Is Ambient Intelligence a truly Human-Centric Paradigm in Industry? Current Research and Application Scenario [3]

Luís Ribeiro (ldr@uninova.pt),
José Barata (jab@uninova.pt),
Pedro Barreira (pab18272@fct.unl.pt), Faculty of Sciences and Technology, Universidade Nova de Lisboa

Abstract

The use of pervasive networked devices is nowadays a reality in the service sector. It impacts almost all aspects of our daily lives, although most times we are not aware of its influence. This is a fundamental characteristic of the concept of Ambient Intelligence (AmI).
Ambient Intelligence aims to change the form of human-computer interaction, focusing on the user needs so they can interact in a more seamless way, with emphasis on greater user-friendliness. The idea of recognizing people and their context situation is not new and has been successfully applied with limitations, for instance, in the health and military sectors. However its appearance in the manufacturing industry has been elusive.
Could the concept of AmI turn the current shop floor into a truly human centric environment enabling comprehensive reaction to human presence and action?
In this article an AmI scenario is presented and detailed with applications in human's integrity and safety.

JEL codes: M15; O32
Keywords: Ambient Intelligence; networks; human-computer interaction

[3] Based on the paper presented at the International Conference "Autonomous Systems: inter-relations of technical and societal issues", organized by IET with the support of the Portuguese-German collaboration project on "Technology Assessment of Autonomous Robotics" (DAAD/CRUP) at FCT-UNL, Biblioteca da UNL, Campus de Caparica on 5-6 November 2009.

Ribeiro, Luis; Barata, José; Barreira, Pedro (2009): Is Ambient Intelligence a truly Human-Centric Paradigm in Industry? Current Research and Application Scenario, *Enterprise and Work Innovation Studies*, 5, IET, pp. 25 - 35.

Introduction

The wide availability of pervasive computing devices and their seamless interaction with network environments renders the implementation of intelligent spaces, centered in human presence, simpler. Despite the success of such technologies in some sectors (marketing, military, health, etc) its implementation in industrial setups remains elusive to date.

However, industrial environments are highly relevant application scenarios since humans interact, on a daily basis, with potential hazardous machinery. It is not yet clear what an intelligent industrial space should be. Recently the notion of Ambient Intelligence (AmI) has emerged to denote these human-centric-context-aware-computing spaces. AmI has been developing along several dimensions: Electronics, Wearable Electronics, Telecommunications, Distributed Artificial Intelligence, Multimedia and Augmented Reality and Social Sciences.

The subject of incorporating embedded-smart devices in the shop-floor has been thoroughly debated in the literature. Nevertheless the focus of that research has been in attaining more competitive response to volatile business opportunities through more flexible and agile process representations and handling. The human factor has been considered in complementary areas such as health and safety. In this context safety devices have been developed aside any paradigmatic integration with the emerging shop-floor control practices and approaches.

One can contend that there are obvious benefits in considering a holistic and integrated approach fusing shop-floor devices' intelligence with the human dimension.

The subsequent details are organized as follows: first a brief survey in the AmI concept and supporting technologies is held; next, exploratory applications of AmI in industry are presented and the true potential of application is discussed; some application scenarios currently being researched by the authors are then presented and finally some preliminary conclusions are drawn.

The Ambient Intelligence (AmI) Concept

The concept of AmI envisions human centric environments where "invisible" embedded technology will be seamlessly enabled by human presence and activity. In fact, the notion of AmI deeply relates to concept of ubiquitous computing described in (Weiser 1991).

The pervasive computer power advocated by both ideas requires however a multidisciplinary contribution. In fact it is difficult to identify all contributing areas. Nevertheless domains that explicitly contribute include:

- Electronics: in the development Ami devices (Aarts and Roovers 2003).
- Wearable Electronics: gathering garment producers, silicon producers, fashion designers to comprehensively meet user's requirement (McCann, Hurford et al. 2005; Rakesh, Katragadda et al. 2005). Moreover wearable electronics find relevant medical application as detailed in (Rakesh, Katragadda et al. 2005).
- Communications: improvement in networked technologies specifically in wireless sensor networks (Akyildiz, Su et al. 2002).
- Distributed Artificial Intelligent: supporting the implementation of intelligent spaces based on intelligent devices. In DAI research in multiagent and service oriented architectures is of major relevance for AmI.
- Multimedia and augmented reality: providing innovative ways of interacting with systems.
- Social sciences: evaluating the impact of Ami in the society and research innovative ways toward user friendly interaction.

The use of such devices and technology has been road-mapped by the European Union, in 2001, in (Ducatel, Bogdanowicz et al. 2001) where a set of Ambient Intelligence (AmI) scenarios is defined where regular people seamlessly interact with complex systems that ease routine tasks associated with traveling, receiving phone calls, shopping, learning, etc. Nearly nine years after, and despite a very significant IT integration effort, people are still far from being immersed in the envisioned scenarios.

What are the main factors responsible for slowing down the effective instantiation of the AmI concept?

As pointed out in (Wright 2005) there is a dark, and often invisible, side of ambient intelligence. To date, the main constraining factors have been on the one side the digital divide ((OECD) 2001) and on the other hand security and privacy threats.

In this context global access to education and technological support is unfortunately far from being reached, limiting the scope of application of the ubiquitous computing scenarios envisioned. In particular the digital divide raises a set of severe social problems namely:

- Exclusion – even in developed countries social asymmetries are increased by an uneven access to AmI supporting technologies.
- Technology Dependencies – there is the concern of creating tech additions in the common citizen which may lead to a generalized feeling of frustration when the level of the services drops or changes.
- Victimization – People are generally concern about public exposure of personal sensitive data. In general anonymous access to e-services is preferred. However, with the rise of terrorism there is a general paranoia associating anonymous e-activities with potential illicit practices.

On the other hand the frequency and level of sophistication of online security and privacy threats is increasing as denoted in (Wright, Gutwirth et al. 2008). Open issues include:

- Identity theft – the access to e-services is typically mediated by a software agent that acts on behalf of the user. This piece of software should ensure correct authentication and validation of user’s actions. However, this presents a security risk in scenarios of impersonation.
- Trust Management – software-mediated interaction with a system also implies a given degree of trust in the underlying IT infrastructure. Trust management across networks has shown not to be a trivial problem (Henttonen and Blomqvist 2005) that has to be addressed if AmI is to have a future.
- Spamming – currently technology has not been able to properly handle the flood of spurious, unintended and malicious data circulating in the internet. Aside directed denial of service attacks, spamming is a privacy and safety threat.
- Malicious attacks – all the emergent web technologies require further maturation to ensure flawless behaviour. The bottom line is that in its essence networks were not designed to be safe communication channels instead their base design is towards openness and ease of access. This hardens the control of illegal and anti-social behaviours.

The nature of the mediated interaction associated with the security threats are the basis for a set of open legal issues and liabilities. As addressed by the SWAMI project (Gutwirth, De Hert et al.)not all the previously mentioned security risks are properly covered in European law.

Ambient Intelligence in Industry

Considering the successive drawbacks in the effective implementation of AmI in general, one cannot expect a thorough implantation in industry. However, there are strict regulations regarding health and safety that have led to the application of sophisticated sensory equipment to handle human presence in hazardous places. Examples of such sensors include: light curtains, emergency switches and recently the use of computer vision.

In the field of computer vision the following initiatives are worth mention:

- SafetyEYE [4] – has developed the first 3D camera vision safety system to be used in the automotive industry. The system allows the definition of distinct safety areas and has the possibility of inhibiting the behaviour of surrounding equipment. The authors of the project claim that their solution improves safety enabling a case-wise reactive decision while reducing the overall operating costs when compared with traditional safety devices.

- NGR Safety for the Next Generation of Manufacturing [5] – the main goal of this project is the study and development of metrics and measures that enable safe human-robot interaction. Similarly to the previous project the shop-floor is divided in distinct risk areas. However, rather than focusing solely on computer vision NGR proposes the fusion of sensorial information of diverse nature the support a most accurate response.

A somehow different focus on the implementation of AmI has been considered in the InLife project (InLife 2006; Barata, Ribeiro et al. 2007; Ribeiro 2007). In this context, the goal was balancing the life-cycle impact of complex manufacturing lines. The approach taken consisted in the use of intelligent shop-floor modules with self-* capabilities as envisioned in (Luck, McBurney et al. 2005). In particular each module had sufficient autonomy to self-monitor and self-diagnose and take preventive measures (self-healing). Further, each device kept track of the relevant life-cycle parameters to reschedule maintenance actions. The results of this device level analysis were then forwarded to the InLife Life Cycle Management System that, analyzing the system maintenance requirements, from an holistic perspective would optimize the maintenance costs and convey all

4 - SAFETY EYE: http://www.pilz.de/products/sensors/camera/f/safetyeye/index.jsp

5 - NGR: http://www.nist.gov/mel/isd/si/safenexgen.cfm

the relevant information to the technicians on the field.

Clearly the focus on AmI was in the availability of context-aware maintenance information in real time and whenever necessary. Therefore, rather than focusing in safety, AmI in the InLife project was used to support humans in routine shop-floor activities. The results of this project were later extended to incorporate the optimization of maintenance teams and e-maintenance (Ribeiro, Barata et al. 2008; Ribeiro, Barata et al. 2009).

The described initiatives have somehow lacked a complete and holistic integration of the AmI concept with the underlying IT infrastructure.

The Instantiation of AmI in Evolvable Production Systems (EPS) – A Safety Application.

Background on EPS

The essence of EPS resides not only in the ability of the system components to adapt to the changing conditions of operation, but also to assist in the evolution of these components in time such that processes may become more robust.

The EPS paradigm is currently developing along three main dimensions (Ribeiro, Barata et al. 2009):

- The knowledge model: Under the framework of the EUPASS project an exhaustive ontology to support EAS has been developed (Lohse, Ratchev et al. 2006). It covers and relates all the main activities and concepts required to run an EPS compliant system.
- System Layout and Control Emergence: With the domain knowledge settled the next challenge is using that information suitably. This includes autonomously handling production/disturbances-driven layout changes and ensuring plug-ability.
- IT infrastructural support: the research in suitable IT supporting platforms has been major developing in the assessment of the applicability of MAS and SOA as the EPS backbone. Initial efforts related to earlier prototyping of the COBASA architecture (Barata, Cândido et al. 2006; Cândido and Barata 2007). Lately the focus has been in the harmonization of MAS and SOA and the exploration of their complementarities (Ribeiro, Barata et al. 2008; Ribeiro, Barata et al. 2008; Ribeiro, Barata et al. 2008; Cândido, Barata et al. 2009; Cândido, Jammes et al. 2009).

- Condition Monitoring and System Maintenance: explored under the InLife Project and currently being further developed to encompass the dynamic of EPS environments. It is a fundamental dimension for the survival of the system and provides the support layer for the work next described.

In this context an EPS compliant system is a natural environment for seamless integration and instantiation of the AmI concept as it is pluggable by design.

A Preliminary Architecture Proposal

The architecture hereby detailed targets state-of-the-art control approaches where systems are envisioned as dynamic compositions of intelligent and autonomous modules (as is the case of EPS).

In order to guarantee a safe human-Robot interaction in the shop floor environment, there must be a continuous and intelligent monitoring process that can provide the system with essential information regarding users' localization as well as hazardous areas. With an increasing number of accidents resulting from overlooking or overriding traditional (reactive) safety devices there is a clear gap in advanced proactive unobtrusive safety tools.

In the proposed architecture a vision system interacts with the existing EPS agent based infrastructure. Rather than considering the Vision system as a physical artefact that provides input for the control system. The vision system is integrated within the agent domain in the EPS cloud supporting transparent and semantic-based interaction between the shop floor agents.

The main purpose of such integration is to ensure a focused and selective inhibition of one or more agents. After determining whether the users are in warning or dangerous areas the camera agent will forward contextualized information to the agents in the area subject of human presence.

That information contains the clearance and expertise level of the humans in the invaded area. The affected agent will then adjust their response in accordance to the context data. Examples of possible actions range from a full stop or termination of ongoing processes to slowing down or reconfiguring running activities.

Additionally the users shall be informed about the potentially hazardous area they are in and the subsystems currently reacting to their presence.

Given the decoupled nature of the whole system, which is supported by the EPS, abstraction, any changes in the underlying control logic are transparent an immediately considered in the safety environment. In this context continuous and systematic system evolution is supported through autonomous adaptations.

An overview of the architecture is depicted in Fig 1. which highlights the separation between physical assets and the EPS layer, where the safety system performs.

Reaction to human presence can be further extended. It is envisioned, following the author's previous work in e-maintenance, that the enhanced functionalities provided by the safety system can be extended to aid in the execution of maintenance actions. In this context the system may respond to direct user commands analyse them in context and execute them in conformity to safety measurements.

For example the user may instruct a robot to position in a specific way. The robot will react depending on the area invaded by the user. For that purpose the vision system determines both entities positioning and validates the required action. Other application scenario includes overriding user action that may be harmful for other humans in the surroundings.

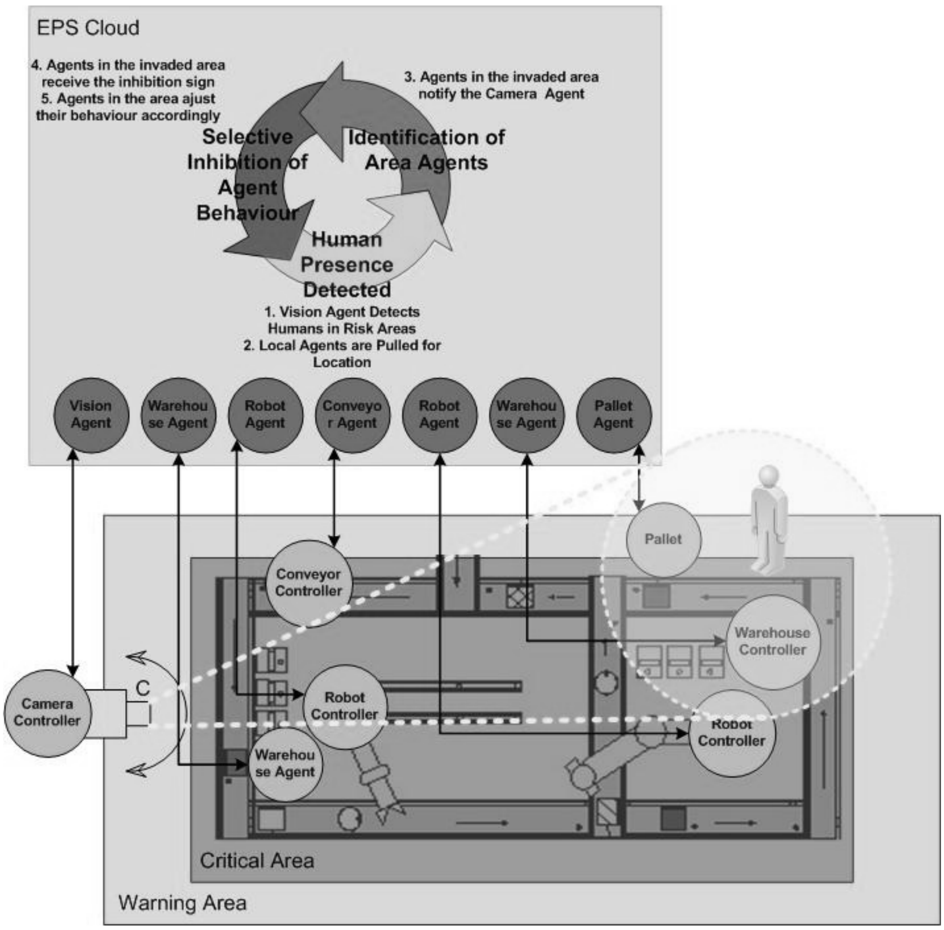

Figure 1. A Preliminary Architecture Proposal

As detailed in the Fig.1 plug ability is a major feature of the proposed system. This provides the required degrees of freedom to seamlessly incorporate existing and forthcoming safety technologies into the present platform.

Conclusions

The shop is increasingly an IT integrated environment. The number of production control tools is increasing as well as the degree of automation. The pervasive and generalized use of industrial manipulators and other heavy equipment present serious risks to human safety. There has been a generalized lack of focus in the study of the machine and human interaction in such environments. In some cases the safety system's action disturbs the work of the human operators which has led to severe accidents resulting from overriding the safety system.

The authors argue that a proactive and adaptable safety system may positively contribute to reduce these risks and, under the proper IT framework, contribute to render the shop floor a truly human centric paradigm where technology sever the human actor and not otherwise.

References

(OECD), O. F. E. C.-O. A. D. (2001). "Understanding The Digital Divide."

Aarts, E. and R. Roovers (2003). IC Design Challenges for Ambient Intelligence. *Design, Automation and Test in Europe*. Munich, Germany, IEEE.

Akyildiz, I. F., W. Su, et al. (2002). "Wireless sensor networks: a survey." *Computer Networks* **38**(4): 393–422.

Babiceanu, R. and F. Chen (2006). "Development and applications of holonic manufacturing systems: a survey." *Journal of Intelligent Manufacturing*, **17**: 111–131.

Barata, J., G. Cândido, et al. (2006). A multiagent based control system applied to an educational shoop floor. *BALANCED AUTOMATION SYSTEMS in Manufacturing and Services*. Niagara Falls, Canada.

Barata, J., M. Onori, et al. (2007). Evolvable Production Systems: Enabling Research Domains. *International Conference on Changeable, Agile,* *Reconfigurable and Virtual Production*. Toronto, Canada.

Barata, J., L. Ribeiro, et al. (2007). Diagnosis using Service Oriented Architectures (SOA). International Conference on Industrial Informatics. Vienna, IEEE.

Bi, Z. M., S. Y. T. Lang, et al. (2007). "Reconfigurable Manufacturing Systems: the state of the art." *International Journal of Production Research* **46**(4): 967-992.

Cândido, G. and J. Barata (2007). A Multiagent Control System for Shop Floor Assembly. *International Conference on Industrial Applications of Holonic and Multiagent Systems*. Regensburg, Germany.

Cândido, G., J. Barata, et al. (2009). "SOA in reconfigurable supply chains: A research roadmap." *Engineering applications of artificial intelligence* **22**(6): 939-949.

Cândido, G., F. Jammes, et al. (2009). Generic Management Services for DPWS-enabled devices. *IECON 09*. Porto, Portugal.

Chan, S., D. Conti, et al. (2006). "Devices Profile for Web Services."

Ducatel, K., M. Bogdanowicz, et al. (2001). Scenarios for Ambient Intelligence in 2010. *User-friendly Information Society*. E. Comission. Seville, European Comission.

Gutwirth, S., P. De Hert, et al. "The legal aspects of the SWAMI project." Editors: Michael Friedewald & David Wright: 17.

Henttonen, K. and K. Blomqvist (2005). "Managing distance in a global virtual team: the evolution of trust through technology-mediated relational communication." *Strategic Change* **14**: 107–119.

InLife. (2006, 01/01/2007). "Integrated Ambient Intelligence and Knowledge Based Services for Optimal Life-Cycle Impact of Complex Manufacturing and Assembly Lines." from http://www.uninova.pt/inlife/.

Jammes, F., A. Mensch, et al. (2007). Service-Oriented Device Communications Using the Device Profile for Web Services. *Advanced Information Networking and Applications Workshops*, IEEE.

Jammes, F. and H. Smit (2005). *Service-oriented architectures for devices - the SIRENA view*. International Conference on Industrial Informatics, Perth, Western Australia, IEEE.

Lohse, N., S. Ratchev, et al. (2006). *Evolvable Assembly Systems - On the role of design frameworks and supporting ontologies*. IEEE International Symposium on Industrial Electronics, Montreal, Quebec, Canada, IEEE.

Luck, M., P. McBurney, et al. (2005). *AgentLinkIII - A road map for agent based computing* (available in http://www.agentlink.org/).

McCann, J., R. Hurford, et al. (2005). A Design Process for the Development of Innovative Smart Clothing that Addresses End-User Needs from Technical, Functional, Aesthetic and Cultural View Points. *International Symposium on*

Wearable Computers. Galway, Ireland, IEEE.

Rakesh, B., Katragadda, et al. (2005). A Novel Intelligent Textile Technology Based on Silicon Flexible Skins. *International Symposium on Wearable Computers*. Galway, Ireland, IEEE.

Ribeiro, L. (2007). A Diagnostic Infrastructure for Manufacturing Systems. *Electrical and Computer Science Engineering*. Lisbon, New University of Lisbon. **MSC:** 121.

Ribeiro, L., J. Barata, et al. (2009). Evolvable Production Systems: An Integrated Viewn on Recent Developments. *6th International Conference on Digital Enterprise Technology*. Hong Kong, IEEE.

Ribeiro, L., J. Barata, et al. (2008). MAS and SOA: A Case Study Exploring Principles and Technologies to Support Self-Properties in Assembly Systems. International Workshop on Self-Adaptation for Robustness and Cooperation in Holonic Multi-Agent Systems. Venice, IEEE.

Ribeiro, L., J. Barata, et al. (2008). A Generic Communication Interface for DPWS-based Web Services. *IEEE International Conference in Industrial Informatics INDIN.* Daejeon, Korea, IEEE.

Ribeiro, L., J. Barata, et al. (2008). An Architecture for a Fault Tolerant Highly Reconfigurable Shop Floor. *IEEE International Conference on Industrial Informatics*. Daejon, Korea, IEEE.

Ribeiro, L., J. Barata, et al. (2009). Maintenance Management and Operational Support as Services in Reconfigurable Manufacturing Systems. *IFAC Symposium On INFORMATION CONTROL PROBLEMS IN MANUFACTURING*. Moscow, IFAC.

Ribeiro, L., J. Barata, et al. (2008). MAS and SOA: Complementary Automation Paradigms. *Innovation in Manufacturing Networks*. A. Azevedo, Springer Boston. 266/2008: 259-268.

Ribeiro, L., J. Barata, et al. (2008). "A high level e-maintenance architecture to support on-site teams." *Enterprise and Work Innovation Studies, Journal of IET Research Center* **4**(4): 129-138.

Weiser, M. (1991). "The Computer for the 21st Century." Sci Amer **265**(3): 94-104.

Wright, D. (2005). "The dark side of ambient intelligence." Info - The journal of policy, regulation and strategy for telecommunications **7**: 33-51.

Wright, D., S. Gutwirth, et al. (2008). *Safeguards in a world of ambient intelligence*, Springer-Verlag New York Inc.