Integrated Maintenance Management System in a Textile Company

Yiliu Tu* and Eddie H. H. Yeung†
Department of Mechanical Engineering, University of Canterbury, Christchurch, New Zealand; and tCentral Textiles (HK) Ltd, Tsuen Wan, NT, Hong Kong

In this paper, an AI (artificial intelligence) approach to the design and control of an integrated maintenance management system is reported. The research work has been done on two levels. At the managerial level, the overall maintenance management system is designed by the GRAI method. This system is designed as an integrated system which makes decisions on maintenance activity scheduling and control, taking into consideration not only equipment working conditions but also maintenance cost, product quality, and production efficiency. At the decision support level, a number of intelligent decision support systems (IDSSs) are developed based on Bayesian theory or causal probabilistic networks (CPNs). In this paper, a generic CPN for the maintenance of open-end spinning mills is reported.

Keywords: Artificial intelligence; Causal probability network; Intelligent decision support system; Maintenance management and control

1. Introduction

Both the Scandinavian [1] and USA [2] maintenance benchmark studies highlight the need to clearly define maintenance objectives, to develop modern methods of maintenance management, to integrate maintenance and production activities to minimise downtime, to decentralise the maintenance organisation, and to use computer-based maintenance systems. Research is needed to develop a new framework for the analysis and design of modern maintenance management systems.

This paper reports the research project which has been carried out at Central Textiles (HK) Ltd in Hong Kong. The main objective of the project is to help the company to develop an integrated maintenance management system by using artificial intelligence (AI) technologies. This AI-based maintenance system schedules and controls maintenance activities, taking into consideration not only the working conditions of equipment in the company but also the production quality, production system efficiency and production cost. By this case study, the authors aim to develop the basic methods and concepts for structuring the framework of integrated maintenance management systems.

The research work has been carried out on two levels. At the managerial level, the overall maintenance management system is designed by the GRAI method. At the decision support level, a number of intelligent decision support systems (IDSSs) are developed based on causal probabilistic networks (or Bayesian networks). These IDSSs support the integrated decision-making for the planning and control of maintenance activities. An IDSS for open-end spinning mills is developed as a generic model. This generic model will be reported in this paper. According to the basic principles of this generic module, the IDSSs for other types of machines in the company can be further developed. The IDSSs are the core modules of the decision centres in the overall maintenance management system which is modelled by the GRAI method on the managerial level. Using this new AI-based integrated maintenance management system, rather than its traditional “run-fail-fix” maintenance management strategy, the company is approaching a more dynamic and integrated maintenance management strategy to enhance its movement towards so-called world-class manufacturing (WCM) [3].

2. Literature Review

The literature and research reports concerned with maintenance management systems and decision support systems are extensive. However, the authors are not aware of any references that discuss the research outlined in this paper in any depth. Numerous references either mentioned the topics discussed here or were indirectly related to them. Some representative papers are reviewed in the following paragraphs. Wireman [2] refers to maintenance planning as the last frontier for manufacturing facilities. In the move to world-class manufacturing (WCM), many firms are seeing a critical need for effective...
maintenance of production facilities and systems. With the
trend to Just-in-time (JIT) production and to flexible, lean or
global manufacturing [4], it is vital that maintenance decisions
become integrated with corporate strategy to ensure equipment
availability, quality products, on-time deliveries, and competi-
tive pricing.

In February 1992, an EUREKA project was initiated that
attempted to benchmark maintenance in Scandinavian countries
[1]. Participating countries were Denmark, Norway, Sweden,
and Finland. Denmark served as the liaison country. Some key
Nordic maintenance societies participated, such as the Danish
Maintenance Association, the Finnish Maintenance Society, the
Swedish Maintenance Society, and the Norwegian Society of
Maintenance Engineers. Through the EUREKA project, the key
features for maintenance in different types of manufacturing
companies were developed. These key features can be used by
companies to:

1. Pinpoint new areas of effort for maintenance.
2. Compare their own efforts and results with those of the
   others.
3. Establish new maintenance goals.

Wireman [2] conducted a similar maintenance benchmark
survey in the USA and found that maintenance costs for
industrial firms have risen 10–15% per year since 1979. Unfor-
unately, the total “waste” in excessive maintenance expenditure
was approximately 200 billion dollars in 1990 which equaled
the total maintenance costs in 1979.

The emergence of decision support systems (DSS) or com-
puterized information systems that contain domain-specific
knowledge and analytical decision models to support decision
making for complex and ill-structured tasks began in the 1960s
at the Sloan School of Management, Massachusetts Institute
of Technology, the Harvard Business School, and the Business
School HEC in France [6]. Although research results are
equivocal, a DSS is intended to enhance individual learning by
providing easier access to problem recognition, problem
structure, information, statistical tools, and methodological
knowledge [7]. A DSS is designed to enable easier and faster
generation of alternatives and to increase awareness of
deficiencies in the current decision-making process.

The important activities to develop and implement a DSS
are knowledge acquisition and representation. As to knowledge
acquisition, there are a number of methods, such as interviews,
open-ended interviews, task performance and protocol analysis,
questionnaires and surveys, constrained task performance, the
tough case method as well as a number of knowledge elicitation
tools, e.g. Knowledge Acquisition Module (KAM), Central
Office Maintenance Printout Analysis and Suggestion System
(COMPASS), Oncology Protocol Acquisition Laboratory
(OPAL), AutoIntelligence, LAPS, etc. Similarly, semantic
networks, frames, production rules, predicate logic, O-A-V
(Object-Attribute-Value) triplets, Hybrids and Scripts are the
methods normally used for knowledge representation.

To design and implement a DSS, a number of computational
tools have been employed, such as knowledge base (KB) [8,9],
analytic hierarchy process (AHP) [10,11], Petri nets [12], neural
networks [13,14], fuzzy logic and fuzzy networks [15,16], and
Bayesian theory [17,18].

Holtzman [19] uses the new terminology of an “intelligent
decision system” to describe a hybrid computer-based tech-
nology for aiding decision makers in complex decision situ-
ations. The tools build upon the methodology of decision
analysis and the technology of expert systems. The idea is to
use expert system technology to automate the skills and factual
knowledge and expertise of a few individuals and to use the
normative characteristics of decision analysis to improve the
quality of the decisions made. The goal is to reduce the time,
cost, and training needed to make decisions in complex problem
domains. Intelligent decision systems may also be used to
make probability assessments in specific situations.

In complex decision-making situations, research suggests that
a decision maker attempts to deal with unstructuredness by
decomposing these situations into familiar, structurable decision
elements [20,21]. Mintzberg et al. [22] developed a model of
strategic decision making that attempts to portray the decision-
making process as consisting of three phases: identification,
development, and selection. Seven distinct, familiar decision
“routines” comprise these phases and there are three “support-
ing” decision routines and six dynamic factors that may influ-
ence the decision-making process. Although real decision mak-
ing is not as static or sequential as the figure presents,
nevertheless, this model provides an insight into the unique
phases of decision making and positions the technology for
decision support.

Tu and Yeung [23] used a Bayesian network or a causal
probability network to develop a prototype of an intelligent
decision support system (IDSS) for the maintenance manage-
ment system in a textile manufacturing company in Hong
Kong. In this IDSS prototype, the cost, quality and production
efficiency were first taken into account for decision making
on the maintenance activities. Tu et al. [24] used the Bayesian
theory to develop an IDSS for open-end spinning mills diag-
nosis. In this IDSS, the knowledge of maintenance experts is
collected and expressed by conditional probabilities. Using a
Bayesian network, an inference engine for automatic diagnosis
of open-end spinning mills has been developed.

In 1991, Luxhoj [25] developed an organisational scheme
for maintenance modelling and Luxhoj et al. [26] further
proposed an intelligent maintenance support system (IMSS).

3. GRAI Grid of the Overall Maintenance
   Management System

The GRAI method was developed in the GRAI laboratory,
University of Bordeaux, France in 1983 to model decisional
manufacturing systems. It includes a conceptual model, GRAI
grids and GRAI nets [27]. In this research project, the GRAI
method has been employed as a modelling tool for the analysis
and design of an AI-based maintenance managerial system for
Central Textile (HK) Ltd. In this paper, the discussion will be
focused only on the GRAI grids of the system.

According to the description of the GRAI method made in
[27], a GRAI grid looks like a table. From left to right along
a row, the information is expressed from the general to the