Some Aspects of Ambient Intelligence

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Abstract: Nowadays the competition among companies, joined to the environmental protection rules, is so compelling that they should not only be on the top of technology in they area, but also run their business according to life-long models. The emphasis on the product post-sale life is common for these models. The most popular model is Product Lifecycle Management, for manufacturing companies, or Service Engineering, for service-oriented companies, and, for both, common paradigms are in maintenance, with conformance-to-use certification. The paper introduces basic research results achieved in application of Ambient Intelligence, and suggests considering maintenance as a cross section of the two business paradigms.

Keywords: Product Lifecycle Management, Service Engineering, Knowledge Based Systems, Condition Monitoring Maintenance, Ambient Intelligence

1 Introduction

In today's highly competitive global economy, the companies should produce high quality products and/or services at lower costs in shorter time (see [1]). This demand forced a number of manufacturing/service industries to apply new strategies for product design, manufacturing and management. For the last decade, the information technology sector made big advance. It made it possible to implement new supply chains, delivering *products-services*, supported by co-operating organizations. This type of changes opened horizons to enable new business paradigms, such as product lifecycle management (PLM) or service engineering (SE), embedding high-intensity information flow, with enhanced transparency of the material resources decay and with increased intangible value added. These paradigms make it possible for networked companies to be more competitive in a novel business area, improving after-sale service, products maintenance and recycling.

This paper will give some details on most necessary disciplines and programming tools and methods to understand and realize a very characteristic example: predictive maintenance.

2 Some Corresponding Production/Business Paradigms

Recently, manufacturing world was moving from an economy of scale to an economy of scope, under the global economy for customers' satisfaction ([1], [3]). Under that conditions, for most companies around the world, surviving in business means to satisfy three challenges, they are: to meet customer requirements; to reduce the time-to-market of their products; and manufacture products at lower environmental impact. These changes in industry have been reflected on human society. Following [3], the earlier affluent society, needs be turned into a more conservative thrifty society, as the world, we are living in, cannot deal with ceaselessly consuming raw materials.

Of course, as well known ([1]), the goal in the industrial economies is value creation by marketing products. Nowadays, in many businesses, the created value consists of many components and the weight of the value related with tangible product turns to be but a fraction of the whole delivery. In the thrifty society, frugality and recycling play a relevant role; the traded artifacts are replaced by products-services, supported by extended enterprises ([3]). This type of business organization has been acknowledged, and led to the so-called Product Life Cycle Management (PLM).

This paradigm makes possible the manufacturing set-ups complying with the thrifty society demands, due to the transparent recognition and control on resources decay and environment burden. The previous challenges for companies add or extend over new ones. If formerly meeting customer satisfaction meant to develop product with high performance and quality, nowadays companies need, moreover, supply lifelong services and maintenance procedures, including dismissal and recycling incumbents. Te above-discussed issues led to Service Engineering (SE) and to new rules on the market:

Rule 1 It is not enough to produce the required product, but the most important is to produce after-sales services, which satisfy or, in some cases, predict, as well, the customer requirements, complying with the enacted environment protection rules.

Rule 2 Reducing the time-to-market period of the product means the reduction of the time-to-market period of the services, supplied as integral part of the delivery, with due concern on the technological sustainability of the traded goods.

Rule 3 Not only goods should be developed to satisfy demands of low cost and eco-consistent quality, but accompanying services shall, as well, satisfy these demands, further providing full visibility of the impacts on the human natural surroundings.

2.1 Product Life-Cycle Management (PLM)

The Product Lifecycle Management, PLM, concept appeared in the second part of the 1990's. This concept provides a platform to share product related knowledge across an extended enterprise, from product design and creation, through dissemination and after sales services, up to product dismissal and recycling. Following [2], PLM is defined as *"a new integrated business model that, using ICT technologies, implements an integrated cooperative and collaborative management of product related data, along the entire product lifecycle, dismissal included"*.

The right hand side of Fig. 1 shows that PLM joins three main chains of the extended enterprise: Engineering chain, Operation chain and Support activities chain. Any chain consists of sub-processes. For example, Engineering chain contains three sub-processes: product design, process planning and factory planning. It is possible to highlight several reasons, which led to build a PLM. From the manufacturer viewpoint, product innovative up-grading, customer-driven quality, operation excellence, etc., require enhanced visibility on actual lifecycle data. From the outer market viewpoints, items responsibility at the point of service, product complexity, shrinkage in the duty life, dismissal incumbents, etc., push toward higher transparency of supply chain and environmental issues. The implementation of the PLM concept is impossible without proper ICT tools. [4] details the impacts which PLM gives to ICT solutions applied in manufacturing. Some of them are the following:

- It makes a closer connection between, on one side, engineering and manufacturing and, the other side, finance and marketing, assessing the criticality of the design steps for the after-sale services.
- It provides a unified information model to take into account all relevant facts throughout the delivery lifecycle, assuring data-vaulting organisation and recording, fulfilling all the needs of the direct or indirect stakeholders.
- It fills the gap between enterprise business processes and product development processes. Following [4], PLM works as a glue which adhere all the processes that have something to do with product and connects all functional silos to make them horizontally integrated.

The build-up of PLM solutions requires to re-engineer the company's business processes and to implement the supporting ICT solutions. As concluded in literature (e.g. [2]), PLM links together, not only processes at the engineering, operation management levels with non-production services (like marketing, sales, after sales, quality or maintenance), but, also, the supporting ICT solutions. The management of maintenance activities is often integrated into Product Lifecycle Management (PLM) tools (see [8]). The two main reasons for using PLM tools are process integration and data integration. Therefore, they usually consist of a workflow and a data integration component (see [8]).

2.2 Service Engineering (SE)

Although, methodologies related with organizations providing services are covered in PLM, it is more focused on integration of services with manufacturing processes. According to that so-called Product-Service supply can be developed, where the emphasis can be either on Product part or on the Service part (see Fig. 1). If the importance is on the Product part, the model is fully applicable for several business cases but, from the authors' point of view, for the non-manufacturing business the discipline, called Service Engineering (SE), is more appropriate. This business paradigm makes the stress on Service part of Product-Service supply (see Fig. 1).

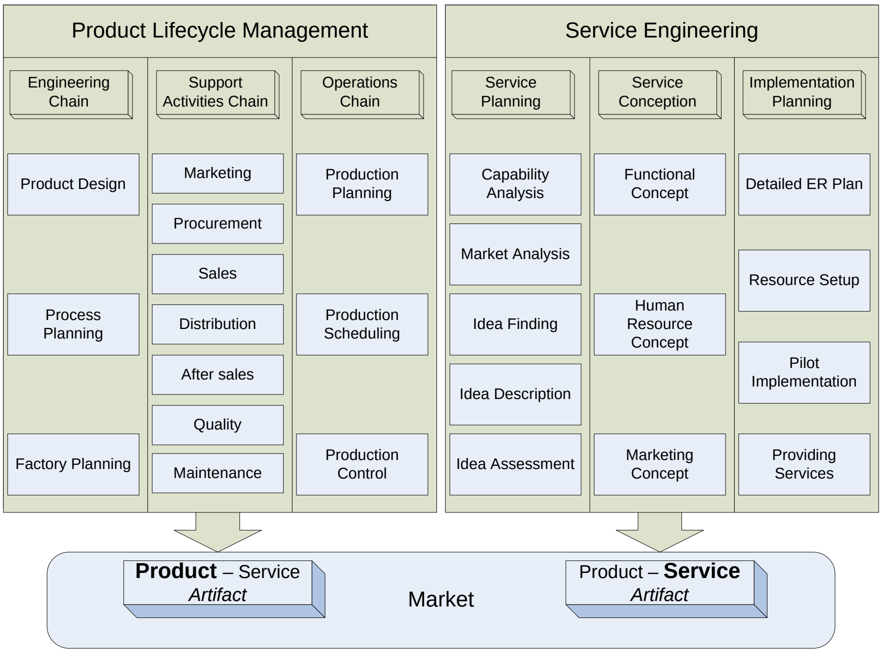

Figure 1
PLM and SE business paradigms

Service Engineering is a new research discipline ([5]), which mainly deals with improving design process of the service, developing, implementing services design, development and execution as corporate function. At last, but not least, the service engineering has to deal with service-oriented human resource management. In some aspects Service Engineering is very similar to the PLM concept. Service Engineering assumes that services can be designed and re-developed in a similar manner as physical products. Based on [5] the process of service design and development has three major phases, which include some set of sub-processes. These are: service planning, service conception and service implementation (see the right hand part of Fig. 1).

One example of the ICT solutions for the tasks considered in SE are e-maintenance systems. These systems can vary from product supported or from engineering/business field of application. Like PLM solutions they may consist of different modules and tools. Some modules can evaluate products, machines or other equipment without human intervention or adjust monitored objects to avoid breakdowns or undesirable situations.

2.3 Extended Products

As the term extended enterprise comprises more than just a single enterprise the term extended product [23] should comprise more than just the core or tangible product. The view of the EXPIDE project of the EU [24] works on extending a formerly tangible product. For that reason different services in an intangible shell around the tangible product should be the focus. The explanation for this idea is depicted in a layered model (concentric rings) that can be applied to various types of products.

The layered model was developed in order to structure the extended product approach. This model shows a type of hierarchical, physical extension of (extended) product services. The concept with three rings can be described as follows:

- There is a core product that is closely related to the core functions of a product. As an example, this approach can be taken to characterize the various types of shapes of a part: Shapes that are relevant for the functionality and others that are not that relevant i.e. shapes where the freedom of the designer to define tolerances, etc. is higher. Consequently core functions of a car are parts like engine or wheels.
- The second ring describes the packaging of the core functions. The second ring only includes tangible features of the chosen product. The features of the tangible product are different from manufacturer to manufacturer (supplier to supplier). In the car manufacturing industry we have Mercedes/Porsche and Daihatsu/Fiat which both supply cars but are they doing this in a similar fashion? The answer is clearly "no".

In spite of the above given logical explanation the distinction between core product and tangible product is not trivial and not (yet) commonly accepted.

- The third ring summarizes all the intangible assets of the product. Intangible assets surround the tangible product. In general they could be the same for similar products. However, in practise they can be quite different, for example, if we compare the Mercedes/Porsche and Daihatsu/Fiat service strategies. While Mercedes/Porsche are very concerned with the customers' demands, Daihatsu/Fiat are continuously concentrating on reducing the costs in order to offer the cheapest possible cars to the customer.

In the following, where we take into account product lifecycle and service engineering we are concerned about services which are necessary for the lifecycle of the product, unlike the EXPIDE project which extends the product mainly by services provided by the product.

3 Maintenance - a Link between PLM and SE

Maintenance activity usually included in PLM paradigm and in Service Engineering as well. In other words maintenance is an overlapping area for these two paradigms (see Figure 2 for a simplified view).

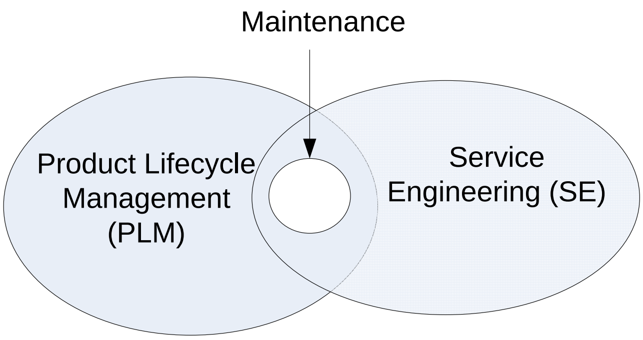

Figure 2
Maintenance is a cross-paradigm area

There are several types of maintenance strategies, commonly in use today. The first one is breakdown maintenance (in some cases called as corrective maintenance, see for example [6]). Alternatively more elaborated strategies can be devised, which partly give possibility to avoid the failures by preventive (or planned) maintenance, either, to detect the symptoms of anomalous running and to enable reactive or proactive maintenance operations, before actual failures develop.

On the base of [6], three different approaches of the preventive maintenance are mentioned.

- Systematic/Scheduled Maintenance
- Conditional Maintenance [12]
- Predictive Maintenance - e-Maintenance

3.1 Knowledge Based Systems

Knowledge-Based Systems are computer programs that use knowledge about some domain to reach a solution for a problem of that domain. This solution is essentially the same as a person knowledgeable enough about the domain of the problem would conclude it when he was confronted with the same problem. Knowledge based systems allow us to separate the knowledge and the search/inference engine.

Reasoning methods and tools are providing ways of Knowledge Management from knowledge capturing to re-use for reasoning. Generally, the complete lifecycle of knowledge management is supported by different ways as:

- To capture, to store and to maintain the knowledge in different forms.
- To provide mechanisms to re-use this knowledge for reasoning on 'similar' problems.

There are several reasoning methods covered by research activities, as: deductive and probabilistic, causal and temporal, frame-based and case-based reasoning.

3.2 Agent Based E-maintenance Systems

The agent based e-maintenance systems are alternative to the centralised KBS approach. In this case, the intelligence of the KBS is distributed between agents, specialised to monitor the different parameters. The benefit of such systems is that the agents can be technologically oriented on the monitored product, communicate to each other and provide not only data, but higher-order information.

An example of agent-based solutions can be found in [9]. Solutions are given to execute predictive maintenance of industrial machine tools. And it can be applied for other product-service delivery, too.

The core-enabling element of an intelligent maintenance system is the smart computational agent that can predict the degradation or performance loss, not the traditional diagnostics of failure or faults. In case of [9], these agents are called as “Watchdog Agents” and can be described as devices with embedded computer (with software agent), which provide the intelligence. Agents may transform data to information, and information to knowledge and synchronize decisions with remote systems, contain embedded prognostics algorithms for performance degradation assessment and prediction. A product’s performance degradation behavior is often associated with multi-symptom-domain information cluster, which consists of degradation behavior of functional components in a chain of actions.

But there is a main drawback of the system described in [9] and many other agent-based solutions available on the market is that their high level system automation possibilities and human oriented interfaces are not incorporated enough. The situation can be changed drastically by implementing Ambient Intelligence (AmI) concepts.

4 Ambient Intelligence - Enabling Technology for Maintenance

4.1 The Concept of Ambient Intelligence (AmI)

The concept of Ambient Intelligence (AmI), relies on provisioning of *ubiquitous computing, ubiquitous communication,* and *intelligent user adaptive interfaces.*

Ambient intelligence is a rapidly increasing field of information systems that has potential for great impact in the future. The term "ambient" is defined by the Merriam-Webster's dictionary [14] as "existing or present on all sides". The term Ambient Intelligence was defined by the Advisory Group to the European Community's Information Society Technology Program [15] as "the convergence of ubiquitous computing, ubiquitous communication, and interfaces adapting to the user" [16]. Ubiquitous should also be defined since the core domain of AmI envelops this concept.

Ambient Intelligence incorporates properties of distributed interactivity (e.g. multiple interactive devices, remote interaction capabilities), ubiquitous computing (the “invisible” computer concept), and nomadic or mobile computing. Ambient Intelligence has the potential to provide the user with a virtual space enabling flexible and natural communication with the computing environment or with other users, providing input and perceiving feedback by utilizing proportionally all the available senses and communication channels, while optimizing human and system resources [13].

The objective of AmI is to broaden the interaction between human beings and digital information technology through the use of ubiquitous computing devices. Conventional computing primarily involves user interfaces (UIs) such as keyboard, mouse, and visual display unit; while the large ambient space that encompasses the user is not utilised as it could be. AmI, on the other hand, uses this space in the form of, for example, shape-, movement-, scent- and sound-recognition or -output. These information media became possible through new types of interfaces and will allow drastically simplified and more intuitive use of devices. Wireless networks will be the dominant technology for communication between these devices. The combination of simplified use and their ability to communicate will eventually result in increased efficiency for users and will, therefore, create value, leading to a higher degree of ubiquity of computing devices. Examples of such devices range from common items such as pens, watches, and household appliances to sophisticated computers and production equipment.

4.2 Ubiquitous Computing

Mark Weiser [17] coined the term "ubiquitous computing", referring to omnipresent computers that serve people in their everyday lives at home and at work, functioning invisibly and unobtrusively in the background and freeing people to a large extent from tedious routine tasks. The general working definition of ubiquitous computing technology is any computing technology that permits human interaction away from a single workstation. This includes pen-based technology, hand-held or portable devices, large-scale interactive screens, wireless networking infrastructure, and voice or vision [18].

In its ultimate form, ubiquitous computing means any computing device, while moving with you, can build incrementally dynamic models of its various environment and configure its services accordingly. The devices will be able to either "remember" past environments they operated in, or proactively build up services in new environments.

Ubiquitous computing is roughly the opposite of virtual reality. Where virtual reality puts people inside a computer-generated world, ubiquitous computing forces the computer to live out here in the world with people [17].

4.3 Ubiquitous Communication

Today, numerous objects are equipped with computers, i.e., our environment already exhibits a relatively high level of ubiquitous computing. However, in most cases, the computers do not operate at their full potential since they are unable to communicate with each other. A major change in the corporate and home environments that will promote ubiquitous communication and, thereby, ubiquitous computing is the introduction and expansion of wireless network technology, which enables flexible communication between interlinked devices that can be stationed in various locations or can even be portable.

The agent technology is one of the enabling technologies for realization of AmI concept in life. Following [7] it is possible to say that agent technology will provide new distributed architectures and better communication strategies for the applications, making easier the information exchange and allowing to integrate new modules like sensors or diagnosis algorithms with less effort from customer and machine tool builders' point of view.

4.4 User Adaptive Interfaces

User adaptive interfaces, the third integral part of AmI, are also referred to as "Intelligent social user interfaces" (ISUIs) [19]. These interfaces go beyond the traditional keyboard and mouse to improve human interaction with technology, by making it more intuitive, efficient, and safe. They allow the computer to know and sense far more about a person, the situation the person in it, the environment and related objects, etc., than traditional interfaces can.

ISUIs encompass interfaces that create a perceptive computer environment, rather than one that relies solely on active and comprehensive user input. ISUIs can be grouped into five categories:

- Visual-recognition (e.g. face, 3D gesture, and location) and -output
- Sound-recognition (e.g. speech, melody) and -output
- Scent-recognition and -output
- Tactile-recognition and -output
- Other sensor technologies

Traditional user interfaces like PC-controlled touch screens in a company environment and user interfaces in portable units such as PDAs or cellular phones can also become ISUIs. The key to an ISUI is the ease of use, say, the ability to personalise and automatically adapt to any particular user behaviour patterns (profiling) and actual situations (context awareness), by means of intelligent algorithms. In many cases, different ISUIs, such as voice recognition and touch screen, are combined to form multi-modal interfaces [20].

Interfaces, especially user interfaces are one of the crucial building blocks for AmI, because they define the experience the user will have with the intelligence surrounding him/her. Major importance is attached to the so-called natural-feeling human interfaces and to multimodal interfaces. Vision technologies and displays are part of the interfaces as well. Breakthroughs in user interfaces are important for consumer acceptance, not only, for the mass markets in general but also for people with disabilities in particular. The vision of AmI assumes that the physical interaction between humans and the virtual world will be more like the way humans interact in the real world, hence the term natural interfaces. Humans speak, gesture, touch, sense and write in their interactions with other humans and with the physical world. The idea is that these natural actions can and should be used as explicit or implicit input to AmI systems. Interfacing should be completely different from the current desktop paradigm (GUI-Graphical User Interface) based on keyboard, mouse and display. This also means that interfaces should be multimodel, as humans communicate in a multimodal way against machines that typically operate in a single mode. Moreover, with current interface technology humans must learn and understand the computer language; in the future, this would be the other way around.

We should also consider the intelligent interfaces between the components (i.e. products, production units) in a shop floor environment. Machines and products should communicate with each other in order to realize the intelligent behavior of the system. This kind of communication requires other types of adaptive interfaces.

4.5 Some Application Fields and AmI Drivers

The AmI vision anticipates that ICT will increasingly become part of the invisible background to peoples' activities and that social interaction and functionality will move to the foreground resulting in experiences that enhance peoples' lives. From this anticipation, it is clear that AmI could and should be found everywhere in the human environment.

The realization of AmI concepts will lead to establish a collaborative working environment, where virtualized entities will communicate to each other. These entities can be (see [11]) humans, artificial agents, web/grid services, virtualized-entities representing the real things (not only human beings), descriptions of human knowledge (knowledge based systems) etc. Following [11] these entities will be able to interact with one another in an AmI environment to leverage the full potentiality of network-centric environments for creativity improvement, boosting innovation, and productivity gains.

Such networks will provide possibility for individuals to experience interaction with human and artificial agents in their working environments. AmI by the means of ubiquitous computing and communication technologies give great impact on future maintenance technologies and business paradigms like PLM and SE, as well.

4.5.1 AmI PLM

The main advantage of PLM solution for a company is that it integrates many enterprise IT solutions in one system, and, as result different processes, can be synchronised. Let us determine AmI PLM system as a system that supports and executes an integrated cooperative and collaborative management of product related data, along the entire product lifecycle by realising ubiquitous computing, ubiquitous communication and intelligent user adaptive interfaces. The implementation of AmI concepts to support PLM business paradigm will drastically change PLM systems. Different processes from different chains (see Figure 1) will be integrated in one virtual environment. The component of this environment will be entities which can be humans, IT systems (as ERP), intelligent software or mechatronical agents. These entities will communicate on peer-to-peer way and build up product oriented dynamic networks. These networks are dynamic because on different steps of product life-cycle different entities participate in the product oriented network.

The implementation of ambient intelligent concepts and integration it into PLM business paradigm will lead to appearance of new paradigm and new environment: the Ambient Intelligent Product Lifecycle Management (AmI PLM). The main benefits of such an environment will be the following:

- Concentrating information around product and creation product oriented environment for all steps of product life-cycle
- Enabling information sharing, easier access and management of the product related data
- Product information updates performed in real-time and in intelligent ways
- Product life-cycle management is getting easier
- Enabling products to carry and process information, which influences their destiny…

4.5.2 AmI SE and Maintenance

The impact of AmI on service providing and service engineering will be similar to impact on PLM. The realisation of the AmI vision will require the development of large, complex, heterogeneous, distributed systems. These must be built on heterogeneous platforms capable of providing seamless networking so as to support the delivery of layers of value added services or functional services to the individual, to industry, and to administrations. The resulting systems, comprising several interacting embedded software components, will need to be intelligent, self-configuring, self-healing, self-protective, and self-managed. It will lead to appearance of new type of services - Ambient intelligence services.

As it was discussed above, the management of maintenance activities is often integrated into Product Lifecycle Management (PLM) tools, or it can be some kind of service supported by independent ICT solution.

Maintenance tasks tend to be difficult (see [7]), they require expert technicians. Maintenance working conditions are characterised by information overload (manuals, forms, real-time data ..), collaboration with suppliers and operators, integration of different sources of data (draws, components, models, historical data, reparation activities).

Ambient Intelligence will provide a new working environment to maintenance technicians offering: access to ubiquitous and up-to-date information about the equipment wherever the equipment or the operator is (enabling remote maintenance and life-cycle management) and user friendly and intelligent interfaces (context-aware applications).

Advantages provided by the use of AmI in maintenance environment come from:

- Simplifying distributed computing: better distributed knowledge management.
- Intelligent resource management.
- Overcoming user interface problems.
- Overcoming data exchange and communication problems.
- Personalization, adaptation to the user.

The implementation of AmI principles in maintenance will lead to appearance of new type of maintenance - Ambient intelligent maintenance - and will give large possibility for realisation self-maintenance.

5 A Demonstration Project

One of our test beds for our ideas was the European Research Project, called FOKSai, [21], of which the acronym stands for "SME Focussed KM System to support extended product in Ambient Intelligence domain".

The main goal of the project is the development of a knowledge management (KM) system as an extension to Ambient Intelligent products for SMEs in four industrial areas. This main goal, common for the four consortium SMEs, will be achieved through the development of a sophisticated support system to the extended AmI-products of the companies. All these SMEs plan to introduce in the near future (next 1-2 years) new and/or improve their current products with even more AmI features seeing this as their crucial competitive edge. A considerable enhancement of business performances of the four SMEs will be reached by introduction of the FOKSai system mainly by reduction of time and costs for customer support (such as product maintenance, solving customer problems, etc.). The new support system should result in a significant shortening of down times of the AmI products and cutting of the maintenance costs.

5.1 Expected Results

Technically seen the project will develop:

- a methodology for extension of AmI products which will strongly observe business and organizational issues relevant for SMEs,

- a knowledge-based system to support extended AmI-products, which will be affordable for the SMEs.

The FOKSai solution is planned to be general enough to be applicable for different products and scalable to support future AmI products in order to achieve a product (methodology and knowledge management system), which can be offered to a wide spectrum of SMEs intending to introduce AmI products in their product portfolios.

The topics of customer and product support to be developed and demonstrated as pilot installations within the environments of four SMEs in the project consortium include:

- remote supervising, problem identification, problem solving, maintenance of heterogeneous customer systems, and subsequently reduction of efforts/costs for searching of the reasons of problems in products containing AmI components,
- e-supporting manufacturer's staff at remote customer site location to solve customer/product problems,
- proper integration and sophisticated knowledge-based interpretation of the intelligent ambience information and "reactions",
- gathering and structuring of the AmI-product and process knowledge, from the problem solutions, for the reuse in innovations introduction,
- direct feedback from user to AmI-product/service design and development.

5.2 Main Concepts of the FOKSai Project

A generic concept of the system was identified based on the requirements of the end-users. According to this basic concept the system comprises the following modules:

- *Common Knowledge Base* (CKB): The central repository of the product related knowledge, containing the data and information on problem solving, knowledge on AmI features in products, results of analysis of AmI information and product reference information.
- *Product Support*: This module includes information, documents and knowledge relevant for product and customer support (e.g. information on new product models, new services, advises how to apply products and services in order to avoid problems etc.).
- *Diagnostic Engine*: The central KM based module providing interactive problem solving assistance to users. This module, based on the proven case-based reasoning method, allows to quickly get the required problem solving suggestion. The interactive features also allow user to add useful

information – the system ‘learns’ as the knowledge base grows.

- *Collection and Analyser*: This is an interactive tool to build the knowledge base, and enabling the user to organise the information in it to suit optimally the decision making support by problem solving. This module provides the facilities for the users to analyse the knowledge in the knowledge base, as well. The users can analyse the most frequent problems and to decipher customer feedback regarding products or services, specifically regarding AmI features.
- *AmI Information Processing Module*: This module processes information from the AmI parts of the product as an input for the diagnostics support and for the Common Knowledge Base.

These modules are connected to the customers with interfaces on one side and to the suppliers to perform design and service on the other side.

5.3 Business Cases

Based on the system concept the four different business cases in the different project partner companies have been identified and the user requirements have been specified, that have resulted in detailing of the system modules and relations among them and to the legacy systems. The dissimilarity of the firms and countries ensures, that the results of the project can be later widely used.

The objective of the first Business Case (RegioData, Germany) is to establish a new form of customer support by implementation of a new methodology and ICT system to support the already introduced extension in the form of remote maintenance system, which is the step further in the customer support. The new system should include not only system status and ambient related data but also the data illustrating the state of the (running) system performance.

In the second Business Case (LANeX, Hungary) the need of very high data security providing the users trusts in such a system is obvious. Taking into account the number of measurements and information, from the intelligent ambient and network, which are analyzed continuously as well as their mutual dependencies, it is clear that a rather complex KM system is necessary for the proper remote product maintenance. The application of the knowledge-based and web-based FOKSai system will have to provide the quick reactions to any disturbance, taking into account the importance of the information processed. The extensions to the products, connected to its monitoring and control system, have to be scalable in order to offer a high variety of services. A pro-active customer support will be needed, offering to the operator an online help and consultancy function. The pro-active concept should enable also a collection of feedback from customers in order to improve services continuously. The feedback from customers will be analyzed and forwarded to design department as well, aiming at continuous innovation of services and equipment.

The third Business Case (DISTEC, Spain) focuses on several activities, which can be mainly summarized as control engineering, technical process automation, tele-management, studies and technical projects. Tele-management can be defined as the remote management for technical installations, which allows the monitoring, management and actuation (when it is required). Furthermore, it can also be applied to different areas, such as chemistry, metallurgy, textile industry, potable and residual waters, control of refrigerator chambers, electrical mini-centrals, etc.

The SME in the fourth Business Case (CTOOLS, UK) produces process automation and cutting machinery and supplies other companies with turn-key solutions. Installation and set-up support as well as problem solving support provided on-line (mainly per telephone), either to own field engineers or to customer maintenance staff, is one of the most important activities of CTOOLS. CTOOLS is though often requested to send engineers to solve problems at the customer's site as well. This 24 hours support, in either form, involves rather high costs. Increasingly complex CTOOLS machines (products) require a number of built-in measurements and control of the correct performance of the machines.

5.4 An Early Prototype

As described in section 0, the FOKSai system is divided into several modules. The early prototype comprises these modules with restricted number of the functionalities (Fig. 3).

Common Knowledge Base

The Common Knowledge base (CKB) has the objective of storing all the information that describes products and processes, as well as all the necessary information related to these components. This repository was implemented at the end users as a relational database, using Oracle or MySQL, depending on their individual requests. Further completion of the data in CKB will be done during the full system prototype development, but no refinements and changes are planned in the CKB structure.

Set-up Module

The Set-up Module is a clear and efficient graphical user interface, that enables the users to understand the meta model and make the best use of it. This Module has been realised in the scope of the early prototype as a stand-alone java application, installed at the companies. This module supports the definition, modification and deletion of all the information that constitutes the static data of the Common Knowledge Base. In addition, this Java application will include in the full prototype the corresponding functionality to administrate the users of the FOKSai system, including the definition of users and user groups, and the definition of rights for each user group, regarding what could be accessed, modified and/or deleted in the system.

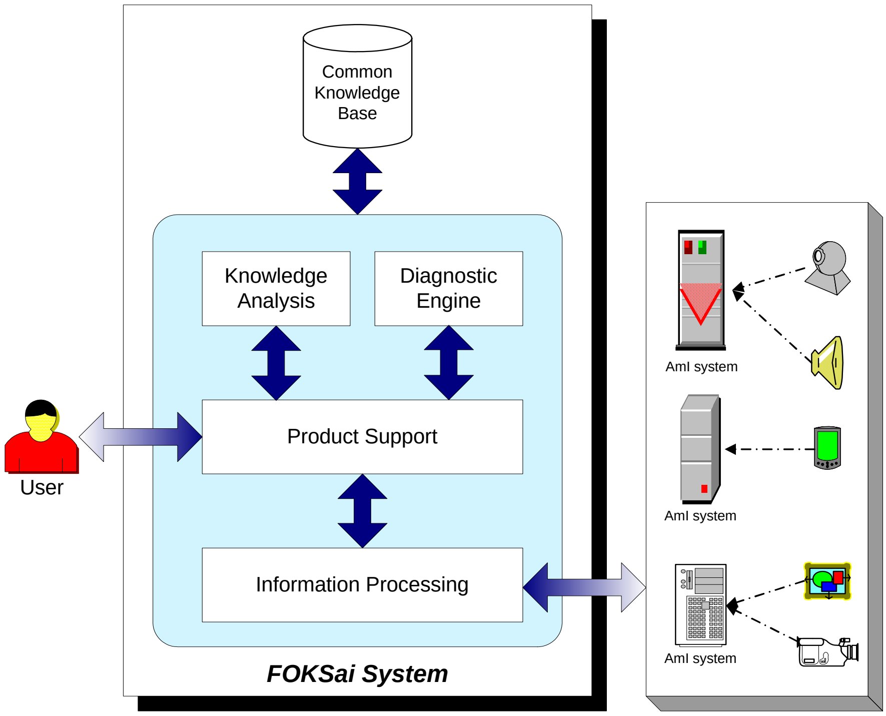

Figure 3
FOKSai modules

AmI Information Processing Module

The main function of the AmI Information Processing Module (AmI IPM) in the early prototype is to map the input XML data to the Common Knowledge Base (CKB). AmI IPM does not have a Graphical User Interface (GUI) in the early prototype, just a command line input, where the input file name can be given, and text based output, to where it writes certain messages to let the user or tester know what is going on during the tests.

This module has been developed using the 1.4 version of J2EE SDK. For the easier development the Eclipse Project software suite was used as a GUI to help the work. For the parsing of XML files the SAX XML Parser was integrated into this module. The early prototype of the AmI IPM - as a standalone Java application - was tested with the simulated data of the business cases. The input data was written into XML files according to the defined structure in the schema file.

Diagnostic Engine

The Diagnostic Engine (DE) provides interactive problem solving assistance to the users, using the structured method of Case-Based Reasoning (CBR) to rapidly get the required problem solving information. This module has been implemented in C++ using the function library of the ReCall [22] tool, and connected to FOKSai system through a CORBA interface. The user uses DE's functionality and accesses its results through the Product Support Module. The testing of this module was done through the assessment of the Product Support Module, as described later in this document and its functionalities are fully hidden from the system user.

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Product Support Module

The Product Support Module (PSM) is the central point of interaction between the user and the FOKSai system, i.e. it contains the Graphical User Interface. In addition, this module will include information, documents and knowledge relevant for product and customer support (e.g. information on new product models, new services, advises how to apply products and services in order to avoid problems etc.). The early prototype of the Product Support Module is implemented in Enterprise Java Beans (J2EE1.4), and available through a Java Graphical User Interface only.

Knowledge Analysis Module

The Knowledge Analysis Module (KAM) is comprised of three main functionalities:

Statistical Analysis: FOKSai users can create Pareto charts of the most common problems by type and severity using the utility. Users also can list all those charted problems using a special utility. This tool is intended to be used for problem identification.

Database Query Tool: It allows FOKSai users to perform flexible database queries simply selecting the predefined items available. FOKSai administrator can create and store SQL queries in order to allow other users to use them.

Administrator can easily create specific queries for CKB Maintenance according the necessities.

Knowledge Analysis (KA): FOKSai users can use a forum in order to provide statistical analysis reports and send feedback to design staff, create and upload maintenance reports, receive online technical support, obtain quick fixes for current problems or know everything about new developments on products.

The KA module is connected to the PSM and the CKB and is accessible using a web browser. At full prototype stage, it will also be accessible through the PSM. In essence, this module allows the users to perform Statistical Analysis of the problems stored in the CKB, lists the problems selected, any table of the CKB for maintenance purposes and provide feedback to FOKSai users via a Forum tool. KAM module uses SSL and form-based authentication, which allows the users to search among all forum elements.

Conclusions

This paper gives a bird-eye view on the emerging options offered by distributed intelligence tools to foster competitiveness in the supply chains of industrialised countries. The ICT tools are recognised driving support, basically, on their ability of providing information-intensive aids, in parallel to the traditional trading of manufactured goods. This has falls-off on the value build-up, enhancing direct intangible provisions, and opening indirect opportunities with *product-service* deliveries, on condition that suitable ICT tools are implemented. The new business paradigms are strictly grounded on the availability of the full transparency over the product lifecycle, with profit of the manufacturers (according to economy of scope rules), of the users (for reliable conformance-to-specification management), and the third parties (for better eco-consistency compliance). The prospected analysis moves from the connections that link Product Lifecycle Management, PLM, and Service Engineering, SE, to show how these are the information prerequisites to aim at Condition Monitoring Maintenance, CMM, set-ups, built as Knowledge Based Systems, to provide the Ambient Intelligence, AmI, consistent with the new business paradigms.

The discussion is restricted to the domain of the ICT co-operative infrastructures, supporting products-services by networked organisations, say, clusters of enterprises that collaborated for any given delivering, with benefit of the customers having a unified responsible over the life-long exploitation of the purchased goods. This certainly does not means that the manufacturer will keep in charge of the whole activity (even if this seems to be prospected by the EU rules, on the suppliers responsibilities), rather than proper out-sourcing could establish, on condition that appropriate PLM/SE tools are provided together with every *extended* artefacts, to make operative the supporting *extended* enterprises.

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