TOWARDS TRUE DYNAMIC DECISION MAKING IN MAINTENANCE

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Abstract

The maintenance of machinery and assets in European industry has been shown to account for a significant proportion of operating costs, however substantial savings are possible through the use of more technologically advanced approaches. Modern industrial production systems are experiencing ever increasing demands for improved machinery reliability, efficiency, safety and environmental performance. Maintenance system technology has progressed to some extent but complete solutions with the flexibility to satisfy the demands of a wide range of users are still not widely utilised.
One current research project, DYNAMITE (Dynamic Decisions in Maintenance) intends to address this problem by developing and applying a blend of leading-edge communications and sensor technology, combined with state-of-the-art diagnostic and prognostic techniques. The objective of the project is to deliver a prototype maintenance system to enable the monitoring of machines and processes for predictive maintenance and control. An infrastructure for mobile monitoring technology is to be developed along with devices incorporating sensors and algorithms to support enhanced capability for decision support systems.
A key strategy of this project involves the extensive use of stored and transmitted electronic data in order to ensure availability fo up-to-date, accurate and detailed information. This strategy provides great advantages for both human and machine-based decision making capability. For instance the system aims to assist in the inspection and maintenance process by identifying priority cases, collating and delivering detailed documentation on maintenance procedures and also to plan and schedule these activities.
Several key aspects of the project will be identified and the methods and technologies used to develop the maintenance infrastructures that allow such rapid, efficient, and cost-effective decisions to be made will be discussed.

Keywords: Maintenance strategy; Decision making; Condition monitoring; Diagnostics; Reliability.

Introduction

The maintenance of machinery and assets is a huge cost to European industry, however it is a particular area where substantial savings may be made through the use of more technologically advanced solutions (Sharma *et al* 2006). Increasing requirements in terms of production, reliability, availability, quality and safety pose big challenges to machinery maintenance activities. Many corrective and preventive schemes adopted by companies are based on limited information and often prove costly and ineffective.

Today maintenance is going through major changes. Industry and the general public are realising that efficient use of industrial assets is key to supporting current living standards. Also the maintenance function plays a critical role in a company's ability to compete on a broad range of factors (Al–Najjar & Alsyouf 2003; Crespo & Gupta 2006; Pinjal et al 2005). Modern and efficient maintenance practices involve, at least, the identification of the root–cause of component failures, reduction of production systems failures, elimination of costly unscheduled shutdown maintenances, and ultimately an improvement both in productivity as well as in product quality.

Nowadays a life–cycle management oriented approach is commonly adopted by companies. Limits on resources and energy consumption impinge directly on manufacturing objectives, requiring efficient and timely production and ensuring customer satisfaction and profitability. Many researchers in the field predict a new culture wherein maintenance activities become of equal importance to production activities (Takata et al 2004).

To support this role, the maintenance concept has undergone several major developments such as the transformation of traditional "fail–and–fix" maintenance practices to "predict–and–prevent" e–maintenance strategies. Such approaches take into account the potential impact on service to customer, product quality and cost reduction (Lee 2004). The key advantage is that maintenance is performed only when a certain level of equipment deterioration occurs, rather than after a specified period of time or usage.

E–Maintenance and the use of mobile devices offering the flexibility to initiate applications at flexible locations in unstructured networked environments has the potential to quickly and efficiently retrieve relevant information from data sources. Personal Digital Assistant (PDA) devices play a key role in bringing Mobile Maintenance Management closer to daily practice on the shop floor. The PDAs enable maintenance personnel to directly gain information from monitored machinery e.g. what is current machine state, which maintenance actions have been carried out.

New technologies (e.g. internet, mobile devices, micro–technology) are waiting to be adopted in the re–design of maintenance strategies to enable cost–effective e–maintenance systems and hence rapid, effective and informed decision making. This is the objective of the DYNAMITE Project.

Dynamic Decision Making

Maintenance engineers can now use PDA devices to give immediate access to all necessary information wherever it is needed. Maintenance personnel can be guided to machinery that needs attention, maintenance actions can be defined in detail and assistance in carrying out the work can accessed. The technologies outlined may also be aligned to existing and future systems, such as those using wireless sensors and smart tags with an increased level of intelligence. The range of information provided by these approaches allows an unprecedented amount of high quality asset condition data to be readily available to maintenance decision makers. Information would typically be available for not only the current situation, but also historical trends and future prognoses.

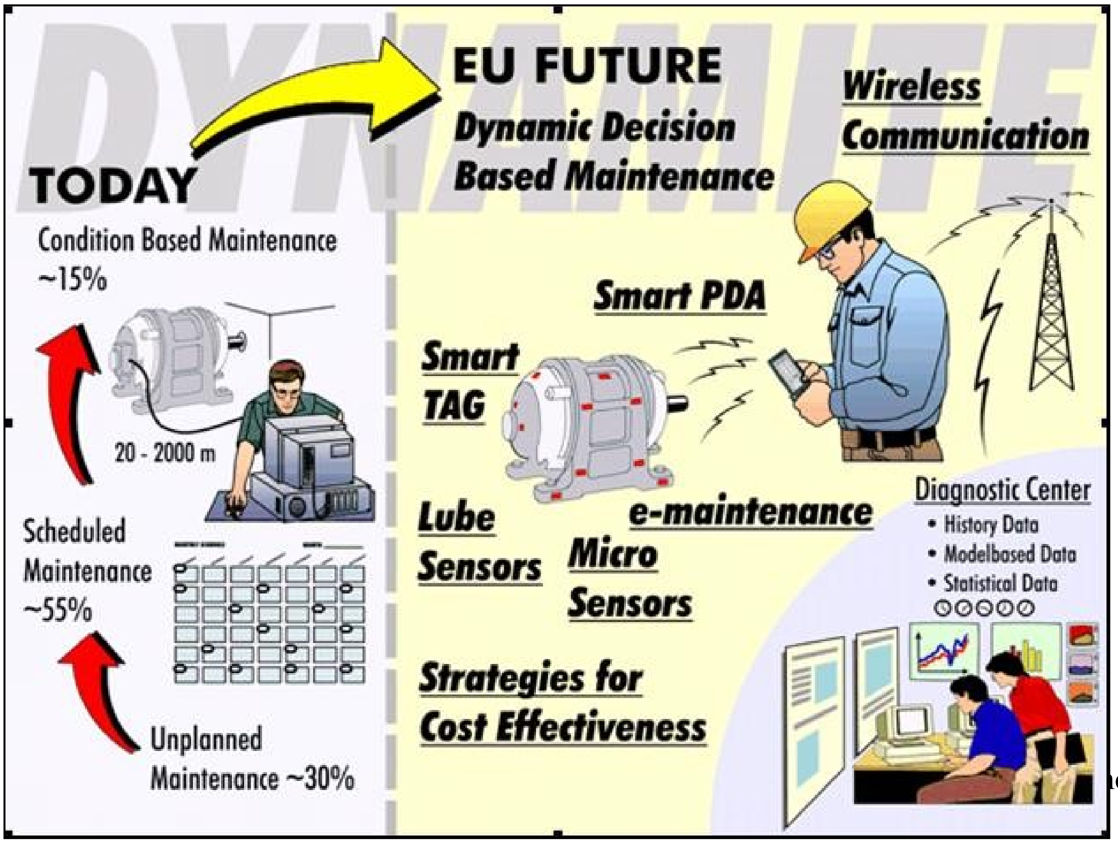
An operational example of the use of the above-described technologies may be described:
1) CMMS re–schedules work orders based on component predictions.
2) Re–scheduled orders are retrieved by the PDA when maintenance personnel become available.
3) Maintenance orders are issued depending on proximity of given PDA to the faulty machines.
4) Additional information retrieved, as required, from wireless sensors and smart tags.
5) Machine health measurements recorded before and after the maintenance action to confirm solution of the problem addressed.
6) Details of actions taken and result achieved are stored locally on smart tags.
7) Automatic reports generated to complete asset management records.

According to Komonen (2005) about 30% of all the maintenance activities in industrial and transportation systems in Europe are unplanned, whereas a 55% of the activities are related to planned and scheduled maintenance. That is, 85% of the maintenance strategies implies unnecessary action costs and machinery breakdowns or service actions like disassembly that have negative effects on the performance and lifetime of components. This leaves a maximum of 15% of the activities being focused on CBM strategies that presumably accounts for the newer and more critical machinery, where cost–benefit ratio clearly favours condition–based approaches.

The DYNAMITE Project

Clearly more research effort is required to face up to the challenges for modern e-maintenance. One focused research direction is offered by the new EU-funded Integrated Project DYNAMITE - Dynamic Decisions in Maintenance. The consortium includes six research institutes in the UK, France, Spain, Sweden and Finland, two car manufacturers FIAT and Volvo, the machine tool manufacturer Goratu, the automation and maintenance services provider Zenon, and seven SMEs representing related business areas.

The DYNAMITE vision (Figure 1) aims at promoting a major change in the focus of condition based maintenance, essentially taking full advantage of recent advanced informa-tion technologies related to hardware, software and semantic information modelling. The main technologies expected to facilitate this upgrade are wireless devices, such as smart tags, micro-size MEMS sensors especially designed for maintenance purposes, and low-cost on-line lubrication analysis sensors. On the other hand, adequate information processing tools should take care of the continuous data flow and suggest appropriate actions to the operators. But most important, at a medium level, smart hand-held devices, such as PDAs (mobile agents) will provide higher communication interfaces with sensors, intermediate processing capabilities and a smart end for human interface to remote web services centres that will compose a distributed web platform system at the higher end of the processing hierarchy. This coupled with wireless data transmission between sensor devices and information processing layers should provide adequate mobility for a distributed and collaborative system, where three different levels of entities can undertake intelligence tasks. At the lower end, sensors can provide certain degree of reasoning, taking into account the ‘local’ scope of this processing.



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Mobile Devices in Maintenance Management

There are several advantages in employing mobile computing compared to conventional wired computer applications. Mobile computing offers the flexibility to initiate applications at flexible locations in unstructured networked environments, to quickly and efficiently search for and retrieve relevant information from heterogeneous data sources, to perform tasks while utilising limited or intermittent connectivity and to provide asynchronous services to client requests (Samaras 2004). Additionally, the ease and flexibility of carrying a handheld wireless device, mobile computing has the potential to transform the way in which many industrial management, monitoring and control tasks are performed (Buse & Wu 2004). This potential is still largely unexplored in maintenance management.

Although the usage of wireless devices within an e-maintenance framework has been suggested in the past (Lee 2001), integrated maintenance management solutions based on combined usage of wireless sensing, RFID tags, hand-held devices and central or remote server-side computing and data-offices (Lampe et al. 2004, Legner & Thiesse 2006, Wittenberg 2003) are still in their infancy. Part of the difficulty is attributed to the challenge of integrating equipment, devices and computing resources and code from very heterogeneous sources (Bartelt et al. 2005, Trossen & Pavel 2005) but also to the great complexity of optimising the management of maintenance in modern industry.

Within DYNAMITE, the usage of PDA devices plays a key role in bringing Mobile Maintenance Management closer to the daily practice at the shop floor. PDAs are used in synergy with intelligent sensing devices and smart tags on the lower-end of the data processing architecture, but also with central server databases and data processing and remote access applications at the higher-end of the architecture.

The mobile worker (i.e. technician), equipped with the PDA, approaches the monitored machinery. The PDA is equipped with an RFID tag-reader enabling the automatic identification of the equipment/component and thus it becomes possible to automatically retrieve relevant data from the central system and quickly present it to the user. Furthermore, the PDA can access measurements logged to the intelligent sensing device (sensing agent) and combine/compare those with the automatically retrieved related historical and reference data from the central database. Thus the PDA becomes a ubiquitous expert advisor and, at the same time, a flexible data collector. Within this architecture there can be several intelligent sensing devices, distributed across the plant, which can wirelessly transmit via short range RF either directly or indirectly via data logger gateways from the shop floor. In this manner, instead of an inflexible costly and rather inaccessible wired monitoring structure, there is a flexible, easy to deploy and operate wireless e-maintenance architecture, which can become a powerful, efficient and easy to use tool for the maintenance engineer, while at the same time can be integrated with the organisation ERP.

Hence the main tasks of the PDA are:

1) The use of Smart Tags for storage and handling of component data, details of maintenance actions, and machine diagnosis results.
2) Communication with Intelligent Sensors and performing local signal analysis and diagnosis.
3) Communication with the CMMS system for handling asset information, spare part information, work orders, asset identification and location issues, etc.
4) Communication with Semantic Web.
5) Performing cost effectiveness analysis.
6) Logical and efficient display of raw data, processed data and summary information based on the above features.

Conclusions

In this paper the great changes of maintenance and its importance in supporting manufacturing industry have been discussed. First a short overview of the enabling tools and technology available to the maintenance engineer in manufacturing industry, in relation to the emergence of e-maintenance practices and the introduction of mobile computing was provided. The challenges of today's maintenance have been briefly described, highlighting a lack of industrial implementation of condition-based maintenance strategies. The potential of using ubiquitous computing in industrial maintenance practice has been discussed, followed by an outline of our vision for the adoption of mobile maintenance management solutions. One expected result is the development of prototype PDA-based mobile maintenance agent devices , which should operate within the e-maintenance architecture (with sensors, smart tags, CMMS, maintenance expert, ERP, MES) in order to bring mobile maintenance management closer to the daily practice at the shop floor. End-user trials are scheduled to be carried out at Fiat and Volvo production sites in order to assess the impact of the e-maintenance architecture and mobile maintenance agent devices on maintenance management.

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