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An intelligent maintenance system for continuous cost-based prioritisation of maintenance activities

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Abstract

A key aspect of competition in industrial maintenance is the trade-off between cost and risk. Decision-making is dependent upon up-to-date information about distributed and disparate plant, coupled with knowledge of sensitive non-technical issues. Enabling technologies such as the Internet are making strides in improving the quantity and quality of data, particularly by improving links with other information systems. In maintenance, the problem of disparate data sources is important. It is very difficult to make optimal decisions because the information is not easily obtained and merged. Information about technical state or machine health, cost of maintenance activities or loss of production, and non-technical risk factors such as customer information, is required. Even in the best information systems, these are not defined in the same units, and are not presented on a consistent time scale; typically, they are in different information systems. Some data is continuously updated, e.g. condition data, but the critical risk information is typically drawn from a historical survey, fixed in time.

A particular problem for the users of condition-based maintenance is the treatment of alarms. In principle, only genuine problems are reported, but the technical risk of failure is not the full story. The decision-maker will take into account cost, criticality and other factors, such as limited resources, to prioritise the work. The work reported here automatically prioritises jobs arising from condition-based maintenance using a strategy called cost-based criticality (CBC) which draws together three types of information. CBC weights each incident flagged by condition monitoring alarms with up-to-date cost information and risk factors, allowing an optimised prioritisation of maintenance activities. CBC does not attempt to change the strategic plan for maintenance activities: it only addresses prioritisation. The strategy uses a thin-client architecture rather than a central database, and is illustrated with examples from food manufacturing.

Keywords: Maintenance engineering; Condition monitoring; Alarms; Criticality analysis; e-Maintenance; Intelligent systems

1. Introduction

To succeed in the competitive global marketplace of today, it is vital for an organisation to optimise its operational costs. The cost of maintaining complex industrial systems is one of the critical factors influencing the enterprise operating costs and it is estimated that 18–30% of this is wasted [1,2]. Hence, the importance of optimising the maintenance function is obvious.

Inadequate maintenance can result in higher levels of unplanned asset failure, which has many inherent costs to the organisation including:

- lost production;
- rework;
- scrap;
- labour;
- spare parts;
- fines for late orders;
- lost orders due to unsatisfied customers.

The nature of maintenance planning is changing rapidly with the uptake of condition-based maintenance, integration and e-maintenance.

1.1. Condition-based maintenance

Condition-based maintenance aims to reduce the number of unplanned asset failures by monitoring equipment condition to

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predict failures enabling remedial actions to be taken. It includes, but is not limited to, technologies such as:

- vibration analysis;
- infrared thermography;
- oil analysis and tribology;
- ultrasonics;
- motor current analysis;
- performance monitoring;
- visual inspection.

Many computerised maintenance management systems (CMMS) use condition monitoring alarm levels to trigger maintenance activities. Incoming condition-based data for assets is compared to predefined thresholds and when the threshold is exceeded an alarm is raised to highlight the event. The quantity of condition monitoring activity, coupled with limitations in setting alarm levels, has led to a problem for maintenance personnel coping with the quantity of alarms on a daily basis. The human decision-maker must assume that the alarms are true until it is proved otherwise. Determining which of the alarms to tackle first can be a difficult and time consuming procedure and is usually reliant on the experience of the operator.

1.2. Integration of criticality

Criticality assessments are procedures which aim to identify those assets that could have the greatest effect on an operation if they were to fail. When deciding on which maintenance strategies to adopt, organisations usually carry out some form of criticality assessment based on collected data or the experience of personnel. However, once a strategy has been adopted it is unlikely that the results of the analysis will be used to prioritise activities on a daily basis. Most criticality assessments are only readily available on paper.

Resource for repair and replacement arising from an alarm is limited. Focus of resource requires accurate information to prioritise maintenance activities and hence optimise return on investment. Forward thinking plant executives, maintenance managers and work planners have always wanted to have information about the condition of equipment assets at their fingertips when they need it. Unfortunately, this information is usually scattered among separate information systems making it difficult or impossible to view on one computer terminal and use as a basis for sound asset management decisions [3].

Integration in information systems provides a potential solution to the problem of isolated data sources. Decision-making is often achieved with uncertainty and unknowns, while measuring against conflicting performance criteria. Maintenance decisions are made in the context of business priorities. Integration must facilitate the bi-directional flow of data and information into the decision-making and planning process at all levels. This reaches from business systems right down to sensor level. Integrated systems should automate the retrieval of information that decision makers require to make sound judgements. Essentially it should be a means of establishing links between data sources and close the loop from the minutiae of data to collection to strategic decision-making [4].

1.3. e-Maintenance

e-Maintenance brings benefits to a distributed organisation, that is where plant, people, expertise or data are physically separate or isolated. Baldwin defines e-maintenance as an ‘‘asset information management network that integrates and synchronises the various maintenance and reliability applications to gather and deliver asset information where it is needed when it is needed’’ [3]. A more general definition is that e-maintenance is a ‘‘maintenance management concept whereby assets are monitored and managed over the Internet’’ [5].

The e-maintenance infrastructure is considered to be made up of several information sectors. These are:

- control systems and production schedulers;
- engineering product data management systems;
- enterprise resource planning (ERP) systems;
- condition monitoring systems;
- maintenance scheduling (CMMS/EAM) systems;
- plant asset management (PAM) systems [3].

1.4. Aims and objectives

This paper will illustrate the problems experienced by a human decision-maker trying to cope with condition monitoring alarms. The aim of the work is to create a method to focus attention automatically on alarms that pose the gravest consequences to the business. The methods and functionality of criticality assessments will be reviewed. The nature of distributed data will be considered and the benefits arising from e-maintenance will be explored.

On-line criticality is an important input to the process. Typical criticality analyses (FMECA, etc.) have been done, but remain on paper. The model of the layout of the plant varies with the product in the case study company. In this work the criticality model will be live and the choice of product affects the numbers used for criticality as an input to CBC. The main purpose of the CBC algorithm is to rank all the alarms arising from condition monitoring. We observe that the alarms can be trusted in mature applications but that they are not all equally important and we do not have the resources to do all the jobs.

The objectives of the paper are:

- to review and understand the limitations of disparate and fragmented data in the decision-making process;
- review the key features of methods for integration and fusion in maintenance decision data;
- to illustrate an automated algorithm for dynamically merging maintenance data streams;
- to demonstrate effectiveness by implementing the algorithm on industrial data.