*New Technologies for the Intelligent Design and*
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# Challenges in Advanced ICT Technology for the Product Lifecycle

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**Abstract**: The "Ambient Intelligence Technologies for the Product Lifecycle" (AITPL) cluster of European projects has been established by the European Commission under the 6th Framework Program in the domain of Enterprise Networking. After the first years of operation, the cluster reflects on the further research agenda and priorities. The presented visions and conclusions are the result of two workshops: "Workshop on Ambient Intelligence Technologies to Enhance the Product Lifecycle (February 27, 2006, Brussels) and the AITPL Forum (June 28, 2006, Milan). The primary intention of both events was to identify and discuss within a broad community the research agenda of the related research domain for the next decade.

## 1 Introduction

The "Ambient Intelligence Technologies for the Product Lifecycle" (AITPL) cluster of European projects has been established by the European Commission (EC) under the 6th Framework Program in the domain of Enterprise Networking. *Ambient intelligence (AmI)* is a concept representing a vision where humans are surrounded by various computing and networking devices, unobtrusively embedded in human environments (ISTAG 2003, ISTAG 2001). This vision emphasises user friendliness and participation, efficient and distributed services support, intelligent interfaces and support for human interactions. The realisation of this vision requires development of numerous new technologies like: unobtrusive miniaturised hardware, seamless communication infrastructures, massively distributed device networks (often referred to as an *Internet of things*), intelligent interfaces, security and dependability.

*Product lifecycle management (PLM)* is the process of managing the entire lifecycle of a product from its conception and design, production, support, and upgrade, to the product recycling. During a product's lifecycle an enormous diversity of workers' competencies, working styles and environments, as well as tools may be required. Often workers and their tools are distributed over numerous enterprises that also can be geographically dispersed. Even a basic analysis of benefits of the use of AmI technologies in PLM reveals a great potential for improvements of numerous characteristics of a product, like customisation, configuration by users, easiness of maintenance and upgrade of product services, self diagnostics, as well as reduction in material waste and increased recycling.

Ambient Intelligence in the 6$^{th}$ Framework Programme of the European Union focussed on human-centred environments, like home, workplace or healthcare. Although this approach still has the prime concern, new AmI technologies address also manufacturing and thus in fact the whole product lifecycle. The visions and conclusions presented in this paper are the result of two workshops, the "Workshop on Ambient Intelligence Technologies to Enhance the Product Lifecycle (February 27, 2006, Brussels) and the AITPL Forum (June 28, 2006, Milan). The primary intention of both events was to identify and discuss within a broad community the research agenda of the domain for the next decade. The output of these workshops will also be used for the identification of potential activities in the context of the European Research Area (ERA).

Following the AITPL Mission Statement, the strength of the European economy is substantially based on relationships among many enterprises, which together form agile networks, able to react to market demands in shortest time. These networks are competing successfully on a worldwide scale with enterprises from distant countries, which offer wages in a completely different dimension. This success can only be maintained if the networks establish and maintain smooth communication and collaboration of workers, as well as integration of enterprise infrastructures and resources, which cover the complete lifecycle of a product. Significant effort has been spent to synchronize the product development in such networks. However, the same exertion is indispensable to improve the manufacturing chain itself, providing means for a radical make-to-order strategy. This includes substantial new methods for product configuration, for supply network management, for the control of the supply network material capability, as well as for propagating forecast for new model variants, and carefully monitoring the time-to-empty of the supply chain for the variants going out of production.

"The AITPL cluster's mission is to bring these topics forward and to identify potential new strategies for further research in order to keep Europe's manufacturing industry not only alive, but fully competitive and in a strategically leading position, thereby enhancing the prospects for employment in Europe. This includes the development of new disrupting methods and IT support as well as the promotion of new stabile networks. This will substantially include field studies, which investigate the real business needs, as well as the constraints, depending on companies' product categories, enterprise structures and size, in order to ensure that the project results will lead to substantial improvements in the immediate future"(AITPL 2005).

## 2 State of the Art

Today's highly competitive markets for new products result in an increased collaboration, often between competitors, during product design and development phases. Current design processes are characterized by the use of distributed resources. 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 of 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. Ambient Intelligence (AmI) technologies like RFID are now more often applied in logistics and Supply Chain Management, but as they are merely replacing older identification techniques they are by themselves not exploiting the full potential of the new technologies. There is no substantial use of AmI at the production ramp-up and manufacturing. Further applications are different stages of pre-competitive research, e.g. approaches for self-controlled production, scalable virtual reality technologies or intelligent supply chain support.

The technological and research challenges, which were discussed during the AITPL cluster events mentioned above, can be classified into the following main areas (Frederix et al. 2006):

1. Development of intelligent products, which possess and collect relevant information during their "lifecycle" supported by Ambient Intelligence Technology.
2. To develop intelligent production processes which adapt themselves according to the request of the customer, the resources or the (intelligent) products
3. Development of new context-aware services and methods supporting AITPL.
4. Development of technologies and processes which lead to trust and confidence with respect to security, policy, privacy, IPR and legacy aspects.

# 3 Towards Intelligent Products and Processes

## 3.1 Intelligent Products

Intelligent products are automatically identifiable and in addition they *own information* about their history and their intended future, as well as potential alternatives for their future path. Historical information can minimize the risk and maximize the economic benefit of critical parts, e.g. in car, aircraft, space or protection products.

Today, significant economic benefit is lost in Europe as the exchange of parts is just decided because of time elapse or a number of use cycles. This is still not eliminating the risk that the part breaks for specific reasons before this exchange. A new generation of products will *collect multiple sensor data* and will use own intelligence to compute the risk of further use, delivering this information to actors such as senders or simply colour indicators. Such intelligence will also reduce the risk of counterfeits and hence protect the European product developers. Furthermore, it will allow a much more effective maintenance, and *enable e-maintenance* of a broad set of products via mobile wireless devices and smart tags. This will again reduce the manual effort for the global service of parts (e.g. in industrial equipment) and thus give advantage especially to European exporting companies.

The lifetime of many products is limited not by wear and tear, but by the outdated software that is included. This is of high competitive importance, as the software value of products is increasing continuously. In a not too distant future, services will be common to update intelligent products at the customer site. Products with these features will be more successful, and they will also significantly contribute to the protection of the environment. In a longer-term vision towards 2020 when products will be online (Internet present), information exchange and thus updates and *mass customisation of services* offered by intelligent products, will be straightforward. Intelligent products 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. As a result of the combination of physical object and virtual/online services that can constitute an integral part of "product-service packages", the value of such products throughout their lifetime will be much higher.

The discussion also revealed additional characteristics of intelligent products like: *self-management* that enables products to manage their own characteristics, move and use. Attention was also drawn to the feedback of product information from the time period of product use to the phase of product design, the use and ageing of a product to recycling, and questions regarding environmental and safety issues.

Intelligent products present a new knowledge-based added value. The design of such products requires novel approaches like inter-organisational collaborative development and participatory engineering methodologies that aim at both products and intelligent services, which are bound with them.

## 3.2 Intelligent Production Processes

Today, mass customization is still not usual, but at the same time it faces its limits already. One of the major challenges in automotive industry is the extreme number of possible variants, where each customer change can have an impact on dozens or hundreds of components. The customer recognizes a limited set of options, only, and even he may not combine them, freely. The European industry would achieve world leadership by replacing mass customization with co-design, giving to the customer a high degree of freedom to change the product or its features. Especially, SMEs could operate successfully even on global markets, offering co-designed niche products (Auto ID Lab 2006).

High product variability requires new approaches to control production. It is expected that the approaches to “self-controlled production” under development will be a starting point, only. Totally new methods will be necessary to exchange knowledge among the single parts (using knowledge for its lifecycle) and the crowd that is represented by a product type, which needs to acquire knowledge from all the “experience” made by its members. Thereby, it is of vital importance to consider the mechanisms related to the entire supply chain. This also affects all types of planning and control systems as well as software maintenance in such highly distributed systems, including the need for new approaches to the modelling and management of highly distributed systems. In fact, today the knowledge about such highly distributed systems with separation of individual and collective experience is merely not existent, which limits current approaches to intelligent production systems, drastically. The nation, which first crosses this barrier, will have significant advantages for years with respect to their competitors from other continents.

Novel paradigms of production may be achieved through adoption of new knowledge-based approaches, like active knowledge modelling. In order to achieve given production goals, the last mentioned approach is built upon reconfigurable visual enterprise models, which enable representation and processing of complex dependencies between intelligent production processes, products and all resources, being technical or human. This visual knowledge-based modelling approach enables the reuse of production models and their components to form new dynamically reconfigurable production flows, and in consequence, supports flexibility and quick responsiveness to market demands.

## 3.3 New Context-aware Services and Methods

Today, the so-called “Digital Factory” is still poor, as it either gives an integration of production system data (typically, with inaccurate 3D information about production, and insufficient information about logical flows) or it is simply the VR representation of a factory, frequently with limited impact on the detection of planning faults.

Methods and services are required that ease the integration of product design, production system development, production ramp-up and manufacturing control. Full integration of these fields is unlikely in the next ten years (and might, if standardized, even block innovation). Therefore, the context-aware provision and scalable representation of information among the disciplines involved is essential, using traditional representations (tables, drawings) as well as VR and AR technologies. A significant reduction of the time-to-market (leading to higher profits and therefore the chance to produce in more expensive countries) can be achieved by integrating the different tasks of factory architecture, layout and media planning, material flow simulation, planning and control system customization in an intelligent, context-aware way, and by the provision of new kinds of services in this area. This could even strengthen the position of SMEs and VSMEs, which could offer clearly dedicated niche services for all kinds of factory planning solutions.

Today, many hindrances are seen in the lack of suitable standards or even terminologies. Therefore, the development of ontology and standards seems to be an important fertilizer. Potentially, new types of coordination activities could work across suitable R&D projects in order to establish first approaches to such standards.

## 3.4 Security, Trust and Confidence

There are many issues which are not solved (or not even recognized) in the AITPL area, which hinder new applications due to missing IPR, confidence and trust. Still, neither the ownership of information and knowledge stored within distributed elements is clear, nor the responsibility for correctness, security and actuality.

Therefore, initiatives, which lead to clear and accepted regulations for these issues will accelerate and fertilize all the topics mentioned above.

Securing engineering data during the whole product lifecycle is a demanding, three-dimensional task: technical, organizational, and legal. One needs to consider all three aspects when constructing consistent, robust and secure infrastructures that enable trust and confidence among the partners involved in the product lifecycle. Organizational and legal issues are relevant for the privacy of involved partners. Assurance of security is not a single act, but rather a process, as apart from already existing sources of threats, new dangers are constantly appearing that need to be correctly recognized and neutralized. The choice of the most adequate security framework for a particular product lifecycle heavily depends on the design and deployment domains of the product. This choice is also influenced by the fact that the organizations involved in a particular product lifecycle have their own legacy systems and are not always able to deploy particular new techniques without interfering with their existing solution.

Although the security issue requires significant attention, both in research and in the domain of the networked enterprises, there are still many R&D challenges that must be addressed during the next decade, like harmonisation between security and collaboration technologies, credible assessment of a security level, and seamless co-ordination among diverse security applications being deployed.

Assessment of a security framework through creation of a universal and (possibly) complete system for assessing the security level would help in establishing more secure product lifecycles (FLUID-WIN 2006).

## 4 Conclusions

The primary goal of the use of AITPL research activities 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.

AmI technologies with novel intelligent product features will enable anthropocentric process automation, advanced knowledge engineering, as well as remote monitoring and maintenance of products. In particular, 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 easily be able to join the network.

Secure collaborative engineering networks, which easily integrate 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 developing a 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.

Many challenges in R&D need to be addressed successfully before the presented visions become an everyday practice. Approaches are required that combine different elements of ambient intelligence for new products or services. The resulting technologies should be in a stage where they can be applied in enterprises of any size, supporting completely new types of information management.

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