/. Ubicomp, created in 2001 as part of HUC 99 and HUC2k (*Handheld and Ubiquitous Computing*).
2 http://pervasive2008.org/, www.percom.org/
3 www.ami-07.org/
4 *Workshop Artificial Societies for Ambient Intelligence*, http://asami07.cs.rhul.ac.uk/
5 www.internet-of-things-2008.org
6 www.iswc.net/
7 www.tei-conf.org/
8 http://hri2007.org/

1.2. A step forward in the evolution of informatics

Waldner [WAL 07] has summarized the evolution of computing by charting the continual miniaturization of electronic components, the spectacular increase in information processing and memory capacity, the omnipresence of networks, and the reduced costs of hardware production. In this approach, development of resources drives changes in the nature of computing. We carry out a parallel analysis using the changes in resources to predict developments in research. We will focus on three areas in particular: the availability of computing power as a critical resource, the individual as the focus of attention, and the physical and social worlds in relation to the digital world.

1.2.1. *Fifty years ago: the computer as an isolated critical resource*

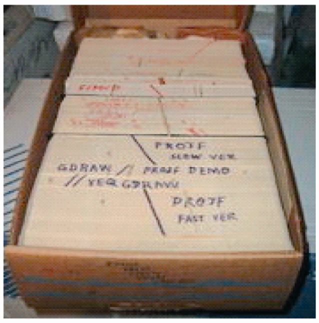
Fifty years ago, computing machines were far too expensive and it was cumbersome to even imagine them being used in everyday homes, as shown in Figure 1.1. Access to computing was restricted to specialist operators and programs were carefully encoded on perforated “punch cards”. Computing results were printed on reams of special fan-folded paper, with punch cards, magnetic tapes, and removable disks used for long-term storage. At best, computing machines had around a megabyte of central memory. Computing networks and packet switching technologies for communications were an avant-garde area of research[9].

Comment [SN3]: AU : Should « data-gramme » in footnote 9 read « datagramme ».

During this period, the user was a programmer specialized in scientific computing, statistics, and management applications (such as payroll). Programs were entered by a dedicated operator, who monitored the use of resources using a specific control language (*Job Control Language, JCL*). Any program that consumed more memory or printed more pages than what was anticipated was automatically terminated by the operating system and the programmer was responsible for declaring the required computing resources. The skill lay in being able to produce a correct program “from the start” using such techniques as memory overlays so that the program ran using the available central memory. The concept of virtual memory therefore became a subject of research. With the emergence of time-sharing systems, punching cards gradually disappeared in favor of personal terminals. These were initially built using TELEX terminals or “teletypes” that were eventually replaced by alphanumerical screens. Bit-mapped displays; however, were judged far too expensive because of memory costs.

9 Louis Pouzin, then a researcher at IRIA (later the INRIA), and his team were responsible for the invention of packet-switching communications. Their data-gramme technique was used within the Cyclade project, with a first network composed of hubs at IRIA, the CII, and the IMAG in France. The first demonstration took place in 1973.

a)



b)

c)

Figure 1.1. *a) A computer for all, the IBM 360, carrying out batch processing (at night) and time sharing (by day). b) A box of cards consisting of what can only be described as a very real program! The program's procedures are given by lines and names written in pencil. c) The Cyclade hub at IMAG (Grenoble, France)*

Comment [E4]: Palpable doesn't really fit this context

The optimization of resources and "virtualization" (found today in *cloud computing*) remained the driving force in computing until researchers (North American, for the most part) turned their attention to the human component of the human–machine system. Indeed, as the cost of computing machines decreased, labor costs increasingly dominated the cost of computing.

1.2.2. *Thirty years ago: the user at the center of design*

The first CHI (*Computer–Human Interaction*) conference of the ACM[10] was organized in 1983. This conference, parallel with the first appearance of personal computers, marked the start of the pursuit of developing useful and usable applications for users. The user was no longer an experienced programmer, but a non-specialist using the computer as a tool for professional activities. An application was considered useful if it provided the functions expected by its user where it was said to ensure "functional conformity". A program was considered usable if the user interface (UI), which gives access to applicative functions, conformed to the cognitive, motor, and sensory capabilities of the target user. This is known as "interactional conformity".

Computer scientists, whether academic or industrial, have, for too long, underestimated the cognitive dimension of the human user. Not only should a program provide her/him with the expected functions, but it should also provide access to these functions in a manner that respects the user's working procedures and abilities to perceive and reason. Not only should this arrangement conform to human thought processes, but it should also be made explicit to the user interface. It was only in 2010 that computing professionals recognized that the design of the human–computer interface was not simply a question of aesthetics, but an issue of user–computer conformity. By contributing concepts, theories, and methods, cognitive psychology and ergonomics have played an important role in addressing this problem.

Comment [E5]: Thought plans doesn't provide much meaning here.

Methods used for user-interface design include participative and contextual design [BEY 06], iterative design (which is well adapted to the practice of "agile" programming), and scenario-based design [ROS 02]. These user-focused methods have given rise to a number of formalisms such as CLG [CAR 83], TAG [PAY 86] and ETAG [TAU 90], UAN [HAR 92], and CTT [PAT 97] to model the thought processes of target users in the form of task models (a tree structure with aims and sub-aims linked by composition operators or temporal relations). Such models go

Comment [CE6]: AU : Please check "[BEY 06]" has not been listed in Bibliography.

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10 CHI'83 followed the first workshop on the subject in Gaithersburg in March 1982, entitled *Human Factors in Computer Systems*.

beyond a simple *Use Case UML*, to specify the functional requirements and task sequences from a user perspective.

Example theories include the Model Human Processor [CAR 83] and Norman's direct correspondence principle [NOR 86], which state that there should be a clear correspondence between the psychological variables encountered by the user mentally and computing objects, as well as a direct correspondence between the internal state of the system in relation to the user and its representation by the user interface. These theories are, or at least should be, part of the toolkit of any competent computer scientist.

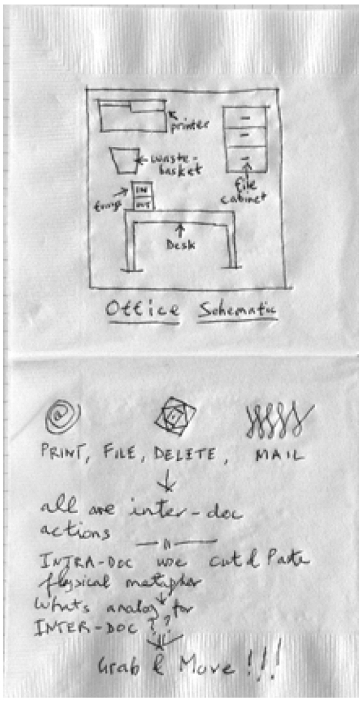

Figure 1.2. *In search of a graphic representation of the desktop metaphor, an idea already being used in the 1970s: sketch produced by Tim Mott at the end of the 1970s (taken from [MOG 06], p. 52). It shows the first generic commands: "Print, File, Delete, Mail, Cut and Paste, Grab and Move"*

Two complementary representations compete in modern user interface technologies: linguistic representations (including natural and artificial languages, as in the Unix Shell), and metaphorical interfaces based on the real world, such as with the desktop environment in modern personal computers. The WIMP (Window, Icon, Menu, Pointing) interaction paradigm, made possible by modern user interface toolkits, is a modern manifestation of the impact of the direct correspondence principle and its theoretical foundation in the Model Human Processor.

Ergonomics and cognitive psychology have also had a major impact on evaluation methods by suggesting protocols and metrics to assess human performance such as task performance duration and error rates. Although these methods are well elaborated and documented, in practice software developers are still reluctant to integrate them into the software development process or, if they do so, evaluation is performed too late in the development process to have a real impact on system usability.

At the same time, the Internet, wireless networks, the web (which celebrated its 20th year in 2010), and web browsers are now used by nearly everyone. From a single computer, we have passed on to an era of "instantly connected" computing.

1.2.3. *The past decade: combining physical, social, and digital worlds*

In contrast to the previous era of computing, in which the desktop computer was the archetype, new technologies increasingly enable mobility and integration of digital systems into the ordinary physical objects. Ordinary objects are increasingly being fitted with technologies for computing, communications, sensing, actuation, and interaction. These devices are increasingly networked, forming a complex infrastructure creating a plethora of new services. Figure 1.3 demonstrates this trend in four images.

The examples in Figure 1.3 lead to three immediate observations: the polymorphism of the computer that weaves, both literally and figuratively, the digital into our everyday activities, from the useful to the pointless. In other words, the physical world has become a resource that can be shaped and (re)constructed by the individual, not only to be more efficient but also to improve the quality of our life, pleasure, and experiences. This has resulted in the emergence of "funology" (i.e. the science of having fun) [BLY 06]. The user is no longer a subject limited to "consuming" applications imposed by the market, but can now take on the role of actor such as "DIYers" who construct and improve their living space using off-the-shelf components. Even the individual's ability to create has itself been surpassed by a new phenomenon, social networking [KRA 10], made possible by the universality of the Internet.

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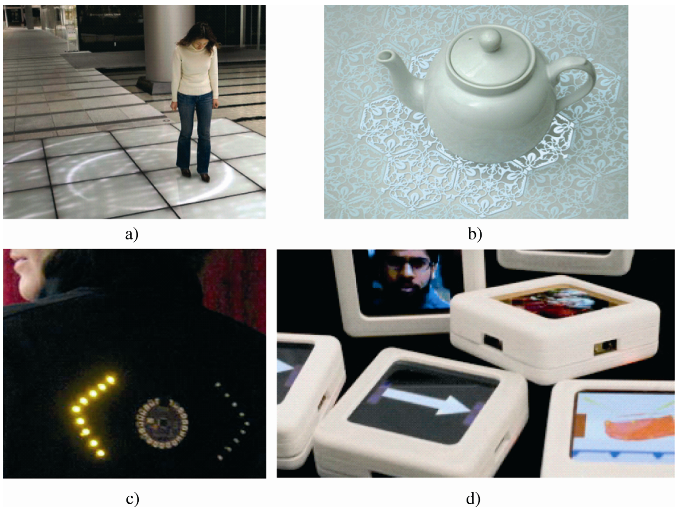

Figure 1.3. *Examples of services and devices: a) a light projection on a floor; b) the "history tablecloth" [GAV 06] that traces the movement of objects on it with a glowing ring gradually forming around the object and then progressively disappearing when the object is moved; c) an Arduino LilyPad application: personalization of a jacket fitted with an indicator showing changes in direction [BUE 08]; d) siftables that can be assembled in different ways to create new applications [MER 07]*

The social dimension of computing has in fact been an area of interest since the end of the 1980s[11]. The initial aim was to develop models, theories, and digital systems, called groupware, designed to improve group activities in terms of production, coordination, and communication. With the web, the change in scale has led to new uses. Every individual, collective, and community can now collect information, relate it, produce new information, and in turn share it with the rest of the world. Schneiderman [SHN 98] refers to this phenomenon with the mantra collect–relate–create–donate. Wikipedia is the most obvious example of a collective construction of encyclopedic knowledge. Other examples include the *Google Image Labeler,* which indexes images and *TopCoder* for thesocial production programs. The digital software stores, inspired by the Apple *App Store,* have led to changes in the software development process and have triggered new economic models and opportunities.

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11 The first ACM conference on the subject *Computer Supported Collaborative Work* (CSCW) took place in 1987.

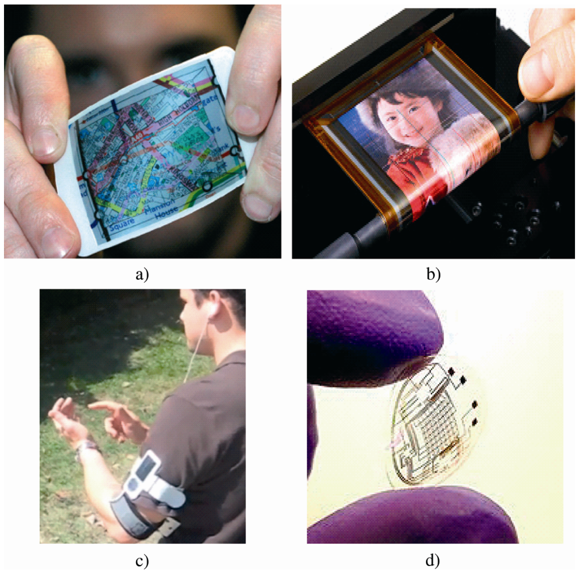

Figure 1.4. *Examples of devices integrating new ICT capabilities, device nanotechnology. a) A Gummi prototype (Sony), a bendable computer. Navigation across the screen is achieved by bending the surface [SCH 04]. b) A bendable OLED screen (introduced by Sony to the SID, Society for Information Display, 2010). c) Skinput applied to a music device: the finger pressure applied to the surface skin is sensed by an armband fitted with sensors [HAR 10]. d) A soft lens fitted with a circuit is placed directly on the surface of the eye*

Despite the constant avalanche of information, the human factor remains constant. The user remains a genuine bottleneck, and requires the invention of new interaction techniques to accommodate a growing flood of information. In this sense, gestural interaction and inertial measurement units in mobile telephones, physical interaction and motion sensing devices using real time 3D reconstruction such as Microsoft's Kinect muscular interaction, multipoint clear screens, and bendable objects are all noteworthy examples, as illustrated in Figure 1.4. These examples show that innovation requires the unprecedented cooperation ICT (information and communication technologies) and ICT–HSS (human and social sciences), from nanotechnologies to software engineering, and from the individual to all levels of society.

This brief overview indicates that we are entering into an era of radical change, which, in turn, raises a number of new challenges.

1.3. Extreme challenges

The scientific, technical, and ethical challenges posed by ambient intelligence have been examined by a number of reports [COU 08, STA 03, PUN 05, WAL 07], specialized journals, conference sessions, and workshops. Research problems are generally organized as a stack of sub-domains shown in Figure 1.5. Three key challenges facing the field cover all of these domains: scalability, heterogeneity, and dynamic adaptation. These three challenges arise from the fact that ambient intelligence pushes computing to its limits.

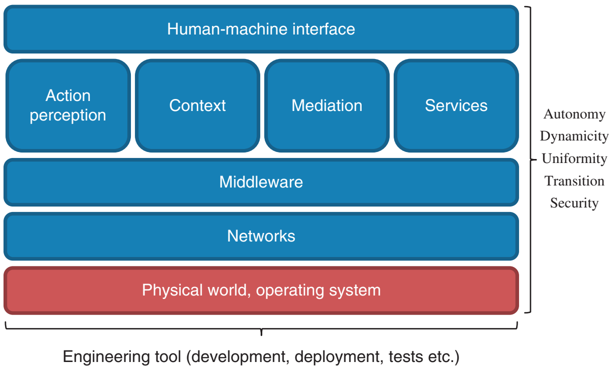

Figure 1.5. *Architectural overview of research themes in ambient intelligence*

1.3.1. *Multi-scale*

Changes in scale can lead to unexpected phenomena. For ambient intelligence, the challenge of scale results from the massive interconnection of a very large number of ordinary devices augmented with computing, sensing, actuation, and interaction. The challenge lies in managing the co-existence of services and systems made possible by the interconnection of devices over a wide range of scales, from personal body-area networks based on wearable computing to city-wide and planetary scale systems. This challenge is greatly complicated by the heterogeneity resulting in part from technical challenges at each scale.

1.3.2. *Heterogeneity*

At any scale, a variety of possible solutions may be used to address competing technical challenges. In addition, each scale raises its own unique challenges.

Integrating devices with different programming frameworks can prove extremely complex. Integrating across scales makes integration even more challenging. While the field has seen concerted movements toward uniform standards, too often such efforts have been carried out in a vacuum, resulting in isolated silos of interoperability. In such environments, dynamic adaptation is therefore impossible.

1.3.3. *Dynamic adaptation*

Dynamic adaptation, with its multiple facets, approaches, and solutions has been examined for over a number of years in a variety of fields and research specialties (see Figure 1.5). For some researchers, the ultimate aim is an autonomous, safe, and secure system that does not require human intervention. For others, however, the user should remain involved if desired. It is therefore necessary that "autonomous software compositions" provide users with interaction points at every level of abstraction in order to control the adaptation process if needed.

These problems have only been addressed in a piecemeal manner to date, constrained by the restricted view of a single specialty or area of application. It is therefore necessary to develop new technologies that are generic, enabling, and malleable. These technologies should be generic so that they can be applied to all contexts and allow the rapid development of services by professionals. Malleability is needed so that they can be organized and changed by the end user, as required, in a non-uniform, constrained, dynamic, and multi-scale world[12]. This is not a question of creating a uniform and standardized world, but respecting diversity and the unexpected. For our part, the "malleable" constitutes a major challenge in coming years because we are placing the means to program (unconsciously), develop programs (without endangering life or property), and share them with others (like the *App Store* over social networks) in the hands of the end user.

1.4. Conclusion

In view of the above, is ambient intelligence a fad or an emerging scientific discipline? In line with Thomas Kuhn's definition, our analysis suggests that ambient intelligence does not have the status of a discipline[13] yet. If a scientific community is said to be organized around symposia and specialized reviews, it does not necessarily entail sharing a standard set of concepts and methods. Ambient intelligence is still "application driven" for its socio-economic benefits.

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12 What Bell and Dourish call, in less technical terms, *a messy fragmented world* [BEL 06].
13 www.electroniques.biz/pdf/EIH200312110541038.pdf (in French).

For the foreseeable future, we believe that the response will be a progressive evolution of research processes and a collaborative approach toward a concrete and lasting integrated strategy. Indeed, each discipline and specialty progress by sharing information with other disciplines (it is a multi-disciplinary alliance that drives "collaborative" research projects) or new shared knowledge will arise from the integration of several disciplines and specialties, a pluri-disciplinary convergence, which is a challenge in itself. Human–machine interaction is a perfect example of the convergence between psychology, sociology, and computing. However, it has taken more than 20 years for it to be recognized as a discipline in its own right. It is therefore a question of time. Nevertheless, let us remember Alan Kay's well-known quote, "the best way to predict the future is to invent it!".

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