Peter Funk, Mats Jackson. Experience Based Diagnostics and Condition Based Maintenance Within Production Systems. In COMADEM 2005, The 18th International Congress and Exhibition on Condition Monitoring and Diagnostic Engineering Management, editor: David Mba, pages 7, United Kingdom, August 2005.

EXPERIENCE BASED DIAGNOSTICS AND CONDITION BASED MAINTENANCE WITHIN PRODUCTION SYSTEMS

Peter Funk[1] and Mats Jackson[2]

[1]Department of Computer Science and Electronics,
Mälardalen University, P.O. Box 883, SE-721 23 Västerås, Sweden,
peter.funk@mdh.se, phone +46 21 10 31 53, fax +46 706 11 91 50
[2] Department of Innovation, Design and Product Development,
Mälardalen University, P.O. Box 325, SE-63105, Eskilstuna, Sweden,
mats.jackson@mdh.se, phone +46 16 15 32 14, fax +46 16 15 36 10

ABSTRACT

Production efficiency within the manufacturing industry averages on 60% and there is large consensus that 80% is a realistic goal. This makes loss of production capacity the single largest loss in a products life cycle costs [1]. Reducing down time within production systems is therefore essential for increased profit. Hence, experience and knowledge on how downtime in production is reduced is one of the most valuable assets in company. Maintenance and down time are directly related. Easy accessible experience and knowledge on how to determine, and then perform preventive or corrective maintenance is essential for a maintenance engineer. Experience and knowledge is directly linked to the down time of the equipment. An issue is addressed by collecting and structuring experience in symptom, diagnosis & case study solutions. Both human experience and automatically collected experience is captured and reused automatically and semi-automatically. This is achieved using decision support systems based on methods and techniques from e.g. artificial intelligence, knowledge discovery and case-based reasoning. In one application experienced operators are able to classify faults by listening to the industrial equipment has been performed [2]. Only the most experienced operators are able to make reliable diagnosis based on sounds. When the expert retired, a case-based system that classifies the fault based on a sound recording was developed. The system generates a list with the most similar cases including symptoms, diagnosis and information on corrective actions. Experience cases may be collected world wide from similar machines improving the performance of the maintenance system. If experience is stored using industry standard [3], a global Internet search for matching cases is possible. The approach will considerably reduce fault identification time and fault correction time and reduce down time. This paper will discuss and describe experience-based diagnostics and condition based maintenance within production systems and applications within robotic cells.

KEYWORDS: Production Capacity, Experience Reuse, Decision Support Systems, Condition Based Maintenance, Artificial Intelligence, Case-Based Reasoning.

INTRODUCTION

Industrial competition is today truly global with customers expecting to get the best product at the best price with immediate availability. Success in manufacturing, and indeed survival, is increasingly more difficult to ensure and it requires continuous development and improvement of the way we produce products. Meeting customer demands require a high degree of flexibility, low-cost/low-volume

manufacturing skills, and short delivery times. There is a need for new methods, tools, and procedures to improve the product development work especially due to an increased complexity and amount of interactions between different sources due to outsourcing of product development and manufacturing.

Loss of production capacity, the single largest loss in a products life cycle costs [1] and with an increase of production efficiency with 33%, seen as a realistic goal, large values would be saved. The main focus is on reducing down time within production systems. In maintenance related costs, Swedish industries spend 190-200 billion SEK (~US$22-24 billion) per year. With a more effective maintenance execution and an increase in availability, the heavy industry in Sweden could save up to as much as 20% in non-realized revenue, due to loss of productivity when non-effective maintenance is carried out [4]. Thus, more companies have begun to realize that maintenance is something one can make money on, and stopped seeing it as just a cost.

Experience at all levels and phases in the life cycle are essential to achieve this target. Artificial Intelligence (AI) has a number of promising and successful methods and techniques of interest. In this paper we will focus on maintenance and system health management [6] and the use of methods and techniques from the field of AI. In particular two areas of high value are; experience-based diagnosis using AI and condition-based maintenance using AI. In the Condition Based Maintenance (CBM) technology, one takes condition monitoring results to account and then plans the maintenance action. The purpose of CBM is to eliminate breakdowns and prolong the preventive maintenance intervals.

ARTIFICIAL INTELLIGENCE METHODS & TECHNIQUES

Recently, Artificial Intelligence (AI) methods and techniques are being continuously developed with more focus on information and knowledge handling from the customers point of view. Previous knowledge management focused strongly on just storing large amounts of data for data mining purposes. Now the increasing use of the Internet and information overload puts a great demand for managing the intelligent information skilfully and efficiently. From this point of view, the application of AI methods and research in the growing area of human-machine interaction is gaining grounds for further investigations.

In the eighties, applied AI had a strong focus on rule-based systems. Rule-based systems are today widely used and successfully implemented for many types of problems and tasks. They require translation of knowledge and experience into rules. If the body of experience and knowledge is larger, this translation is costly and large rule-based systems often require continuous & improved maintenance. This means new experience and knowledge has to be integrated into the rule corpus and constantly validated and verified. One faulty rule can in worst-case ruin the complete performance of a rule-based system. Also, many areas do not have such precise and evolved theories and methodologies which can easily be translated into rules. In the nineties artificial neural networks (ANNs) got much attention. Now there are many valuable and successful industrial applications of ANNs.

Today, an emerging research trend in AI is to focus on the application of knowledge and experience, a very fertile area which is finding increasing importance, as enormous amounts of information of varying quality is collected on the internet (Google™ finds 3,2 billion pages with the word “the” despite that the largest part of the web is hidden in databases and not accessible by search engines). Features and applications are possible to implement today that were not feasible to deploy in real applications only a few years ago.

AI has a range of successful methods and tools that are used in a wide range of applications such as, search engines, personalization, helpdesk applications, limited natural language understanding and intelligent agent technologies. AI methods enable learning and adaptable solutions. These methods and

techniques can be used to improve and aid efficient on-line communication in collaborative environments [6]. AI and CBR enable a number of desirable features, i.e. capture, match, adapt, personalize, and present information tailored to a specific user, facilitating the navigation in a workspace.

EXPERIENCE SHARING AND KNOWLEDGE CAPTURE

In this section a number of features will be listed, where AI methods and techniques support experience sharing and knowledge reuse valuable in a product development and manufacturing scenario. Many of the features already exist in some AI systems or even commercial systems, but the combination and the context is not fully explored [7] and it is seen as an important step towards a full deployment of OSA-CBM [osacbm]. In Figure 1 the main OSA-CBM architecture is illustrated.

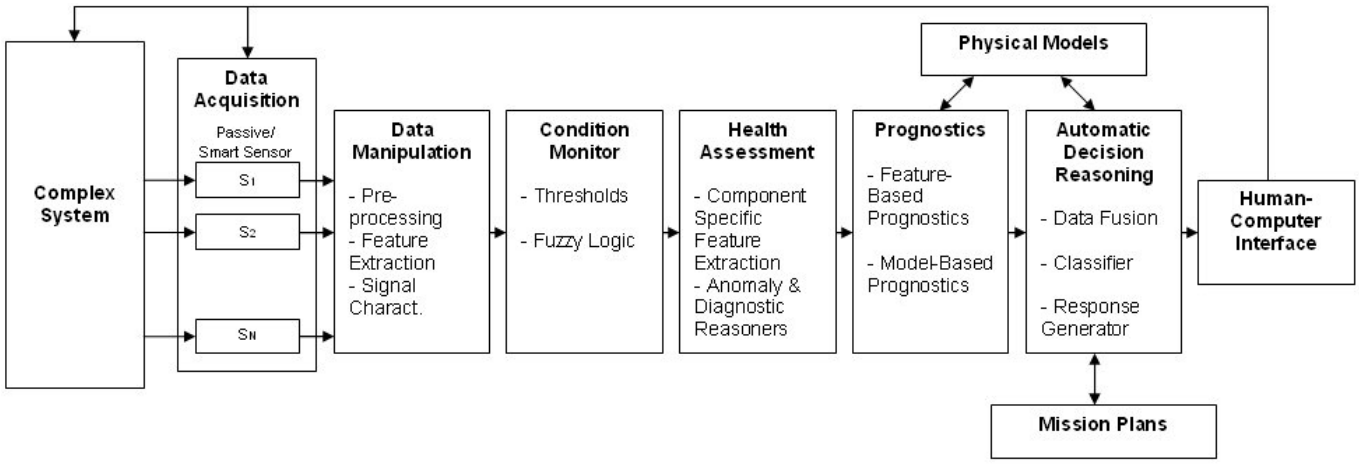

Figure 1: Illustration of the OSA-CBM architecture standard proposal (Lebold et.al, [8]*), adapted from [2].*

User experience and AI methods are invaluable in any of these phases and once integrated in all phases, a large step towards intelligent manufacturing machines can be realised.

Some examples of valuable AI methods and techniques that have been or are under exploration in a number of research projects with industry in the ExAct project funded by the Swedish Foundation for Strategic Research are presented. The main idea is given in Figure 2.

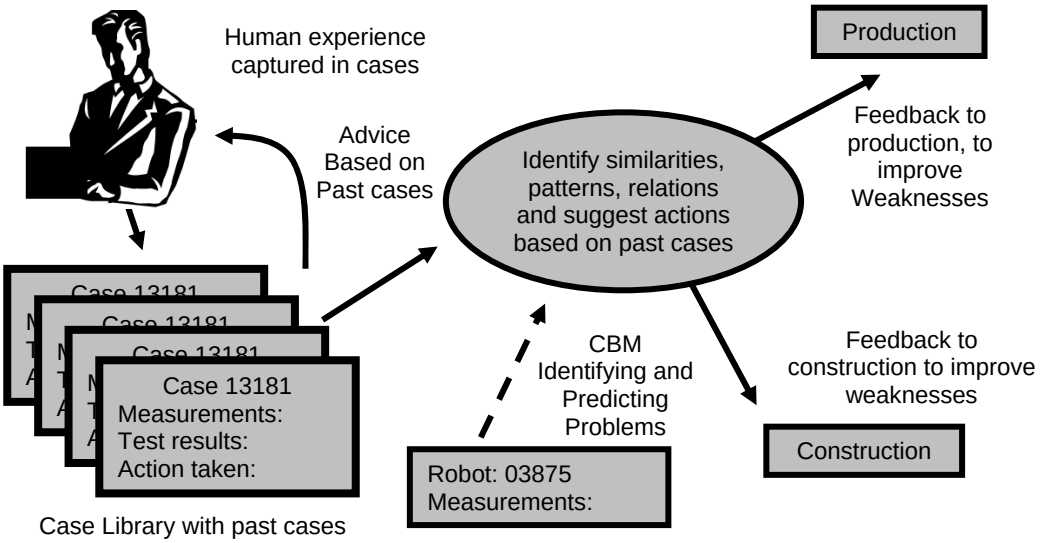

Figure 2: Integrated CBM, diagnostics and testing into product development and manufacturing

Case-based reasoning, domain specific ontology, natural language processing and intelligent agents are examples of three methods and techniques that have valuable applications in many areas, e.g. in [7]. In a collaborative and personalized framework there are a number of features that may benefit by using AI methods and techniques [6]:

Ontology in an intelligent search engine

For technicians and engineers it is essential that they find the right documents. Searching in the corporate body of documents using keywords is a difficult task. Important documents essential for the current task or activity may be lost resulting in heavy and costly damages running to millions (e.g. using the wrong lubrication for a robot in a production line, causing it to brake). Ontology may be used in an "intelligent" search engine to search for a document without any keywords in it. Instead the document uses keywords on a different abstraction level (e.g. vehicle instead of lorry) or related words (horsepower instead of KW) or keywords not used in any documents but being a subpart of other common keyword ("Teflon, a component used in synthetic lubrication"). A traditional search would fail in finding good matching document in these situations, but using an ontology would resolve this efficiently and elegantly. But to develop such tools the industry needs to realise the potential benefits and value & be prepared to invest on for such features.

It is still surprising that many technicians and engineers use crude tools such as Google™ in their information gathering and search. Search engines of this calibre are optimised to search billons of documents, and to make this possible many compromises are made. It is possible to make searching tools that are comparable to Google™. These specialized search engines may have limited natural language processing capabilities, use word nets, spell checkers, synonyms, ontology and cluster techniques. Since the value of such functionality is not fully explored and evaluated, companies tend to continue using free software, primitive for the tasks, and also missing many relevant and important documents causing unnecessary and costly expenses with dire consequences.

Intelligent agent technology to identify expertise

In any organization most skills are undertaken by employees, but the problem is often to find the persons with the specific knowledge. Using Intelligent Agent Technology it is possible to identify the needed expertise thus reduce consultancy costs and create healthy interaction between employees. One method such an agent may use is to identify relevant expertise from which it should be possible to create a profile of users using a specific in-house "information search tool". All documents can be retrieved and all keywords or phrases can be used for this purpose. Profiles for users retrieving and also writing and adding documents to the corporate storage would become very precise and surpass any CV or personal biography system. Integrity is not an issue since the profiles data are directly connected with work. The agent may never store or reveal any information on the match, just suggesting a number of people having the right skill and knowledge for a specific task.

Case-based reasoning (CBR) structuring experience

A Case-based reasoning structuring experience containing a problem description, a diagnosis, the solution to the problem was resolved. CBR is an AI technique with many successful research projects with promising results and commercial applications [10]. Every time a new problem is solved it is added to the case library. The next time a similar problem occurs, the relevant cases will be retrieved. The Case-based reasoning system may have adaptation knowledge adapting similar cases to solve the current problem. Such a case library would be an invaluable asset to any corporate information management system.

User feedback is also an important factor in a Case-based experience-sharing tool and if users repeatedly reuse a specific case and are satisfied with the solution, then the case is obviously valuable and has

succeeded with its knowledge transfer purpose.

If a user selects a case for reuse, and makes adaptations to the specific problem and context, this “new” case is added to the case library. This expands the total amount of experience in the case library. The case library adapts to the users needs, and the probability that a suitable case requiring little adaptation is stored in the case library increases. If any new problems not previously covered arise, the solution needs to be solved with traditional methods and may need to be authored by an expert before less experienced end users may be allowed to use the case. Next time when a similar problem or situation occur, the experience sharing system has a solution to offer.

If a user needs to make an important decision and is given a number of previous cases where decisions have been made under similar conditions, and their outcome is recorded, the user has much more experience to base her/his decision. This not only improves the quality of the decision making system but also transfers experience between users.

CASE STUDY IN EXPERIENCE BASED DIAGNOSTICS AND CBM

Success and failure is often directly or indirectly connected with the ability to share and communicate each other’s experiences. In [7] the engineers experience when repairing a robot is directly captured in a case together with measurement readings from the healthy equipment. The system collects experience through cases and becomes more competent as more new cases are added to the case library. When a case occurs for the first time, an experienced engineer may identify and repair the fault. In a CBM scheme, all measurements are recorded before a fault occurred, and contain significant information to identify the fault within a given time frame and suitable maintenance tasks are performed to repair the fault. The difference between corrective and preventive maintenance is small in case-based reasoning when seen from a CBR implementation point of view.

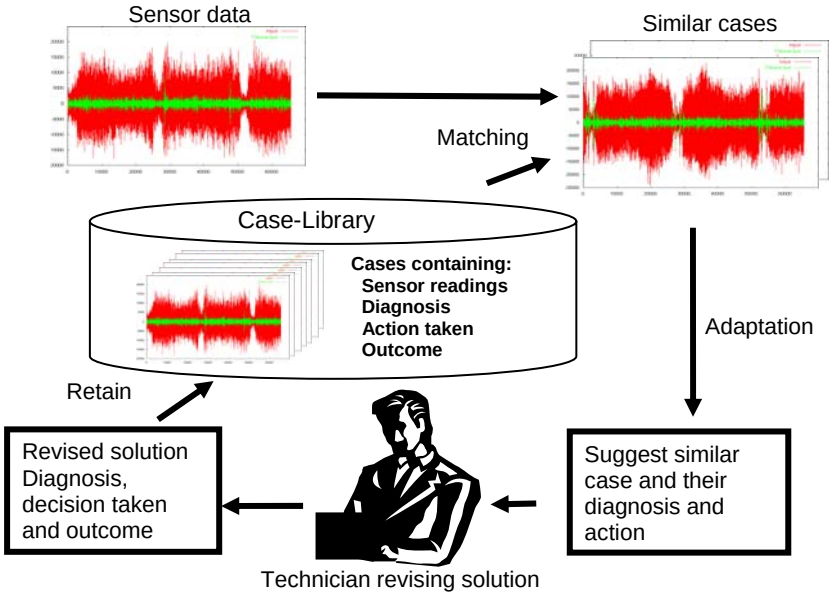

Figure 3. A typical case-based reasoning (CBR) cycle instantiated for maintenance tasks.

INTEGRATED INTELLIGENT-BASED CONDITION BASED MAINTENANCE

As industrial competition grows, greater emphasis will be placed towards efficient maintenance strategies. This has led to the development and implementation of different maintenance strategies, such as Total Productive Maintenance (TPM) and Reliability Centred Maintenance (RCM), which are designed to take care of industrial assets in a production environment. The Condition Based Maintenance (CBM)

strategy judiciously utilizes condition monitoring tools and techniques to assess the health of equipment's condition in order to decide both the maintenance intervals as well as maintenance tasks. Thus decreasing the corrective maintenance (impending faults are found before they become critical) and the predetermined preventive maintenance (maintenance intervals are decided when a need for such action has arisen to execute planned production smoothly and efficiently).

The development of CBM systems is directed towards the ability to diagnose any abnormalities and to calculate the remaining useful life (RUL) using Artificial Intelligence (AI) techniques. AI encompass the application of Neural Networks, Case Based Reasoning, and Fuzzy Logic tools and techniques. They are ideally suited to efficiently handle large amounts of data which are generated in pattern recognition, non-linear and complex systems etc. Significant progress is being made in developing a number of CBM system. A variety of different commercial products can be found on the market. One way to improve the development of CBM technology to a much wider application areas is to fully explore and exploit the potential benefits of the artificial intelligence technology.

CONCLUSIONS

Success and failure is often directly or indirectly connected with the ability to communicate and share knowledge, goals, vision and ambitions. Industry is realizing its needs, benefits and value by supporting collaboration and knowledge in a serious and efficient manner. It is the core issue and value of many companies. Evaluations of existing frameworks for collaborations have revealed the urgent needs and demands for an efficient collaboration and knowledge sharing. Artificial Intelligence offers a number of powerful methods and techniques, which offers potential benefits if harnessed properly.
The importance of experience sharing within organizations, companies and projects, and some AI methods and techniques have been discussed. Some possibilities with AI in a product development context has been presented and discussed.

ACKNOWLEDGEMENT

This work is sponsored by the Swedish Foundation for Strategic Research, ProViking and part of the ExAct and Factory in a Box projects.

REFERENCES

[1] Hägg, B. The Great Profitability Potential in Swedish Industry (In Proceedings of the 16th International Conference on Condition Monitoring and Diagnostic Engineering Management, Sweden 2003, Sweden, Växjö University Press, 19-22.
[2] Bengtsson, M. Olsson, E., Funk, P., Jackson P. Technical Design of Condition Based Maintenance Systems - A Case Study. MARCON (Maintenance and Reliability Conference), Knoxville, TN, USA, 2004.
[3] R Lewis, C Roberts. Using XML to Support Distributed Maintenance Management (In Proceedings of the 16th International Conference on Condition Monitoring and Diagnostic Engineering Management, Sweden 2003, Sweden, Växjö University Press, 199-209.
[4] Ahlmann, H., R., From Traditional Practice to the New Understanding: The Significance of the Life Cycle Profit Concept in the Management of Industrial Enterprises, "IFRIMmmm Conference", Växjö University, Sweden, Växjö, 2002.
[7] Olsson, E., Funk, P., Bengtsson M. Fault Diagnosis of Industrial Robots using Acoustic Signals and Case-Based Reasoning, In 7th European Conference on Case-Based Reasoning, editor(s): Funk González Calero, Springer, August 2004.

[5] Hadden, G.D., Bergstrom, P., Samad, T., Bennett, B.H., Vachtsevanos, G.J., Van Dyke, J., Application Challenges: System Health Management for Complex Systems, “IPDPS 2000 Workshops”, 2000, pp. 784-791.
[6] Funk. P. Intelligent Human Computer Collaboration (HCC), In GWEM2002, German Workshop on Experience Management, Berlin, editor(s): Steffen Staab and Mirjam Minor, March 2002.
[8] Yam, R. C. M., Tse, P. W., Li, L., Tu, P. Intelligent Predictive Decision Support System for Condition-Based Maintenance, “International Journal of Advanced Manufacturing Technology”.
[9] Lebold, M., Reichard, K., Boylan, D., Utilizing DCOM in an Open System Architecture framework for Machinery Monitoring and Diagnostics. “Aerospace Conference Proceedings”, 2003, pp. 1227-1236.
[10] Watson, I. Applying Case-Based Reasoning: Techniques for Enterprise Systems. Morgan Kaufmann. 1997.