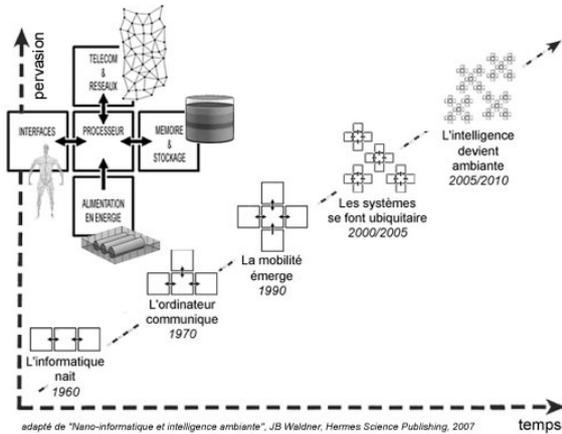# Ambient intelligence

An (expected) evolution of computing from 1960–2010.

In computing, **ambient intelligence** (**AmI**) refers to electronic environments that are sensitive and responsive to the presence of people. Ambient intelligence is a vision on the future of consumer electronics, telecommunications and computing that was originally developed in the late 1990s for the time frame 2010–2020. In an ambient intelligence world, devices work in concert to support people in carrying out their everyday life activities, tasks and rituals in an easy, natural way using information and intelligence that is hidden in the network connecting these devices (*see Internet of Things*). As these devices grow smaller, more connected and more integrated into our environment, the technology disappears into our surroundings until only the user interface remains perceivable by users.

The ambient intelligence paradigm builds upon pervasive computing, ubiquitous computing, profiling, context awareness, and human-centric computer interaction design and is characterized by systems and technologies that are (Zelkha & Epstein 1998; Aarts, Harwig & Schuurmans 2001):

- **embedded**: many networked devices are integrated into the environment

- **context aware**: these devices can recognize you and your situational context

- **personalized**: they can be tailored to your needs

- **adaptive**: they can change in response to you

- **anticipatory**: they can anticipate your desires without conscious mediation.

Ambient intelligence is closely related to the long term vision of an intelligent service system in which technologies are able to automate a platform embedding the required devices for powering context aware, personalized, adaptive and anticipatory services. Where in other media environment the interface is clearly distinct, in an ubiquitous environment 'content' differs. Artur Lugmayr defined such a smart environment by describing it as ambient media. It is constituted of the communication of information in ubiquitous and pervasive environments. The concept of ambient media relates to ambient media form, ambient media content, and ambient media technology. Its principles have been established by Artur Lugmayr and are manifestation, morphing, intelligence, and experience.[1][2]

A typical context of ambient intelligence environment is a Home environment (Bieliková & Krajcovic 2001).

1 Overview

More and more people make decisions based on the effect their actions will have on their own inner, mental world. This experience-driven way of acting is a change from the past when people were primarily concerned about the use value of products and services, and is the basis for the experience economy. Ambient intelligence addresses this shift in existential view by emphasizing people and user experience.

The interest in user experience also grew in importance in the late 1990s because of the overload of products and services in the information society that were difficult to understand and hard to use. A strong call emerged to design things from a user's point of view. Ambient intelligence is influenced by user-centered design where the user is placed in the center of the design activity and asked to give feedback through specific user evaluations and tests to improve the design or even co-create the design together with the designer (participatory design) or with other users (end-user development).

In order for AmI to become a reality a number of key technologies are required:

- Unobtrusive hardware (Miniaturization, Nanotechnology, smart devices, sensors etc.)

- Seamless mobile/fixed communication and computing infrastructure (interoperability, wired and

wireless networks, service-oriented architecture, semantic web etc.)

- Dynamic and massively distributed device networks, which are easy to control and program (e.g. service discovery, auto-configuration, end-user programmable devices and systems etc.)

- Human-centric computer interfaces (intelligent agents, multimodal interaction, context awareness etc.)

- Dependable and secure systems and devices (self-testing and self repairing software, privacy ensuring technology etc.)

2   History

In 1998, the board of management of Philips commissioned a series of presentations and internal workshops, organized by Eli Zelkha and Brian Epstein of Palo Alto Ventures (who, with Simon Birrell, coined the name 'Ambient Intelligence') to investigate different scenarios that would transform the high-volume consumer electronic industry from the current "fragmented with features" world into a world in 2020 where user-friendly devices support ubiquitous information, communication and entertainment. While developing the Ambient Intelligence concept, Palo Alto Ventures created the keynote address for Roel Pieper of Philips for the Digital Living Room Conference, 1998. The group included Eli Zelkha, Brian Epstein, Simon Birrell, Doug Randall, and Clark Dodsworth. In the years after, these developments grew more mature. In 1999, Philips joined the Oxygen alliance, an international consortium of industrial partners within the context of the MIT Oxygen project,[3] aimed at developing technology for the computer of the 21st century. In 2000, plans were made to construct a feasibility and usability facility dedicated to Ambient Intelligence. This HomeLab [4] officially opened on 24 April 2002.

Along with the development of the vision at Philips, a number of parallel initiatives started to explore ambient intelligence in more detail. Following the advice of the Information Society and Technology Advisory Group (ISTAG), the European Commission used the vision for the launch of their sixth framework (FP6) in Information, Society and Technology (IST), with a subsidiary budget of 3.7 billion euros. The European Commission played a crucial role in the further development of the AmI vision. As a result of many initiatives the AmI vision gained traction. During the past few years several major initiatives have been started. Fraunhofer Society started several activities in a variety of domains including multimedia, microsystems design and augmented spaces. MIT started an Ambient Intelligence research group at their Media Lab.[5] Several more research projects started in a variety of countries such as USA, Canada, Spain, France and the

Netherlands. In 2004, the first European symposium on Ambient Intelligence (EUSAI) was held and many other conferences have been held that address special topics in AmI.

3   Example scenario

Ellen returns home after a long day's work. At the front door she is recognized by an intelligent surveillance camera, the door alarm is switched off, and the door unlocks and opens. When she enters the hall the house map indicates that her husband Peter is at an art fair in Paris, and that her daughter Charlotte is in the children's playroom, where she is playing with an interactive screen. The remote children surveillance service is notified that she is at home, and subsequently the on-line connection is switched off. When she enters the kitchen the family memo frame lights up to indicate that there are new messages. The shopping list that has been composed needs confirmation before it is sent to the supermarket for delivery. There is also a message notifying that the home information system has found new information on the semantic Web about economic holiday cottages with sea sight in Spain. She briefly connects to the playroom to say hello to Charlotte, and her video picture automatically appears on the flat screen that is currently used by Charlotte. Next, she connects to Peter at the art fair in Paris. He shows her through his contact lens camera some of the sculptures he intends to buy, and she confirms his choice. In the mean time she selects one of the displayed menus that indicate what can be prepared with the food that is currently available from the pantry and the refrigerator. Next, she switches to the video on demand channel to watch the latest news program. Through the 'follow me' she switches over to the flat screen in the bedroom where she is going to have her personalized workout session. Later that evening, after Peter has returned home, they are chatting with a friend in the living room with their personalized ambient lighting switched on. They watch the virtual presenter that informs them about the programs and the information that have been recorded by the home storage server earlier that day.

4   Criticism

As far as dissemination of information on personal presence is out of control, ambient intelligence vision is subject of criticism [e.g. David Wright, Serge Gutwirth, Michael Friedewald et al., Safeguards in a World of Ambient Intelligence, Springer, Dordrecht, 2008]. Any immersive, personalized, context-aware and anticipatory characteristics brings up societal, political and cultural concerns about the loss of privacy, as soon as any third party gets control over the respective information and status data.

However, any disabled person may welcome the implicit information presentation and access to improve support and individual assistance. Hence there must be a distinction between solutions for personal improvement and any other purpose.

Power concentration in large organizations, a decreasingly private, fragmented society and hyperreal environments where the virtual is indistinguishable from the real (hyperreality) are the main topics of critics. Several research groups and communities are investigating the socioeconomic, political and cultural aspects of ambient intelligence. New thinking on Ambient Intelligence distances itself therefore from some of the original characteristics such as adaptive and anticipatory behaviour and emphasizes empowerment and participation to place control in the hands of people instead of organizations.

As long as there is no legal obligation to open one's individual status data to any access by third party, the degree of freedom<unclear> still is to stay away of any such solutions and all services with inherited methods of that type.

5   Social and political aspects

The ISTAG advisory group suggests that the following characteristics will permit the societal acceptance of ambient intelligence:

- AmI should facilitate human contact.

- AmI should be oriented towards community and cultural enhancement.

- AmI should help to build knowledge and skills for work, better quality of work, citizenship and consumer choice.

- AmI should inspire trust and confidence.

- AmI should be consistent with long term sustainability — personal, societal and environmental — and with lifelong learning.

- AmI should be made easy to live with and controllable by ordinary people.

6   Business models

The ISTAG group acknowledges the following entry points to AmI business landscape:

- Initial premium value niche markets in industrial, commercial or public applications where enhanced interfaces are needed to support human performance in fast moving or delicate situations.

- Start-up and spin-off opportunities from identifying potential service requirements and putting the services together that meet these new needs.

- High access-low entry cost based on a loss leadership model in order to create economies of scale (mass customization).

- Audience or customer's attention economy as a basis for 'free' end-user services paid for by advertising or complementary services or goods.

- Self-provision – based upon the network economies of very large user communities providing information as a gift or at near zero cost (e.g. social networking applications).

7   Technologies

A variety of technologies can be used to enable Ambient intelligence environments such as (Gasson & Warwick 2007):

- Bluetooth Low Energy

- RFID

- Ict implant

- Sensors

- Software agents

- Affective computing

- Nanotechnology

- Biometrics

8   Uses in fiction

- Minority Report (film) (2002). One scene illustrates adaptive advertising in the future: consumers are identified via retinal scans, and receive targeted ads (Parker 2002).

- The Hitchhiker's Guide to the Galaxy by Douglas Adams. The doors have emotion, and express this when people use them.

  - See also: Technology in The Hitchhiker's Guide to the Galaxy

- The Diamond Age by Neal Stephenson. The Diamond Age depicts a world completely changed by the full development of nanotechnology that is present everywhere.

9   See also

- Augmented reality
- Cyborg
- Internet of Things
- Mobile computing
- Context awareness
- Context-aware pervasive systems
- Ubiquitous computing
- Wireless sensor network
- RFID
- Sensor
- Smart, Connected Products
- Ambient media
- Light

10   Research groups

Several research groups have been founded to tackle the question of the manifestations of ambient intelligence — what can be done and what will the actions most probably result in:

- Ambient Intelligence Group, CITEC, Bielefeld University.
- Ambient Intelligence Laboratory, National University of Singapore.
- Ambient Intelligence Research Group, Ulster University, UK.
- Artificial Intelligence Group in the Informatics Department, University of Minho
- AMBIT research group - e-lab, Artesis University College of Antwerp.
- Agent Systems Research Group.
- Alcatel-Lucent Research&Innovation. Ambient Services Group.
- Ajou University, CUSLAB – Well-Being Life Care Research
- AmIVital. Spanish project to develop intelligent services for elderly and disabled.
- Autonomous University of Barcelona – CAIAC.
- Autonomous University of Madrid – AmiLab.

- Carlos III University of Madrid – Applied Artificial Intelligence Group (GIAA).
- Carnegie Mellon University. CyLab – Ambient Intelligence Lab.
- DAI – Domotics and Ambient Intelligence, University of Alicante (Spain).
- University of Deusto, MoreLab – Mobility Research Lab.
- Fraunhofer Institute. Ambient Assisted Living,
- Fraunhofer Institute. IGD,
- Fraunhofer Institute. InHaus
- Heriot-Watt University - Pervasive, Ubiquitous & Mobile Applications (PUMA) Lab.
- Hydra – European research project on ambient intelligence middleware
- iHomeLab Living Lab, Lucerne University of Applied Sciences,
- iAMEA, International Ambient Media Association,

- Intelligent Environments Research Group, University of Essex (UK).
- SeNSe Lab, Sensor Network and Smart Environment Lab, Auckland University of Technology,
- Jožef Stefan Institute, Department of Intelligent Systems,
- Kingston University London, Ambient Intelligence Research Group.
- LIMSI-CNRS, Laboratoire d'Informatique pour la Mécanique et les Sciences de l'Ingénieur
- MAmI – Modeling Ambient Intelligence – UCLM, Spain.
- MIMOSA project – Microsystem Platform for Mobile Services & Application -
- MINAmI project – MIcro-Nano integrated platform for transverse Ambient Intelligence applications
- MERL. Ambient Intelligence for Better Buildings.
- MESH Cities - A project researching and distributing information about the future of smart, livable cities MESH Cities
- MIT Media Lab. Ambient Intelligence group.
- e-Lite Research Group, Politecnico di Torino.
- University of Palermo. Department of Computer Engineering. Distributed Artificial Intelligence group.

- NTT Research. Ambient Intelligence Research Group

- Philips Research. Ambient Intelligence Research in ExperienceLab.

- University of Reading, Ambient & Pervasive Intelligence Research group.

- SERENITY Security & Dependability in AmI,

- SWAMI: Safeguards in a World of Ambient Intelligence.

- SERCO: Contextual Services Group in the Information Technologies and Communications Department, Technical University of Cartagena

- EMMi Lab., Tampere University of Technology, (formerly New AMbient Multimedia Research (NAMU) Lab.)

- GECAD – Knowledge Engineering and Decision Support Research Center

- CETpD – Technical Research Center for Dependency Care and Autonomous Living

- GREC – Qualitative Reasoning and Learning Systems Research Group

- LST – Life Supporting Technologies

- OSAmI-Commons. Open Ambient Intelligence

- Vellore Institute of Technology – AMIR

11 Sources and further reading

- AMEA – Ambient Media Association - multidisciplinary association for developing an interdisciplinary viewpoint towards ambient media

- Proceedings of the Semantic Ambient Media Workshop Series (iAMEA)

- Eli Zelkha and Brian Epstein – first use and definition of **ambient intelligence**

- Malcolm McCullough, Digital Ground: Architecture, Pervasive Computing, and Environmental Knowing, MIT Press, 2005

- X. Wang, J. S. Dong, C. Chin, S. R. Hettiarachchi and D. Zhang. Semantic Space: A Semantic Web Infrastructure for Smart Spaces. IEEE Pervasive Computing, 3(3):32-39, July–September 2004

- B. Guo, D. Zhang, M.Imai. Towards a Cooperative Programming Framework for Context-Aware Applications. ACM/Springer Journal of Personal and Ubiquitous Computing, Vol. 15, No. 3, pp. 221–233, 2011.

- Artur Lugmayr – **first definition of ambient media**

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- Joseph Pine and James Gillmore, The Experience Economy: Work is Theatre and Every Business a Stage, Harvard Business School Press, 1999

- Bryon Reeves and Clifford Nass, The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places, University of Chicago Press, 1996

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- Yang Cai and Juli Abascal (eds.), Ambient Intelligence for Scientific Discovery: Foundations, Theories, and Systems, Springer Lectures Notes in Computer Science (LNCS 3345)

- Dipak Surie, "Egocentric Interaction for Ambient Intelligence", PhD. Thesis, Dept. of Computing Science, Umeå University, Sweden, 2012.

- Juan C. Augusto and Daniel Shapiro (Eds.). Advances in Ambient Intelligence. Volume 164, Frontiers in Artificial Intelligence and Applications (FAIA) series, IOS Press. 2007.

- Mehul Bhatt and Hans Guesgen (Eds.). Proceedings of the 1st International Workshop on: Space, Time and Ambient Intelligence (STAMI 2009). Co-located with the Conference on Spatial Information Theory, 2009 (France). Also published within: Report Series of the Transregional Collaborative Research Center SFB/TR 8 Spatial Cognition, University of Bremen Bremen/ University of Freiburg. SFB/TR 8 Spatial Cognition Report No. 020-08/2009, Bremen, Germany STAMI 2009.

- Jürgen Bohn e.a. Social, Economic and Ethical Implications of Ambient Intelligence and Ubiquitous Computing .

- ISTAG Scenarios for Ambient Intelligence in 2010

- ISTAG Ambient Intelligence: from vision to reality

- JRC/IPTS-ESTO Healthcare Technologies Roadmapping

- Ambient Intelligence blog - Blog about news on Ambient Intelligence, wireless sensor networks, and related topics (in Spanish)

- AmbientIntelligence.org – Website for Ambient Intelligence, e-Health, virtual reality and future technologies in healthcare

- Architectradure – Weblog on architecture and design

- awareIT – News blog about Ambient Intelligence, Ubiquitous Computing and intelligent devices.

- Digital Experience – Blog on interaction and experience design.

- Information Aesthetics – Weblog on information visualization

- Pasta and Vinegar – Weblog about emerging technologies usage/research/ foresight

- Putting People First – News on user experience, experience design and people-centred innovation

- José Encarnação (Ed.) et al.: *Ambient Intelligence – The New Paradigm for Computer Science and for Information Technology*. Special Topic of Journal *it – Information Technology*, Oldenbourg Verlag, Munich. Vol.50(2008) Issue 1.

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- Gasson, Mark; Warwick, Kevin (2013), "D12.2: Study on Emerging AmI Technologies", *FIDIS Deliverables* **12** (2)

13 External links

- SAME Series – Semantic Ambient Media Series Workshop

- STAMI Series – Space, Time and Ambient Intelligence (STAMI). International Workshop Series.

- UCAmI '10 – Symposium of Ubiquitous Computing and Ambient Intelligence – UCAmI

- HAI'09 – International Workshop on Human Aspects in Ambient Intelligence

- AmI-07 – European Conference on Ambient Intelligence

- COSIT-Space-AmI-09 – Workshop on "Spatial and Temporal Reasoning for Ambient Intelligence Systems"

- Sensami – a congress on ambient intelligence.

- AITAmI – Workshop on "Artificial Intelligence Techniques for Ambient Intelligence"

- IJACI – The International Journal of Ambient Computing and Intelligence

- JAISE – The International Journal of Ambient Intelligence and Smart Environments.

- AISE – Book Series on Ambient Intelligence and Smart Environments.

- I-o-T.org – Internet of Things : mainly based on Ambient intelligence

- IE'09 – Intelligent Environments Conference 2009

- AmI-11 – International Joint Conference on Ambient Intelligent 2011

- AmI-12 – International Joint Conference on Ambient Intelligent 2012

- Rethinking The Internet of Things Nature driven view of M2M cloud communications

- AmI – International Joint Conferences on Ambient Intelligent

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