Ambient Intelligence in Manufacturing: Organizational Implications

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ABSTRACT
There are several references to research projects involving the Ambient Intelligence concept (AmI) in technical publications. These are mainly focused on applications linked to the everyday life of individuals - at home, in the street, in the car, in public spaces – and largely related to leisure and to a specific concept of quality of life. But, we wonder, how does the AmI concept apply to the manufacturing field? What's going on in the industrial environment? In this article we introduce a research project, Tekniker Foundation[1] is currently conducting on organizational implications of the application of the AmI vision in a Manufacturing environment.

Author Keywords
Ambient Intelligence, Manufacturing, Organizational implications.

ACM Classification Keywords
H5.3 [Information interfaces and presentation (e.g., HCI)]: Group and Organization Interfaces---Computer-supported cooperative work, Organizational design.

H5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces---User-centered design.

INTRODUCTION
There are several references to projects linked to the AmI concept in technical publications. These are mostly centered on applications linked to everyday situations concerning human beings: at home, in the street, in the car, in public places and relating to leisure. What happens in the Industrial environment? The opportunities for its application in the field of work are frequently referred to, although it is mainly the office environment that is ever mentioned [1].
In two of the most important studies relating to manufacturing recently completed [2] [3], where some of the key technologies in the future of manufacturing have been identified such as flexible manufacturing and control systems, decision support systems, improved people-machine interfaces, equipment, re-configurable and adaptable processes and systems, distributed computation, etc., the link to AmI related technologies has been made clear.
Potentially, the adoption of this vision could affect all stages in the manufacturing process: the design of the plant or the product, engineering, the organization and management of production, process control, quality control, maintenance, logistics and the management of the product throughout its life cycle, including its re-cycling.
In this perspective:

- AmI approach affects the products that are manufactured: the products designed for this type of manufacture will also be intelligent, and able to communicate and report on advantages throughout the life cycle. The products will have greater added value, since they will incorporate "intelligence" and "connectivity" capabilities which will make it possible to provide new services.
- Systems will be easier to use, not because they are aimed at less well trained operators, but because operators with the right skills can find the most relevant information, at the moment they need it and use it to make more appropriate decisions. A consequence of this process will be freeing the worker from most routine tasks.
- Integrating human and technical resources to improve satisfaction and efficiency among workers. Given that the vision is human – centered, the implementation of all technologies will be thought from the workers perspective, to accomplish their needs and help to solve their potential problems.

How does this affect the work processes, the physical and mental health of the operators, motivation, stress, satisfaction, team work, the method of learning? For AmI to be socially accepted in the workshop, a great effort will have to be made to provide a human - centered design, in order to prevent it from becoming an environment where people feel surrounded by a unit of electronic parts. The present research also issues aspects such as privacy and

[1] http://www.fundaciontekniker.com

social impact of the implementation of AmI in a manufacturing environment.

AMI LABORATORY AT TEKNIKER

AmI in Manufacturing: a scenario

"At the Hirurak manufacturing plant the daily routine goes on. Mikel is going to the office area to have a meeting with Jon. As he passes by the transfer machine being operated by María, he receives a warning on the optical device fitted to his glasses. The monitoring agent has detected that the motorized spindle performing the second drilling operation is vibrating at slightly above the nominal levels. Mikel displays the RMS signal for the vibration on his glasses, together with possible causes for this, suggested by the agent. He has time before the meeting with the manager and decides to solve the problem.

Mikel goes to the rear part of the machine and opens the gate leading to the access to the motorized spindle. The tracking and localization system has detected him. The maintenance agent uses this information to help him carry out the maintenance. He can see the steps to be followed, estimated time and materials needed on his glasses An alarm message is displayed on his glasses, Mikel is not wearing the safety gloves demanded by internal Health and Safety at Work procedures. Mikel reluctantly puts them on. Now he can continue with his work.

There is very little space in which to carry out the maintenance. Fortunately, he has all the necessary information within his reach. Mikel does not remember what the X21 connector is referred to in the instructions. He asks in Basque, his first language, for a detailed plan, and it is made available immediately on his glasses.

Meanwhile, María is preparing the programs for the next manufacturing order which is starting this afternoon. María is not a great expert in machining, but it does not matter. The Hirurak programming system is able to interpret what María wants when she expresses it in a semi-colloquial language that it can translate to the ISO programming language understood by the CNC on the machine. María, who is slightly disabled in one of her hands, often uses her voice as an interface device with the machine. This has made her able to find a job much more easily."

Mikel has finished the maintenance and is going to the office to have the meeting. He is arriving there a little late, but his personal agent had been in contact with Jon's personal agent, and they had re-arranged their agendas. There was no problem in starting half an hour later."

Description of the AmILAB Laboratory at Tekniker

Tekniker is a research foundation centered on subject matters related to manufacture and micro-technology. It has set up a laboratory to spread the model of AmI to the area of manufacturing.

In order to achieve this, there must be convergence in areas traditionally linked with manufacture (quality, production, maintenance, design, safety, etc.) and the technology made possible by AmI (multi-modal interfaces, communications, learning systems, embedded systems, etc.)

The main research objectives of the laboratory are:

- to support complex tasks with a minimum of human-machine interaction
- to enable mobile professionals to keep their attention focused on the interaction with the work environment.
- to investigate the user acceptance of wearables, methods for user interaction
- to identify processes suited to wearables in industry

Figure 1. General vision of the Laboratory. The Milling Machine in the center of the image

The central unit in the laboratory is a high-speed milling machine with linear motors and a magnetically positioned head, and applications/functions normal in a manufacturing environment, such as monitoring and operating the machine, production control and maintenance.

Its functions have been augmented by accessorizing to it various devices such as a voice recognition system, 2 head mounted displays, 1 tablet PC, 2 PDAs, 1 Xybernaut wearable computer, 1 smart phone (Nokia 6600), and a localization system based on radio frequency identification tags (RFID).

Maintenance and production control applications have been re-designed and implemented in the form of Agents on the JADE platform [4], incorporating the concept of intelligent interfaces, context sensitivity and automatic learning.

From the point of view of the interfaces, we are currently conducting experiments to incorporate the voice recognition system and the Head Mounted Display to control the machine and provide access to the information needed by the worker.

Fig.2. A worker wearing HMD connected to the Xybernaut and using the Milling Machine's CNC keyboard to interface the wearable computer

In the next months new equipment will be introduced in the laboratory to explore new forms of interface with the machine: a robot and new interface technologies based on haptic systems.

Even assuming that the AmI vision is technically possible, we do not know if it will be economically, but what we believe is that social acceptance will be the critical factor that will enable it to come into being. To help construct this vision of the future whether in manufacturing or in any other area, aspects that go beyond the purely technological must be confronted: Sociological, legal, organizational and ethical aspects [5], such as the perception of loss of independence, control and privacy, the augmentation of the physical surroundings, accepting and using new interfaces, new learning opportunities, new ways of interacting, have to be taken into account whenever AmI vision is tried to be accomplished. All these aspects centered on people at work are also tackled in the laboratory.

The AmILAB is a research funded by the Basque and Spanish Science and Technology Research programmes, starting in the late 2003. Tekniker is also the only Spanish partner to take part in the largest world-wide European Commission funded IP (Integrated Project) on the area of wearable computing: "wearit@work: Empowering the mobile worker by wearable computing"[2].

INTRODUCING AMI IN INDUSTRIAL COMPANIES

When planning the introduction of AmI vision in industrial companies, we are talking about supporting complex tasks with a minimum of human – machine interaction to enable the workers to keep their attention focused on the interaction with the work environment, co-workers and tasks. [6] We are talking here about an organizational change process, where the focus relies on identifying suitable processes for the implementation of AmI technologies in industrial companies.

In this paper we will summarize a preliminary vision on organizational issues that will entail the introduction of AmI, exploring three main research questions: do organizations have to fulfill any previous conditions? Which role plays the General Management in this process? How should the process be implemented? [7] [8]

There are different criteria to define the characteristics and type of company suitable for the introduction of this vision:

- Management Style. AmI implementation asks for a participative process, present in management styles such as self-management models, cooperatives models. But it is also possible to implement it in a more autocratic managed company.
- Type of activity. One could think that knowledge based companies are more suitable, but in some purely manufacturing companies AmI related concepts might be easier to introduce, i.e. workshop workers find very useful interface technologies that allow them an easy command of the machine and a better acquisition of information
- Type of knowledge predominant, tacit knowledge vs. explicit knowledge companies. Experience "stored" in people vs. experience formalized in forms and procedures. Which type of company is more adequate to implement AmI?
- Human resources policy, here aspects such as transparency and an open communication policy are definitely positive. But the key is the agreement or social contract between workers and management about the use of the information handled by the AmI systems, potentially highly disruptive with large influence on privacy and control issues.

The conclusion is that there is no right combination of criteria that guarantees a successful adoption of AmI. Some are more adequate than others – a company with a

[2] http://www.wearitwork.com

participative management style and a transparent human resources and IT resources policy, but regarding types of activity or knowledge predominant we can't take a position.

Regarding criteria to apply in the process of implementing this type of vision, we can say that participation, a step-by-step process, voluntary where people can opt in or out of it when desired, and where a social contract or agreement between the different stakeholders are key issues to be taken into account:

- Participation. All stakeholders involved have to take active part, from the very beginning, on the implementation, providing their unique expertise and perspective. This will smooth the process and will help to create a common and tailored vision that answers to the real needs of the people working on the company.
- Step-by-step process. Start with a pilot Project inside the company to put in practice the vision. In order to demonstrate benefits and minimize inherent risks to the implementation of new technologies in any company.
- Voluntary, the possibility of opting in and/or out of the technology is key in this process. People have to feel in control of the technology.
- Social contract. A multilateral commitment between the different stakeholders in the company – management, workers, trade unions – has to be achieved. The negotiation and agreement on the managerial and social rules of use of AmI technology has to be explicit and revisited when possible new unsuspected aspects arise:
    - Understanding by the workers that they are working in an AmI environment, and that some of their activities, movements and interactions are registered by the system.
    - Allow opt-in/opt-out options of use of the system
    - Allow access to the personal information registered and stored by the system. And the possibility of modify or delete it.
    - Assure the absolute confidenciality of the data stored.
    - Clearly define which personal data are going to be used by the management.
    - Creation of "AmI free" spaces
    - Guarantee not to use the data for punitive processes (rewards. Salary policy)
    - Consider the possibility of a total rejection of AmI by the workers. Contingency plan.

During the implementation process a strong leadership is needed in order to motivate the workers and to lead the change process. The leader, recognized by the staff and who transmits authority, has to facilitate a context in which the human mistake is acceptable while using these new devices.

CONCLUSION

In the area of manufacturing, AmI is not only going to affect the way in which processes develop, but will also provide new ways of working and doing business. The development of new products and services and the shift in the focus of attention of the worker from the machine to their immediate working environment will be the immediate consequences of the adoption of AmI vision. In no case this is proposed as a new manufacturing paradigm, but, whatever models are followed, these will have to take into account these changes and feed organizational processes and communication and collaboration interactions.

Not only several technological challenges such as miniaturization, inter-operability and energy management have to be addressed by research teams across the world in the present decade, but also a strong focus on the social and organizational aspects of AmI has to be taken to overcome barriers to its realization.

The introduction of this new range of information and communication technologies in industrial companies entails changes in working procedures and the way people interact and relate to each other, having a potentially significant influence in the way these organizations will be managed and experienced in the near future.

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