Workshop on Ambient Intelligence Technologies to Enhance the Product Lifecycle

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Workshop Report

Authors: Florent Frederix, Waldemar Jaroński, Peter Friess

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Commission européenne, B-1049 Bruxelles / Europese Commissie, B-1049 Brussel - Belgium. Telephone: (32-2) 299 11 11.
Office: BU 29 02/037. Telephone: direct line (32-2) 299.67.51. Fax: (32-2) 296.83.87.

E-mail: Florent.Frederix@cec.eu.int, Waldemar.Jaronski@cec.eu.int, Peter.Friess@cec.eu.int

1. Executive summary

A product in 2020 will be online (Internet present), ambient aware, and information rich. It will offer more value and better user experience throughout the entire product lifecycle, as well as enable manufacturers and service providers to respond faster and in a flexible manner to changing market demands. The value of such products throughout their lifetime will be much higher as the result of the combination of physical object and virtual/online services that can constitute an integral part of "product-service packages". Ambient Intelligence technologies will enable novel product features, such as mass customisation, agile production plants, anthropocentric process automation, advanced knowledge engineering, as well as remote monitoring and maintenance of products. New business models and new forms of organizations will emerge making use of novel business and processes. Industrial change in the production process will follow.

Such a vision engenders many RTD challenges. The generated information for and by these objects will require new methodologies and applications in order to cope with the increased complexity. At the same time, provisions have to be made for increased network capacity needs and granularity. Progress in current state of the art telecommunication technologies is needed to support these objects, often exchanging messages in harsh environments and dense networks. Most emerging solutions use the public internet as a carrier, thus triggering governance issues, such as the traffic congestion management, and priority issues, like the linkage of these objects with their virtual space, and the coexistence of virtual private networks in the public domain. Physical location is an important new parameter that will be exploited by these future products to extend their usefulness and even the reason for their existence. In addition, identity theft using electronic means, now being a number one problem of the modern information society, will become much bigger in a world consisting of intelligent networked objects. More research work is needed to assure anonymity, security, both for the intelligent object and its surrounding network. Technologies such as authentication and encryption need extensions, and adaptation to work in systems with often limited computing capabilities. Further research is still needed to build the 'intelligence' components that satisfy the needs of these products.

2. Overview

The workshop on "Ambient Intelligence Technologies to Enhance the Product Life-Cycle" took place on 27 February 2006 in Brussels. The event attracted approximately 50 participants from academia, research institutes and industry.

The objective of the workshop was to recognize the need of the European stakeholders for concerted collaborative research on the potential future applications of Ambient Intelligence Technologies (AmI) at different stages in the life cycle of a product, as well as the prospects for and identification of new, innovative information-rich, ambient-aware products and services.

The workshop was opened by Dr Gerald Santucci, Head of Unit "ICT for Enterprise Networking" of the European Commission. During the panel session, presentations stimulating the discussion were given by Dr Florent Frederix (Project Officer, European Commission), Dr Markus Rabe (Head of Department, Fraunhofer IPK), Per

Hogberg (SW & Business System Manager, Kongsberg Automotive Group), Alex Wong (Auto-ID Center at University of Cambridge), Prof. Bengt-Olof Elfström (Research Director, Volvo Aero and Professor Luleå University of Technology), and Dr Michael Baumann (Head of Group, Fraunhofer IITB). The discussion was then arranged in group work in the form of three thematic “Knowledge Cafés” in order to let participants speak out their reflections and statements and facilitate the generation of new, potentially useful ideas on the subject.

The first café addressed the use of AmI at the initial stages in the product lifecycle, such as **product design and development**. Design of complex intelligent and enhanced products is an interdisciplinary multi-phase process which involves numerous groups of engineers that very often are distributed. Involvement of dispersed engineering groups is justified e.g., by reduction of “time to market” and a need for involving specific competencies or engineering abilities. Interdisciplinary approach to design is required due to complexity of modern products including contributions and components from various engineering disciplines.

The topic addressed in the second knowledge café was the relevance of **AmI for the design of the production** (including industrial engineering) and the related logistics, for the ramp-up of the production and for the operation of production systems. This includes design and operation of distributed production in global enterprises or supply chains.

The application of AmI for **the usage, maintenance and end-of-life** stages in the product lifecycle was covered extensively in the third thematic session. The discussion included aspects ranging from product configuration, customization and definition of product features, the use and maintenance, and ageing of a product to recycling. Furthermore, attention was drawn also to feedback of product information from the time period of product use to the phase of product design, and questions regarding environmental and safety issues.

3. State of the art

Today’s highly competitive markets for new products require an increased collaboration, often between competitors, during product design and development phases. Current design processes are characterised by the use of distributed resources (engineers, tools, digital libraries of Intellectual Property components). Knowledge sharing in design processes is practiced only in established partnerships based on mutual trust and appropriate agreements. Large enterprises prefer proprietary solutions to integrate their suppliers. Distributed collaborative engineering, which is an innovative method for product design and development that integrates widely distributed engineers for virtual collaboration, is typically restricted to engineering groups from large global companies. Inter-company collaboration in collaborative networks formed by SMEs is still a challenge. This is a consequence of a lack of inter-company secure collaborative infrastructures enabling easy “join and leave”, adequate network-aware design methodologies including methodologies for participatory design that will enable smooth involvement of users in a design process and adequate business models for accessing engineering services over the network.

AmI technologies, such as Radio Frequency Identification, are becoming more often applied nowadays in logistics and Supply Chain Management, but they are mostly not used in an intelligent way and only replacing other identification technologies. There is no substantial use of AmI at the production ramp-up and manufacturing. Further applications are in different stages of pre-competitive research, e.g. approaches for self-controlled production, scalable Virtual Reality technologies or intelligent supply chain support.

4. Socio-economic goals

The vision is to achieve a leading position in research and in the application of AmI technologies as a key technology in Europe. The primary goal of the use of AmI is to maintain competitiveness of European industries and thus be able to keep the respective employment in Europe. Related goals are reduced time-to-market and the efficient use of resources by increased knowledge sharing, the avoidance of unnecessary pollution of the environment and the improvement of safety and reliability in European working environments.

5. Future - beyond the state-of-the-art

AmI should be in a stage where it can be applied in enterprises of any size, supporting completely new types of information management. Company networks form a specific strength of Europe's industry. Therefore, it will be especially important to support the cooperation with AmI technologies, in order to stabilize and even improve this European advantage.

The following areas are considered parts of this vision. Sharing engineering knowledge in design and development will be radically simplified. Standardized knowledge representations and techniques for protecting IPR on a "pay-per-use" base of knowledge-modules will facilitate ad hoc co-operations and knowledge sharing. Management of collaborative networks will be simplified, including set-up extension and discontinuation of networks. New interdisciplinary partners will be able to join easily the network. Secure collaborative engineering networks easily integrating new SMEs are a long term goal, including facilities for finding the right resources (individuals, enterprises, systems) meeting the required constraints for a design and development target.

Early design phases of the product lifecycle will be better supported with:

- cooperation of manufacturer and supplier,
- analysis of requirements from different fields (technology, materials, economy, and business strategy), and
- an early integration of components based on models or executable specifications.

6. Key issues to be solved

AmI is a holistic approach that needs to integrate more than one mechanism. Approaches are required, that combine different elements of ambient intelligence for new products or services. AmI is also a new approach for the integration of humans and computers. AmI of world-excellence will not derive from replacing technologies (e.g. bar codes by RFIDs), but from approaches that establish new control mechanisms (e.g. production controlled by products) or that provide new access to data and data representations (e.g. virtual realities scaled to purpose and device, from CAVE to mobile devices).

Future R&D on collaborative engineering networks should address seamless interoperation of technologies supporting distributed inter-company collaboration, a standard-based network infrastructure for offering engineering services, and bridging cultural differences. A new approach is required for engineering knowledge representation and management, including standardised knowledge representation based on semantic technologies (ontologies and beyond), infrastructures supporting build-up and evolution of this structure, approaches for IPR-protection and trading of clearly defined knowledge units, and knowledge sharing based on work context.

New design methodologies, like participatory design that enable significant customisation of products need to be further investigated. Knowledge protection mechanisms for design and development should be adopted. New collaborative environments providing better support for creativity in distributed design and development require research on a holistic framework with respect to different user groups, technologies, and business models.

Using new physical technology, the challenge is the selection and presentation of relevant information. This includes multi-disciplinary and multi-dimensional approaches to select and analyse knowledge.

Production system engineering and ramp-up are still driven by personal experience, but due to the long cycles (for large systems, engineers might only run 5-10 projects in their business life) significant knowledge might be lost. Experience has to be presented as associative, context-aware knowledge ("know-how", previous experience).

7. Topics to be addressed

Topics related to engineering knowledge representation are detection and discovery of design knowledge, transformation of legacy data models into semantically enriched representations, or support for design teams by context-based knowledge supply and decision support. Furthermore, on-the-fly sharing of knowledge and integration of new knowledge in design processes meeting emerging needs of the stakeholders is required.

The topic of collaborative networks includes how to set-up extended enterprises in situations of "competition" (cooperation and competition at the same time), including technical, legal, process and organizational aspects. Management of collaboration lifecycle and support for interdisciplinary teams have to be addressed. Finding and integrating the right resource (individuals, enterprises, systems) offering the required capabilities for design and development target is a further issue.

With respect to product lifecycle support, early integration of sub-systems and components based on models or executable specifications, simulation of process and decisions, identification of the most effective product lifecycle parameters in the early design phase and performance parameters and indicators that are necessary for the monitoring of condition/status of a system/component during the usage phase are to be addressed and identified. Integrated product and service lifecycle processes and integrated management of requirements from different fields (technology, materials, economic aspect, and business strategy) contributed to this area.

Topics related to product development, such as development processes focused on functional products (physical product plus service) involving all relevant stakeholders should be addressed as well as design and development of products orchestrated with factory lifecycle and factory planning.

Intelligent techniques are required to interpret and transform product field data into information and knowledge in a context-aware way, and present resulting data and relationships for different environmental contexts. This includes procedures ("how to humans produce such parts?") as well as equipment or product information ("Where are my parts right now? Is the real equipment identical with information in the 'Digital Factory'? What is the current field of application of the product? What is the current status of the product parts? What is the current product configuration?). These aspects address especially companies of medium size, where data are less complete and qualified, as well as the providers of production systems which need to acquire the real situation in the target shop floors and distribution areas. The processes concerned include industrial engineering, the preparation and start of production and the production with continuous improvement, for a single shop up to complete supply chains, the product configuration for customer specific requirements, the product use and recycling.

Ambient intelligent monitoring could analyse information in a specific context, thus supporting decisions, avoiding critical situations or identifying unknown potentials. For instance, the problem of counterfeits (which can provoke severe security problems) can be addressed avoiding the assembly of non-authorized parts.

Furthermore, ambient intelligence technologies for "know-how" acquisition and management coupled with intelligent evolutionary models of products, processes, and resources (human and machines) and their complex relationships can be the basis of advanced knowledge based quality management system.

In combination with ambient technologies, evolutionary models can be used for the management of product-process-resource quality relevant problems. The use of evolutionary models can support the ambient digital factory to make use of the 'know-how' accumulated throughout previous experiences, for enhancing the productivity of its production system. In this context, the issues of development of evolutionary modelling methods and tools for product-process-resource quality management, as well as development of appropriate ambient intelligence technologies and framework for "know-how" acquisition and management should be addressed.

8. Acknowledgments

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Commission européenne, B-1049 Bruxelles / Europese Commissie, B-1049 Brussel - Belgium. Telephone: (32-2) 299 11 11.
Office: BU 29 02/037. Telephone: direct line (32-2) 299.67.51. Fax: (32-2) 296.83.87.

E-mail: Florent.Frederix@cec.eu.int, Waldemar.Jaronski@cec.eu.int, Peter.Friess@cec.eu.int

Appendix A: Statements from the workshop

A.1. General statements

- AmI has to be targeted to customer profits (AmI is only successful if it leads to customer benefit)
- AmI is a holistic approach, that needs to integrate at least some mechanisms – single elements are not seen very beneficial (call for integration)
- In supply chains, win-win situations are necessary to implement successful solutions
- AmI needs to integrate humans and computers – and to respect that humans are not simply "users" with predefined frameworks
- New infrastructures are required for AmI that provide modularity, ontological stratification of knowledge and sectorial aspects
- New types of authorization procedures may be necessary for information which is "moving" through different environments along the product life cycle
- It is necessary to develop a legal environment to deal with aspects of the handling of data.
- Standards need to be developed for data integration, the use of ontologies might be useful approach.
- In order to handle the information and data in an AmI technology environment, methods to evaluate the important sensors and data, to identify essential, appropriate data are needed. Based on identified data an intelligent decision making needs to be supported.
- Generation of context aware data.
- A new type of job can arise through the massive application and use AmI technologies: the job of a service provider. One important task in this job will be to give advice and support in the implementation and use of new technologies.
- How to assure user and designer acceptance
- Trust building between manufacturer and supplier
- Information flow between stakeholders based on context
- Adopted business models

A.2. Product design and development

Statements on product design

- Ambient Intelligent Technologies can assist to trace how, where and by whom a product is used. Based on this tracking feedback can be given to optimise product requirements for the development of the next product generation.
- How can Ambient Intelligent Technologies be used to put intelligence directly to the product? This shall result in new intelligent products.
- Ambient Intelligent Technologies can be used to create an intelligent support system for the optimisation of product design and new services (new materials, new techniques, …)

Statements on product lifecycle

- Early integration of sub-systems and components based on models or executable specifications (early integration, model-based integration of design components)
- Simulate process and decisions as early as possible in the lifecycle
- How to identify most effective product lifecycle parameters in the early design phase
- Integrated product and service lifecycle processes
- Align the lifetime of software and information environment with the lifetime of the product

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- Integration of requirements from different fields (technology, materials, economic aspect, business strategy

Statements on product development

- New development process focused on functional including physical products as basis for extended enterprises involving all relevant stakeholders
- Design and development of product orchestrated with factory lifecycle and planning

Statements on collaborative networks

- How to set-up an extended enterprise in situations of competition (cooperation and competition at the same time) including technical, legal, process, organisational aspects)
- Ease integration of various partner into collaborative networks encompassing the technical (interoperability), organizational (processes and team structure) and conceptual level (taxonomies, models, knowledge representations)
- To facilitate characterizing, finding, and integrating the right resource (individuals, enterprises, systems) meeting the required capabilities for your design and development target;
- Support interdisciplinary teams in bridging differences in business culture, technical discipline or social background.
- Management of collaboration lifecycle from formation to discontinuation

Statements on engineering knowledge representation and management in collaborative networks

- Detection and discovery of design knowledge with respect to intellectual property, individual and enterprise competences, existing solutions
- Integration or transformation of legacy data models into semantically enriched representations
- Support for design teams by context-based knowledge supply and decision support. Context encompasses relevant information about environment and profile of stakeholders.
- On-the-fly sharing of knowledge and integration of new knowledge in design processes meeting emerging needs of the stakeholders (express your needs, find available support)
- Coordinating the flow of data coming from operation and requesting analysis from design office and integration into knowledge management infrastructures

A.3. Ramp-up and Production

Statements on information acquisition

- Intelligent means are required to identify the as-is-status of factories (measurement/scanning techniques linked with context information), both for the “static” factory (e.g. layouts) and the “dynamic” factory (vehicles, pallets, parts, personnel, …)
- Record (manual) procedures to collect knowledge “how to plan a factory / how to produce things”
- Record operations on products in order to ensure that processes have been performed in the right sequence and quality (“integrated quality control”)
- Identification of one-of-a-kind parts through codes and/or through their production history.
- Use virtual environments to present specific context
- Use virtual environment to prove new or automatically proposed production solutions
- Augmented/ virtual reality will support the right reactions in a given situation, which is usable in production engineering as well in maintenance and product design

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Statements on processes and knowledge

- New methods are required for context-aware modelling of knowledge (e.g. find structures that stratify/divide/categorize knowledge)
- Context aware provision of previous experience: the knowledge transfer is a great challenge; knowledge needs to be captured and provided through clear processes; the transfer of human personal experience requires new "languages"; retention of knowledge needs new mechanisms; facilitating "learning by doing"
- Definitions can only be used context-aware if they are bound to processes
- Human capital development: Education is a fundamental aspect of knowledge transfer. Challenges are the impossibility to collect complete information, procedures to collect someone's way of working, respecting the culture evolution and the working culture change
- Adaptation of information to persons' profiles (not only roles, but background and experience) requires a standard description of capabilities and qualifications
- Focus necessary on knowledge of industrial engineers (duplicating a factory is relatively easy, but duplicating the engineering is a matter of many years). New types of project management systems could be targeted on the management of detailed resources in terms of profiles and knowledge)
- KBE systems are seen as facilitators, but new approaches are required that reduce the danger of blocking innovation and human creativity by the use of earlier "dominant" designs (e.g. for a production line) and processes (e.g. standardized processes like ISO 9000ff approaches by principle operate also as restrictions)
- Environments are needed to enable supply network interoperability and supplier coordination (including information from suppliers to OEM). While OEMs orientate on the product, suppliers are still often resource-managed.
- Integrate the customers' "behaviour to buy" into the product planning (in multiple tiers)
- The orchestration of the partners in SCM requires the description of concrete abilities of companies, down to the shop-floor level, and solution-oriented networking
- Reconfigurable production lines call for new types of production processes. This includes concepts for modular design of production, mass customization, techniques to influence complex products even after production start, which has impact on quality procedures (the responsibility shifts from the design to the production)

Statements on monitoring

- Avoid faulty situations by embedded information
- Identify the products in order to avoid unauthorized copies
- Track the history of work pieces
- Detect relationships from collected data that are not directly visible (data mining)
- There are requirements that cannot be measured, leading to the need for new verification and performance "indicators"
- Today, data integrity is incorporated into (localized) IT systems. What happens when data is delocalized with the product?
- Information is requested to flow back from suppliers to OEM instead of just "pushing" information

A.4. Product use and recycling

Statements on product configuration and product features

- In the future not only just a product will be sold by companies, instead it will be a crucial competitive advantage to offer services around the product.

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- Intellectual property rights (IPR) need to be considered: if more than one company is engaged in the production, use, maintenance and service of a product, clear regulations for the distributions of IPR need to defined.

Statements on product use

- Ambient Intelligent Technologies can assist in dealing with environmental and safety issues.
- Ambient Intelligent Technologies can assist to trace how, where and by whom a product is used. Based on this tracking feedback can be given to a company to support the user in handling the product, e.g. explanation of complex functionality.
- Ambient Intelligent Technologies can be used to enable a product to develop resp. adapt itself to the needs of its environment or the user.
- Feedback of knowledge from self-adapting (intelligent) systems to the producer.
- Usage of the technologies Virtual Reality and Augmented Reality to support of the product use and recycling.
- In conjunction with a wider use of Ambient Intelligent Technologies it is likely that the number of sensors used in a product will increase. Thus, it is important to work on the robustness of sensors (Develop highly stable sensors). This will contribute to the stability of the complete product.
- Ambient Intelligent Technologies shall be used to allow a life-long monitoring of products.
- Ambient Intelligent Technologies shall be used to allow federated access to product services.
- Plug & play features of Ambient Intelligent Technologies should be developed to allow an easy usage and integration of these technologies.
- Ambient Intelligent Technologies should be applied to create intelligent products that support the user through interaction. This will help user (without having to have specific knowledge) to easily understand and use complex products that have a large range of functionalities.

Statements on product maintenance and recycling

- Ambient Intelligent Technologies should be applied for an advanced product maintenance services, e.g. intelligent products report automatically about necessary maintenance work to the after sales unit of a company.
- Ambient Intelligent Technologies should be used to assist in the ageing products, e.g. sensors detect which parts of a product need to be replaced.
- It needs to be considered that the lifetime of the Ambient Intelligent Technologies products might be shorter than the product life. Therefore the question needs to be answered what happens if for example a sensor expires and the product shall still be in use. The use of sensors in an airplane is a good example to describe the complexity. Several hundreds of sensors are used in an aircraft to allow its functionality. In general, the lifetime of an aircraft constitutes around 30 years of use whereas the lifetime of sensors is in most cases much shorter. Thus, the question arises how to maintain or replace which sensors in order to permit a long life time of the complete product?
- The use of Ambient Intelligent Technologies will influence the course of business processes. Therefore it is of interest to examine if not only the Ambient Intelligent Technologies can be reused but also if altered business processes can be reused.
- Ambient Intelligent Technologies can assist in dealing with environmental and safety issues.
- Ambient Intelligent Technologies can assist to trace how, where and by whom a product is used. Based on this tracking requirements for maintenance and recycling can be derived.
- In the field of the redesign/reuse of products methods/tools need to be developed that allow the use of Ambient Intelligent Technologies.