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Implementation of an AmI System in a Manufacturing SME

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Abstract: SME are facing greater challenges due to increased labour cost and reduced cycle times. To adapt to this change more effectively and efficiently they need systems in place that adapt to change easily and seamlessly. This is the case in the customised product and service manufacturing SME sector. Ambient intelligence (AmI) has the ability to help SME to become more flexible to change and build on their already dynamic nature. The ability of the AmI system to adapt and learn in different situations is the key to maintaining the competitiveness in an organisation. This paper seeks to demonstrate the development and implementation of an AmI system in the manufacturing SME environment. It presents an AmI system in industry reference model that highlights the implicit and explicit interaction between the user, process and environment in an AmI system. The reference model is applied to a case study and the benefits arising from implementation are highlighted and discussed.

1. Introduction

Manufacturing is an important part of the economic development in Europe. It has a multiplier effect on the economy as both a generator of employment and wealth [1]. Over recent year it has been in a state of flux due to various factors including reduced cycle times and increased labour costs. Small to medium size manufacturing outlets are especially facing these pressures. Small to medium enterprises (SME) retain their completive advantage by remaining flexible however responding to price competition involves streamlining manufacturing processes and practices. This has a knock-on effect of reducing the flexibility previously mentioned. This creates a dichotomy for many SME’s involved in manufacturing, these pressures are causing challenges for SME. They need the ability to adapt to the rapidly changing business environment and to compete in the market place efficiently and effectively [2]. They also need to be more flexible and dynamic in adapting to change in demand from customers [3]. Existing systems in manufacturing are suitable for large scale manufacturing whereby products are standardised and there is a high range of production volume. If SME’s are to remain competitive a new type of system is called for, one that can overcome such a dichotomy. Enhanced flexibility while at the same time promoting efficiently and effectiveness of processes requires knowledge from the surrounding environment to become readily available to the decision maker. The new system should have the ability of controlling the environment or ambience. Ambient intelligence is such a solution.

Ambient intelligence (AmI) is a means of integrating electronic technology with information technology creating the ability to adapt and learn in the physical environment that encircles the user [4]. Ambient can be described as the environment that surrounds the user, where the physical environment becomes the users interface with technology [5].

Intelligence is the ability to adapt knowledge to different situations and to be capable of taking advantage of them [6]. Technology moves into the background through the use of embedded technology such as radio frequency identification tags and speech recognition systems which results in a more human orientated interaction between the user and the technology that surrounds them [7, 8]. The use of speech and gestures to communicate with technology creates a more dynamic and flexible surroundings in manufacturing, particularly on the shop floor. It can be said that AmI is an adaptive and flexible technology that caters to the needs and wants of the user by modifying its responses inline with the changing manufacturing environment.

2. Objectives

The proliferation of ambient situations and the approach for identifying and developing such solutions to ensure accurate and effective results currently does not exist. The aim of the paper is to demonstrate the development and implementation of an AmI system in the manufacturing SME environment. This is done to alleviate the problems that are facing SME that manufacture customised products and services. The paper examines the analysis and development of an AmI system in the areas of scheduling and materials management within a SME case study. To accomplish this, an outline of the concept of ambient intelligence is provided. The review of the concept leads to the development of an AmI in industry reference model. The reference model examines the user in the AmI system with regard to their implicit and explicit interaction with the process, environment and the AmI system, which works as both an observer and controller of the manufacturing surroundings. The model outlines the generic requirements of the system in the manufacturing environment. The reference model is discussed further in the paper. The technologies used in developing the AmI system within the case study are examined. A manufacturing SME case study is analysed through the application of the reference model. Problems specific to the SME are identified and overcome using the AmI reference model. The implications of the system developed using the reference model is discussed with regard to the benefits and the issues of implementations.

3. Methodology

A case study was used in this case as there was little understanding of the AmI concept except through definitions. Therefore the case study approach was taken to find out the ‘how’ as to the application of AmI to a SME manufacturing setting [9]. A case study approach was also chosen as it assumes that the human is the variable in the situation and is in a state of flux and in AmI the user is placed at the centre of the system [4, 9]. The researcher is required to investigate the whole system and look for similarities and find explanations [10]. As part of the case study, the requirements of the company were gathered, and an analysis of the current situation was conducted. The weak points from the analysis were categorised and further analysed. This resulted in the identification of the problems effecting the organisation. The problems that would be covered in the solution were then selected. The solution was developed using the AmI in industry reference model and implemented in the case study. The reference model was validated through the case study and the findings were analysed with regard to the benefits and drawbacks of the solution. [9, 11, 12]

4. Technology Description

Ambient solutions place the human decision maker at the centre of the solution. Hence optimising the role and impact of the decision maker is a key objective of such technologies. AmI can provide greater product efficiency by providing improved visibility over the user, process and environment in manufacturing. This visibility can be utilised to make more informed decisions by all users of the AmI system and in turn improve the time frame in which decisions are made, as well as providing the decision maker with the relevant information that they need to make an informed decision. Through accomplishing this it will empower the human worker to make more effective and efficient decisions. Therefore all aspects of manufacturing will be built around them. This section reviews the concept of ambient intelligence within a manufacturing setting and some of the technologies that can be used to achieve an AmI system.

4.1 What is Ambient Intelligence?

Ambient intelligence is a user centred concept. This means that the user is placed at the centre of the technology embedded environment. In essence the move is away from one computer one user to an environment where many computers interact seamlessly with one user [13]. Gill and Cormican [14] define ambient intelligence "as a people centred technology that is intuitive to the needs and requirements of the human actor. They are non-intrusive systems that are adaptive and responsive to the needs and wants of different individuals." Technology in the AmI environment moves to the background by becoming embedded in everyday objects like cloths and furniture [15-17]. The AmI system works on the principles of evaluated inputs and outputs from the user, process and environment in which the user inhabits.

In developing an AmI system the AmI in industry reference model and the technologies applied in the case study are outlined below.

4.2 Modelling AmI

The model attempts to present a structured approach to understanding AmI in the manufacturing setting. The AmI in industry reference model (see Figure 1) was developed based on the findings of the AmI-4-SME project in conjunction with project partners. The models incorporate the user, process and environment within the manufacturing setting.

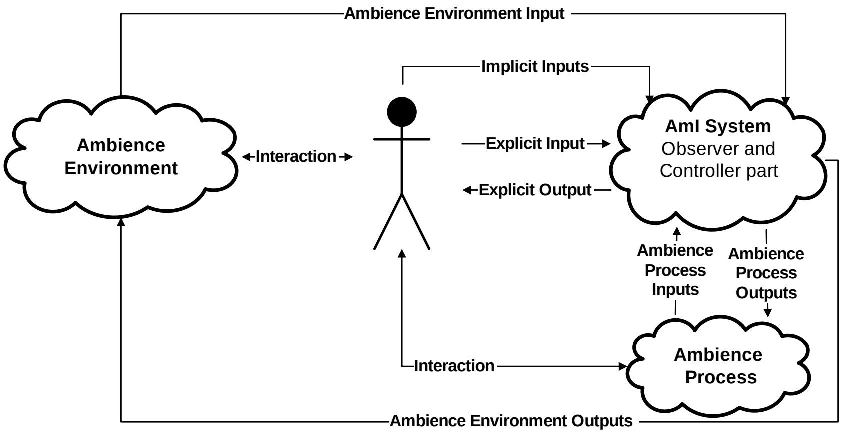

Figure 1: AmI in Industry Reference Model Adapted from Stokic et al[18].

The model identifies the information inputs and outputs of the system; it incorporates the user, process and environment within the information and data retrieval, processing and output. This provides for implicit interaction between the human operator and the AmI system. The AmI system takes a holistic view of the manufacturing system by incorporating the user, process and the environment. This is accomplished through a network of devices that are embedded into the background and can collect information implicitly. The acquisition of information from the shop floor is processed to incorporate context. To communicate the gathered information requires the need for high intelligence in the system. The system needs to provide information in context for it to be of use, to the users of the AmI system. Therefore the AmI system acts as both an observer and controller as the information is provided to it through the network of embedded devices and it has the ability to process the information and take action.

In the case of a machine losing calibration and slowing down production the AmI system can notify a technician of the problem immediately so that there will be less of an impact on the production schedule. The AmI system can also assist the scheduler by providing them with real-time information from the shop floor so that production can be adapted to take account of the machine that requires calibration and testing. Different technologies are used in combination to achieve the AmI system. Some of these are examined in the following section.

4.3 Enabling Technologies

For the AmI system to be achieved requires the advancement of traditional information communication technology (ICT). As such AmI is an advancement of ICT. The technology requirements for achieving an AmI system are "very unobtrusive hardware, seamless mobile or fixed web-based communication infrastructure, dynamic and massively distributed device networks, a natural feeling human interface" and "dependability and security" [4]. In achieving these requirements there needs to be an amalgamation of a number of fundamental developments in the area of ICT which will assist in the development of AmI in the manufacturing sector [4, 19]. These developments are needed to achieve a user centred system that is based on having an omnipresent system that adapts to the users needs and requirements. The three technologies that were used in the developing the AmI system in the case study are outlined below. These include semantic web, radio frequency identification and multimodal services.

The semantic web is the next generation in the development of the web. It is designed to provide meaning to web content. By accomplishing this it allows for more intelligent searches of web content, as well as improved interaction between human and computer. In the manufacturing environment this may lead to an intelligent search of the information stored in the database by the technical staff to assist them on repairing machines on the shop floor in the most efficient manner based on previous repairs and similar machine failures. [20, 21]

Radio frequency identification (RFID) tags are considered to be the next generation of bar-coding. It can be used to track shipments around the world as well as products on the production line. Information related to products can be stored on the tag. This information can be read at different distances depending on the tag. There are two main types of tags, active and passive. Active tags as their name implies are continuously sending information to the reader. They also are more expensive then passive tags, which only respond when, read. [22, 23]

Multi-modal services provide the ability to access and interact with data on a computer through the use of multiple interfaces e.g. both text and speech. This can be accomplished through the use of a keyboard and mouse entry system as well as the speech recognition system (SRS) inputs and outputs. This interaction can also be accomplished through the use of multiple input and output devices e.g. mobile telephone, personal digital assistant (PDA) or computer. In the case of a technician repairing a machine on the shop floor they can access the previous repair history of the machine on their PDA and can through the use of SRS input and also receive information with regard to repairing the machine. [24, 25]

No single technology incorporates the characteristics of the AmI environment. Only when combined seamlessly with other enabling technologies is the concept realised.

5. Business Case Description

The approach outlined in the previous section is validated in the implementation of a case study. The SME case study manufactures customised fabricated emergency vehicles for the

Irish domestic market. It is located in a remote location in the west of Ireland. The company is managed by owners who all work in the organisation in managerial positions. They employ approximately 28 people. The company not only produces emergency vehicles but also services them as well. The main competitive advantage of the company lies in their flexibility to adapt to customer requirements at any time during the design and production process.

The company used a database system to manage all resource planning and scheduling. The database system was designed in house by a member of the engineering staff. The database system evolved with the ever evolving user requirement of manufacturing operations. This created an environment where only the employees that had been at the company from the beginning of the deployment of the system had a full understanding of the system and used it to its full potential. New members of staff were more hesitant to use the system and information in the database became no longer accurate. Particularly in critical areas of raw materials usage, as work orders were sent to the shop floor and only during production were material deficiencies found. On the shop floor the level of traceability was low. It was not always known how many components were used in the production or if they were assembled in the correct manner. The overall problem lies in the area of knowledge management. Due to this the lead time for products was greater than their competitors.

There were three options available to the SME with regard to possible solution. The first is to buy an off the shelf information management system, the second is to design a new in house AmI system that caters to their specific requirement and can be adapted to deal with future changes. The third option is to combine the first two, use the off the shelf system to manage the resource planning and scheduling, and create an in house AmI system that, is interoperable, can interact with the information management system and make it more adaptive and flexible to the needs of the SME. This would help to ensure that they maintain their competitive advantage of being able to adapt to customer requirements at any time during the design and production processes. In this case study the third option was chosen.

5.1 Decision Information Production Algorithm

The solution was developed in relation to the users, process and technology, and applied to two areas, scheduling and materials management, see Figure 2. Within the new system all users, subassemblies and machines have been tagged with passive RFID tags. RFID readers have been mounted at workstations. The RFID readers send the collected information back to the AmI system.

1. The new process begins by the AmI system having all the scheduling and work instructions finalised with the scheduler. This means that the AmI system is ready to execute the work orders on the shop floor and has ensured that all materials for completing the orders will be available for production as they are required.
2. When the operator arrives in the morning or after completing a work task goes to the LCD monitor to interact with the AmI system. The AmI system recognises the operator from his/her RFID tag and can provide the operator with a new work assignment in relation to their skills level competence in that specific area, log a problem, or adapt the work assignment instructions to the operators specific skill requirements for example it can provide a detailed break down of the task to be performed for a less experienced operator or just the specifics of the task for a more highly skilled operator. Not in all but in some areas of the shop floor the operator can interact with the AmI system through SRS.

3. If the AmI system detects a problem or is notified of one it will inform all relevant personnel. For example a technician can be notified of a machine malfunction or rejects being generated by a specific machine.
4. All the manager and supervisors are contactable and can view and update shop floor operations in real-time, due to the integration of PDA's with SRS into the AmI system network. This allows them to track problems and solution on the shop floor as they happen.
5. Materials usage and availability can also be tracked in real-time. The materials manager can then ensure that there is adequate availability of materials for production on the shop floor so that production is not delayed due to lack of raw materials.

The benefits and issues of the implementation of the AmI system are discussed in the following section.

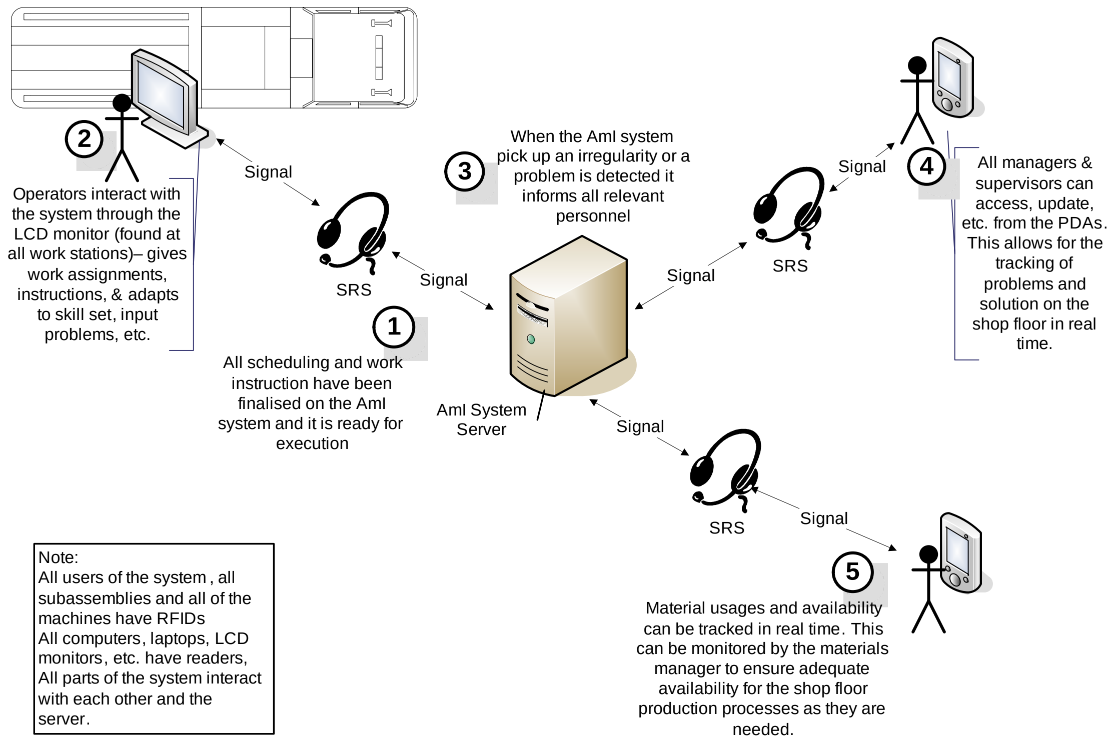

Figure 2: AmI System

6. Business Benefits

The product, which is developed, is a system that enables integration between electronic hardware and software to develop an AmI system. It occurs in three parts:

- A set of information technology services are provided by the vendors which expands the functionality of the core technologies to allow the system to be integrated in the SME manufacturing environment.
- Vendors provide for the expansion of existing hardware and middleware. This is accomplished through the development of services that are available for download to provide middleware for integration of legacy systems.
- Developers are provided for implementation of the ambient system. The ambient consultants will guide the implementation and integration of both the technology vendors and service providers.

For these solutions to be successfully available all three stakeholders must play a role.

In the case study the production schedule was improved by providing real-time updates on production progress information by operators and reducing downtime with improved time and resource management. Materials management benefited from the material in the warehouse being tracked on the shop floor, so keeping accurate records of stocks and its utilisation. The holding cost of stock could be reduced by reducing the lead time as well as improving the accuracy due to traceability of materials and work being conducted on the shop floor. As a result, the manager now has greater visibility over the shop floor, the traceability of raw materials usage in production and utilisation of personnel is improved. The AmI system assists scheduling and materials management in four ways, by collecting real-time information from the shop floor and using it to update the existing schedule, providing decision support to the scheduler, providing shop floor personnel with the information that they require to complete their assigned tasks, and tracking any and all problems that occur on the shop floor and updating the schedule to reflect them. This resulted in lead time reduction from 14 to 8 weeks through improved decision making

In the implementation of the AmI system in the case study, a number of lessons were learned in relation to system development. Issues included privacy with regard to tagging, training of users, creating boundaries between personal and business time and user involvement through the design and development process. Some of the risks with development and implementation of an AmI system are, will the user use the system, accuracy of information and continual maintenance. Financial investment by SME's must be made. However, the solution will depend on the accuracy and availability of the legacy data, also the willingness of users to adopt the solution. The SME solution needs to be one that promotes efficiency, effectiveness, flexibility and can only be delivered through such ambient solutions. AmI is an inspiring concept and with its introduction will change the way that we work and live our lives.

7. Conclusions

SME are facing greater challenges due to the faster changing business environment. To adapt to this change more effectively and efficiently they need systems in place that adapt to change easily and seamlessly. This is the case in the customise product and service manufacturing SME sector. AmI has the ability to help SME to become more flexible to change and build on their already dynamic nature. The ability of the AmI system to adapt and learn in different situations is the key to maintaining the competitiveness in an organisation. This paper examines the implementation of an ambient intelligence (AmI) system in a manufacturing SME. To achieve this, an AmI in Industry reference model is applied in a SME manufacturing case study. To create an AmI environment, requires the use of a combination of technologies as well as an understanding of the need and requirements of the user, process and environment in which the AmI system is to be implemented. The aim of the paper is to demonstrate the development and implementation of an AmI system in the customise product and service manufacturing SME environment. To achieve this, the case study is analysed with regard to the weak points to be improved through the development of an AmI system. The AmI in industry reference model is used to assist in developing the system as it shows the user, process, environment and AmI system as well as the interaction between these elements. The solution is discussed with regard to business benefits and issues in implementation.

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