A Context-Centric Ambient Intelligent Framework for Manufacturing Process Optimisation

Gearóid Hynes

Digital Enterprise Research Institute (DERI), National University of Ireland, Galway,
IDA Business Park, Lower Dangan, Galway, Ireland
gearoid.hynes@deri.org
http://www.deri.org

Abstract. This paper discusses a proposed framework to optimise manufacturing processes for small to medium enterprises through the application of ambient intelligent technologies. To profit in today's market, small manufacturers must be efficient and agile to minimise cost and to meet variable market demand. The framework will provide decision support for the manager by supplying intuitive access to the real-time data describing the status of the shop floor environment and the ability to automate responses depending on environmental conditions.

1 Description of Purpose

The modern market is increasingly volatile and in order for small to medium sized enterprises (SMEs) to survive they are called upon to produce smaller batch sizes with a larger range of variants of those products [1].Manufacturing companies are constantly required to adjust their production volume of products, variants and quantities, in particular SMEs that rely on the flexibility and agility provided by their relatively small size to compete with larger competitors. SMEs have to meet the challenges of the increasing product variants and service content of products by improving their manufacturing processes. Plant managers must also protect long-term investments in manufacturing systems. Therefore there is a need for flexible and agile manufacturing systems that provide the capability for systemic innovation to the plant manager. In particular, two processes that systemic innovation can be beneficial to are shop floor control and machine maintenance.

Ben-Arieh et al state that "shop floor control involves the efficient and effective utilisation of resources at the lowest level in a manufacturing facility" [2]. Deterministic solutions to the problem of shop floor control are inappropriate as they are intended to solve it in an ideal predictable world, and are not suited to harsh, real-world environment due to variables in the manufacturing process such as machine failures, delayed arrival of parts and priority changes [2]. Dynamic solutions involving the gathering of hard real-time data are desirable instead [2] to help the manager to consider various alternatives quickly. Machine maintenance further constrains manufacturing performance as machine downtime must be kept to an absolute mini-

Tom Pfeifer et al. (Eds.): Advances in Pervasive Computing 2006
Adjunct Proceedings of Pervasive 2006, Dublin, 7-10 May
books@OCG.at Vol. 207, ISBN 3-85403-207-2

mum to remain efficient and competitive in today's market [3]. Unbehend calls for systems that can constantly monitor machines, recognise maintenance requirements in time, diagnose faults, troubleshoot and help maintenance engineers in preventative and repair actions [3].

2 Goal Statement

Thanks to ISTAG adopting Ambient Intelligence (AmI) as one of their primary themes for the 6th Framework on IST Research there has been quite a great deal of AmI research carried out since 2001, however the factory floor application domain has largely been left untouched by this. There are numerous software solutions focused on the area of manufacturing, each with their relevant advantages and disadvantages, however there is no system available which utilizes the full potential of context-awareness in the manufacturing environment. Existing context-aware systems such as CoBrA[4], which is aimed at the office environment, and other general frameworks such as the Context Toolkit are not sufficient for deployment in the factory environment [5].

The goal of this research is to develop an AmI based framework which provides decision support to the SME user in optimising their manufacturing processes and to facilitate the introduction of new manufacturing processes. In order for the framework to be flexible and agile, and hence of benefit to numerous manufacturing SMEs, it requires loose-coupling, a generic core, extensibility and plug & play functionality. The solution will incorporate technology from the fields of AmI and the Semantic Web in order to provide increased efficiencies to the processes of shop floor control and machine maintenance.

The AmI philosophy sees this human actor surrounded by environments which are sensitive and responsive to their wishes [6]. This AmI based framework is a human-centric solution with the aim of aiding them to optimise their companies manufacturing processes. By constantly monitoring the context of the primary actors in the factory environment - employees, stock and machinery - the user will be provided with intuitive access to the real-time data describing the status of the shop floor environment and the ability to automate a response.

2.1 Machine Maintenance

The machine maintenance portion of the framework is designed to help the maintenance engineers implement their maintenance strategies, be they total productive maintenance, reliability centered maintenance etc. As a result machine maintenance is looked at from two perspectives within this AmI framework, the first is providing the maintenance personnel with accurate and relevant real-time information on their machines in order to enable them to introduce and implement the appropriate strategies. The second perspective is helping the staff carry out all necessary maintenance, be that scheduled or unscheduled, in order to get the machines up and running in as quick a time as possible. The framework will incorporate a scheduling assistant in order to help the manager complete the maintenance as efficiently as possible. It will also incorporate maintenance execution assistance which will provide necessary machine information to engineers as they perform their duties.

2.2 Shop-floor Control

Shop floor control is concerned with the efficient management and usage of resources at the lowest level of control on the shop floor of a manufacturing plant. Long range planning and deterministic solutions to scheduling problems in shop floor control to date have included mathematical models, heuristics and knowledge-based systems, each of which has met with varying success [7].In place of these, Ben-Arieh et al call for solutions which monitor the environment in real-time and present relevant information to the manager so that they can make timely, informed decisions.

Within the framework the real-time information coming from the product manufacturing provides exact locations for each of the batches. Should a certain machine fail the batch location information can be used to re-route the effected batches as efficiently as possible in order to keep the impact of the machine failure to a minimum. The same location data combined with machine sensor data can also be processed to provide the user with information on traceability, accountability and reliability.

Orders go through several phases as they progress from when the order is placed to the finished product. In order to have complete traceability, records are automatically kept of what components went into each product, when and from where those components were supplied, who worked on the product at each stage of its production and who performed the final inspection. Using this information, efficiencies and accountability related to employees, stock usage and the assembly line over various periods of time can be provided to the user when required. This allows important information to be gathered such as recognizing individuals with high error rates, most common overall errors, and it allows the company to take measures such as increased employee training to decrease the overall error level and hence increase the overall productivity. Traceability and accountability are of particular significance as they are necessary for meeting the strict guidelines laid down by international standardization bodies such as the ISO. They also allow product errors to be traced to the exact source of the problem in order that customer complaints can be dealt with as efficiently as possibly.

3 Approach

It is important when developing a system or framework to be deployed in industry that user requirements are thoroughly researched and that the proposed system meets these requirements. For that reason plant visits have been undertaken with five Irish based companies which range in size from 24 employees to several thousand. From these plant visits it has been established that a combination of the previously mentioned data gathering (traceability, accountability, efficiency) and automated responses (scheduling assistance, maintenance execution assistance) would be of great benefit to each of the companies.

3.1 Technologies

In order to realize the vision of a flexible and agile framework, where the various functionalities can be plug & played, it has been decided to use a Service Oriented Architecture (SOA). Each of the functions will be represented by a service which will be described using the Web Service Modeling Language (WSML)[8]. The Web Service Modelling eXecution environment (WSMX)[9] will be used as the core of the framework. WSMX, is an execution environment that enables discovery, selection, mediation, invocation and interoperation of semantic web services. It will allow service to be added and removed from the framework at will without requiring the framework to be reconfigured. Semantic Web technologies also provide benefits in terms of interoperability with other systems and services.

The resulting framework will be completely novel, not only in terms of context systems in manufacturing but also in terms of context systems in general. Baldauf et al [5] state that the use of standardized technologies and protocols such as Web Service Description Language (WSDL)[10] could help to build more interoperable context aware services. This proposed framework hopes to go beyond the vision of Baldauf by utilizing the potential of WSML and WSMX to create a semantic SOA.

Context ontologies will be used for the purpose of context modeling within the framework. As outlined by Strang [11] ontologies are the most effective and complete solution for modeling context data. Compared with alternative context modes such as logic based, object oriented or graphical, ontologies are the most expressive while maintaining a high level of simplicity, flexibility and extensibility.

3.2 Hardware

In contrast with both Pervasive and Ubiquitous Computing, Ambient Intelligence is not focused on the development of hardware; its focus is on developing user centric applications using existing technologies. Therefore the hardware outlined in this section is mature, commercially available and well understood. A combination of tags, PDA's and machine sensors will be used within the framework.

Every product goes through many different stages before the product is complete. By applying tags (RFID, barcode etc) to the product batches at the beginning of the production cycle the status of each batch can be monitored in real-time throughout production process. The type of tag used will be dependent on many factors such as the type of product, company size, complexity of production, production techniques etc. Employees will also be equipped with tags, this enables the framework to track who worked on each batch or in the case of maintenance staff who performed maintenance on a particular machine

Certain employees, such as maintenance personnel, will have wireless PDA's equipped with tag readers. The PDA's will supply the user with information appropriate to their current task. The tag readers will allow users access get information on particular product batch or machine.

The production machinery will be equipped with networked sensors which monitor the status of the machines (idle, off, processing product, failure). This information will be available in real-time to the maintenance staff.

3.3 Initial Prototype

In terms of framework development, an initial small-scale proof of concept prototype is being developed. The prototype is focused on the data gathering aspect of the proposed framework and will be limited to one work-station within the factory. All batches passing through this workstation and all staff working on the workstation will automatically be monitored. This prototype will contain all the key technologies of the final framework. Once completed, the prototype will be extended to incorporate all the functionality of the framework. For validation purposes two SMEs have been recruited in which the final framework will be deployed.

References

1. Heilala, J. and P. Voho, *Modular reconfigurable flexible final assembly systems.* Assembly Automation, 2001. 21(1): p. 20 - 30.
2. Ben-Arieh, D., Chopra, Manoj and Bleyberg, Maria Zamfir. *Data mining application for real-time distributed shop floor control*. in *IEEE International Conference on Systems, Man, and Cybernetics*. 1998. San Diego, California.
3. Unbehend, C. *Knowledge based monitoring and diagnosis in machine maintenance*. in *Second International Conference on Intelligent Systems Engineering*. 1994. Hamburg-Harburg, Germany.
4. Chen, H., T. Finin, and A. Joshi. *An Intelligent Broker for Context-Aware Systems*. in *Adjunct Proceedings of Ubicomp 2003*. 2003. Seattle, Washington, USA.
5. Baldauf, M., S. Dustdar, and F. Rosenberg, *A Survey on Context-Aware Systems.* International Journal of Ad Hoc and Ubiquitous Computing, 2004.
6. Aarts, E.H., H.; Schuurmans, M., *Ambient Intelligence*, in *The Invisible Future*, P.J. Denning, Editor. 2001, McGraw Hill: New York. p. 235-250.
7. Ben-Arieh, D., M. Chopra, and M.Z. Bleyberg. *Data mining application for real-time distributed shop floor control*. in *IEEE International Conference on Systems, Man, and Cybernetics*. 1998. San Diego, California.
8. Lausen, H., et al. *WSML - a Language Framework for Semantic Web Services*. in *W3C Workshop on Rule Languages for Interoperability*. 2005. Washington DC, USA.
9. Haller, A., et al. *WSMX - A Semantic Service-Oriented Architecture*. in *International Conference on Web Service (ICWS 2005)*. 2005. Orlando, Florida.
10. Chinnici, R., et al., *Web Service Description Language (WSDL) Version 1.2 Part 1: Core Language*. 2003, World Wide Web Consortium: Boston.
11. Strang, T. and C. Linnhoff-Popien. *A Context Modeling Survey*. in *First International Workshop on Advanced Context Modelling, Reasoning And Management*. 2004. Nottingham, England.