ROLE OF KNOWLEDGE MANAGEMENT IN DIAGNOSING AND PROGNOSING SYSTEM'S FAILURES

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Summary

In this paper we emphasize the importance of condition monitoring fault diagnosis and prognosis in modern dynamic systems, if they are to remain healthy, competitive and profitable, and to meet the challenges of the future. We argue that there is an urgent need for deep knowledge based reasoning and analytical capability to effectively deal with various ongoing issues related to systems operations, performances enhancement and failures. We put forward that Knowledge Management plays an important role in an integrative approach to enhance the quality, reliability and safety aspects of such systems in today's global environment.

Keywords: Knowledge Management, Intelligence, Knowledge Representation, Condition Monitoring, Fault Diagnosis and Prognosis.

ROLA ZARZĄDZANIA WIEDZĄ W DIAGNOZOWANIU I PROGNOZOWANIU USZKODZEŃ SYSTEMU

Streszczenie

W pracy przedstawiono rolę zarządzania wiedzą na proces diagnozowania i prognozowania uszkodzeń systemu. Autorzy przeanalizowali interakcje pomiędzy wiedzą, działaniem i uszkodzeniem oraz przedstawili koncepcję zarządzania wiedzą ukierunkowaną na jakość, niezawodność i bezpieczeństwo systemu.

Słowa kluczowe: zarządzanie wiedzą, reprezentacja wiedzy, monitorowanie stanu, diagnozowanie i prognozowanie uszkodzeń.

1. INTRODUCTION

A business enterprise is an open and highly interactive system with its own operational environment, and needs to be proactively monitored, diagnosed, prognosed and effectively controlled if it is to remain profitable and sustainable. Global Enterprises are becoming highly innovative and entrepreneurial, and are under constant pressure to continuously improve their performance. Today's modern enterprises have no alternative but to intelligently manage its physical and human assets in order to achieve its intended mission to the satisfaction of its stakeholders and global customers with maximum efficiency and minimum delay. The philosophy of Condition Monitoring and Diagnostic Engineering Management (COMADEM) encourages the management to involve in the processes of Knowledge Discovery, Generation, Dissemination and Management activities as an ongoing dynamic process.

Section 2 is concerned with the interaction between knowledge, action and failure. In section 3 we discuss the basic concepts of data, information and knowledge. Section 4 deals with the Knowledge Management (KM) Process. In section 5, we discuss some Knowledge Representation (KR) issues in KM. Section 6 is concerned with the nature of cooperative work and in section 7 we argue the need for COMADEM and criteria for the assessment of knowledge bases. Finally, in section 8, we propose, that Knowledge Management should play a central role in diagnosing and prognosing system failures.

2. KNOWLEDGE, ACTION AND FAILURE

In order to remain competitive and sustain the market forces of today, an enterprise has to act proactively and intelligently to boldly meet the challenges of the future. Intelligent knowledge can only be realized by acquiring appropriate educational skills, training and experiences. It is a life long process. Intellectual assets include appropriate knowledge characterization, deep understanding, appropriate judgment, manipulative and meta knowledge of a situation. Abilities include capabilities to clearly identify what is needed for a given situation, determine how to handle it, and implement the desired and corrective timely actions successfully. In addition to information and knowledge, intelligent behavior also requires ability to take bold initiatives, harnessing the needed resources and other forms of logistic support for appropriate follow-up. The degree to which an enterprise can act intelligently depends on the competencies of its capabilities and its decision-making processes. The competencies, which determine how well tasks are performed, are a function of the knowledge (understanding, expertise, and skills) that is available or embedded in the enterprise's capabilities and culture.

The success of an enterprise depends on the interplay of many conditions. Some of theses are:

(1) The effectiveness of teamwork through coordination, cooperation, and collaboration.
(2) The effectiveness in dealing with normal requirements and the ability to respond to both internal and external demands.
(3) The effectiveness of a System Performance Monitor that gives an indication of how well various operations are performed and business targets are achieved, together with the ability to accurately predict and effectively control unexpected, unusual events and challenges.
(4) The degree to which information/knowledge is effectively networked and skillfully communicated.
(5) The degree to which appropriate resources to perform various tasks are provided.

Needless to say that Knowledge Management play a significant role in fulfilling the above conditions.

However, there are many factors like, limited resources, lack of appropriate knowledge and ignorance that may lead to failures. We believe that understanding and dealing with failures require deeper understanding of the system under investigation. In other words, modeling the normal behavior of a system requires knowledge of its components and their interactions with each other and the operational environment and not ignoring the human factors issues. Dealing with failures require understanding of the root causes of failure mechanisms of the components and the system in its operational environment.

3. DATA, INFORMATION AND KNOWLEDGE

There is a consensus among researchers that there is a distinction between *data*, *information* and *knowledge*. Emphasizing such a distinction may help in understanding the full scale of these issues.

We begin with *data*, which can be considered as raw information that is meaningless to an interpreter. *Data* becomes information when some meaning is added to it. Methods such as contextualizing or categorizing may be employed to add meaning to *data*. *Information* represents an understanding of the relationships between pieces of *data*, or between pieces of *data* and other information. *Information* relates to different forms of descriptions and definitions.

Unlike information, *knowledge* is less tangible. It is inferred from information by humans using methods of comparison, consequences, connections, and conversation.

According to Davenport and Prusak [4]:

"Knowledge is a fluid mix of framed experience, values, contextual information, and expert insights that provides a framework for evaluating and incorporating new experiences and Information. It originates and is embedded in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms."

Knowledge represents a self-contextualizing pattern relation between pieces of information (or data). It encompasses what we may call strategies, practices, methods and principles. There are several types of *knowledge* and some of these types are difficult to distinguish from *information*. Indeed, *information* is somewhere between *data* and *knowledge*. To appreciate the degree of overlap, we only need to consider the scope of the notion of an information system that spans database systems and intelligent knowledge base systems. For instance, *knowing* a fact does not resist being classified as a piece of information. However, *knowing* how (a skill) or *knowing* that the occurrence of some event might affect the operational capacity of a machine or the conditions in the market is proving more difficult to codify, suggesting that such type of knowledge may have a human dimension. Knowledge can inform us of how the pattern it represents will evolve.

Other definitions of *data*, *information* and *knowledge* are found in Brooking [1].

Intelligence is more associated with the principles of generating, manipulating and applying knowledge.

It is clear that the notion of *knowledge* encompasses *information* and *data*. It also seems incomplete to manage knowledge without taking into consideration the possible ways it can be manipulated in order to satisfy a goal. Thus, Knowledge Management (KM) cannot disregard embedded intelligence. In addition, it cannot dispense with data and information because they form the basic constituents of knowledge.

This view is in accordance with that of Davidson [5] who states that the key for success of an enterprise is based on an understanding, specifying and realizing the following objectives:

Goal: What is to be accomplished?

Performance: How the results are to be delivered?

Change: how to deal with change and see it as an advantage?

In the case of a competitive environment, how to gain a competitive edge?

4. THE KM PROCESS

Knowledge Assets (KA) can be regarded as the knowledge regarding all aspects that an enterprise needs to employ to achieve its goals. KA include appropriate characterization, deep understanding, appropriate judgment, manipulative and meta knowledge of a situation. *Abilities* include capabilities to identify what is needed for a situation, determine how to handle it, and implement the desired actions successfully.

Knowledge Management (KM) is an interdisciplinary area that deals with all aspects of managing the KA of an enterprise. The primary purpose of an enterprise KM system should be to make knowledge accessible and reusable by its users (whether human or software agents) [10]. This has an essential role to play in enhancing an enterprise intelligent behavior, which results from appropriately applying the available (**right)** KA at the right moment. In addition to information and knowledge, *intelligent behavior* also requires the ability to take initiative, access to needed resources and other form of support for appropriate follow-up.

Such a view of KM has many implications and important key words such as inter-disciplinarity, knowledge, forms of knowledge, management, access, use and reuse, agent and multi-agent systems. The term KM encompasses not only these concepts independently but also what they may imply and the different ways they could interact in order to achieve the enterprise goal(s). This can only possible if there is an appropriate evaluation mechanism which necessitate criteria that need to be satisfied and conditions that must not be violated and require monitoring.

At a global level, KM presses for a deeper communication between, restructuring and regrouping of workers and researchers in multidisciplinary fields such as Artificial Intelligence, Information Science Technology and Management. At a more local level, it is rekindling interests in areas such as knowledge representation, underlining the need for multi-agent systems and for cooperation/fusion and coherence between different knowledge sources and so on.

KM is essential to an enterprise to realise the following objectives regarding the:

- degree of complexity of the operations and machinery it employs;
- market pressure and the severity of competitiveness;
- unpredictability of the environment and working conditions;
- pressure to cope with *changes* in many aspects.

Enterprises are expected to make optimal use of their knowledge (and tangible) assets to achieve their goals. Some of the expected benefits to an enterprise from pursuing this line of thought include:

(a) Better understanding of its processes and how to control them. This implies:
  - Rises in productivity (both in quantity and quality)
  - Enhanced ability to handle different types of uncertainties and unexpected problems.
  - Ability to take advantage of novel and innovative ideas and opportunities.

(b) Easier access to richer resources, techniques and tools.

The process of KM involves the activities of generation, codification and transfer of knowledge [4].

There are many approaches to knowledge generation. Among these are *acquisition* and *fusion*. The latter tolerates different viewpoints and experience. Both codification and transfer emphasize the role of knowledge representation. The aim of codification is to represent knowledge in a form that makes it accessible to and understandable by the users. The way knowledge is represented /codified influences its role and value and the extent to which it is open to changes and updates. *Transfer* involves (human) communication and cooperation in solving problems. Explicit knowledge/information can be represented in documents, databases, knowledge bases and communicated with reasonable accuracy. Tacit knowledge such as skill, expertise, heuristics, preferences and strategies, are more difficult to articulate and communicate. However, what can be represented can be communicated. Here comes the role of *artificial intelligence* and the emphasis of *representation*.

KM also involves the identifying, analyzing, planning and execution of appropriate actions to develop an enterprise KA.

There are many problems associated with realizing KAs and how they could be harnessed in an efficient and cost-effective manner. Hence, KM requires:

(1) identification of the KA of an enterprise, its effect and its accessibility.
(2) specification of execution of manipulating its use to optimize the required outcome.
(3) proactive monitoring of its use to maintain a beneficial and healthy growth.

More specifically to be able to manage its KA and control the management of all its assets, an enterprise needs:

- to identify, model and explicitly represent its knowledge. This entails modeling its processes, their control and its decision-making;
- an enterprise-wide vocabulary (ontology) to ensure that the represented knowledge is correctly understood, shared, among several applications and for various types of users and re-used;
- systematic approaches to designing and building knowledge-based applications and tools to support modeling, validation, verification, maintenance and constant updating of the knowledge in these applications;
- - the ability to handle the computational aspects of multi-agent systems such as task allocation, interaction and coordination, process and organization representation, collective learning, consistency management, protocol, adaptation and evolution of knowledge, manage heterogeneity and achieve interoperability;
- the ability to monitor deviation from expected outcome and pre-defined goals and to detect what might have caused such deviation and propose appropriate actions to restore the system to its normal behaviour with minimum delay;
- the ability to assess the performance parameters of the system in real time with the latest knowledge to maintain pre-defined goals.

5. KNOWLEDGE REPRESENTATION IN KM

Knowledge and *expertise* are essential ingredients in all enterprise activities in order to:

- competently handle tasks.
- provide innovative approaches to solve problems
- evaluate the consequences of decisions and actions

Consequently, enterprises will benefit if they can control and monitor the efficiency and the usage of its KA. Furthermore, there is a need to investigate how knowledge can be acquired/generated and how it can be represented so that different applications can make optimal use of it according to what is needed. The knowledge should also be accessible, modifiable and understandable to different types of users who need knowledge to perform their tasks. The emphasis should be on knowledge representations that are open to:

(a) Assessment to ensure that there is an adequate understanding of the knowledge in the application and for inspection/ verification processes. Continuous monitoring and evaluation may help to decide whether there is a need for revision, update and learning new knowledge.
(b) Modification to allow an update of the knowledge as needed to meet the requirements of the applications and the needs of users.

O'Leary [10] says that, "We need additional research to expand the use of artificial intelligence and knowledge based systems in Knowledge Management (KM). We need to know what forms of knowledge representation appears to work best for particular types of knowledge". We agree with this proposal and suggest that condition monitoring and diagnostic engineering management (COMADEM) should be an integral part of the KM processes.

It is clear that these objectives can only be realized with knowledge, if it is appropriately represented and intelligently manipulated. KM is only important if it enhances an organization's ability to perform each of the objectives mentioned above. However, this requires a broad view of the different roles that a Knowledge Representation (KR) could play, bearing in mind that its central role is capturing the complexity of the real world. We believe that following [6], a KR can offer:

(1) a description, of the world, which enables a reasoner to determine the consequences by reasoning about it.
(2) a set of ontological commitments which could form a basis for defining the appropriate ontologies.
(3) a (possibly incomplete) theory of intelligent reasoning, expressed as:
    (i) the representation of fundamental conception of intelligent reasoning.
    (ii) the set of inferences the representation sanctions.
    (iii) the set of inferences it recommends.
(4) a means of communication.
(5) a method for efficient computation.

Furthermore, representation and reasoning are entangled. Thus, the recognition that a (particular) representation embeds a (possibly incomplete) theory of intelligent reasoning encourages diversity because what the reasoning theory, embedded in one representation, may have ignored or overlooked would be emphasized in the reasoning theory of another representation. Thus, diversity could be a step towards completeness if an integrative approach to KR is employed. By combining representations within a unified reasoning theory, good use of both the similarities and differences could be beneficially exploited.

We may distinguish, along another dimension, between a static (possibly timeless) representation of knowledge, which is particularly useful for knowledge re-use and a dynamic representation of knowledge needed for knowledge creation. The degree of adaptability of a KM system is dependent upon its capability of sensing complex patterns of change in the environment(s) and using that information for adapting the appropriate knowledge to guide decision-making processes and actions. One key characteristic of a dynamic representation of knowledge is that the performance outcome need to be continuously re-assessed to ensure that it represent the appropriate/best performance for the global enterprise which is constantly exposed to changing conditions. This view of KM is consistent with that of Davenport and Prusak [4] mentioned above in Section 4.

The dynamic view is based upon the ongoing reinterpretation of data, information and assumptions while pro-actively deciding how the decision-making process should be adjusted to deal with future possibilities. It also allows for diversity of interpretations of the same information across different contexts and at different times. Allowing for diversity in representing the same situation is one of the keys to success in properly managing and making an optimal use of the knowledge of an enterprise. The diversity of representations allows for a deeper and a better understanding of the different patterns and characteristics of a situation, and naturally supports distributed and multi-agent systems which is the concern of the next section.

6. COOPERATIVE WORK

An *agent* is a computer system that is situated in some environment, over which it may only have a partial control, and can flexibly and autonomously act and make decisions that meet its objectives in that environment. *Agents* are specialized problem-solving entities that have well-defined boundaries and interfaces (cf. Wooldridge and Jennings (1995)). Agent autonomy is a reflection of its control over both its internal state and its behavior. It relates to an agent's ability to make its own decisions, e.g., about what type of information is to be communicated, which of the agents it knows about and what to make out of incoming information from other agents. *Autonomy* can be restricted by the agent's designer or by the role taken by the agent for some specific period and/or task. Associated with agent autonomy is agent *adaptability*. Such features are usually associated with intelligence/sophistication of an agent.

An agent theory consists of its knowledge of the subsystem with which it is concerned and its interaction with other subsystems, together with some abstract knowledge about other parts/models of the system and other specialized knowledge. In addition to the usual components of an agent theory, the model should include objects of communication and dialogue such as, the available alternatives to an agent and the criteria for evaluating these alternatives.

Effective cooperation is essential in multi-agent systems. The need arises from different types of interdependence between the various sub-systems. One form of interdependence is related to sub-systems overlap or different perspectives and/or models of the same sub-system. Another form of interdependence occurs when two sub-systems are part of a larger sub-system.

Ideally, the agents cooperate among each other in order to achieve some individual objectives, to handle the dependencies that result from what they are involved with or to reach a consensus regarding a goal. Cooperative work:

- assumes no omniscience (i.e., cooperation is a necessity) of involved agents;
- enables a group to accomplish a task that would be infeasible for any of the agents to achieve individually;
- combines different expertise;

- allows the application of multiple problem-solving strategies and heuristics to a given problem;
- facilitates the application of multiple perspectives on a given problem.

Cooperative work is distributed in time, space and logic (control). The pattern of interaction and cooperation changes dynamically with the requirements and constraints of the situation. Of course, in this context, the entire enterprise must react simultaneously and cooperatively (cf. [8]).

7. CONDITION MONITORING, FAULT DIAGNOSIS AND CRITERIA FOR ASSESSMENT

Condition Monitoring (CM) can be defined as a proactive monitoring of key performance parameters/conditions of a dynamic system in operation. In the context of machinery and equipments, the objective is to continuously evaluate the health and to predict the failures well in advance in order to prolong its operational life. Such knowledge is essential to maintain the assets in a fit or use condition throughout its life. In the context of decision-making and management, it determines the effects of the different types (and chunks) of knowledge employed, the effects of particular (knowledge-base) management strategies and the response of systems to changes in harsh environments.

Obeid and Rao [9] proposes that, in an enterprise, there is a need for:

(1) an Asset Management System (AMS) in order to make the processes of decision-making easier by providing information about the (current and future) conditions of essential production assets.
(2) an integrative and proactive approach to monitoring, diagnosing, prognosing and managing all the assets to yield maximum profitability and safety.

However, this requires:

(1) Intensive knowledge that may **transcend** the knowledge of a system's model and its normal operating conditions. Both monitoring and diagnosis require knowledge of a system's *acceptable* goals, system's *reasonable* performance, conditions that cannot be violated, potential failures (if at all possible), the effect of the different types of failures on the normal working conditions of the various components that constitute the system and so on.
(2) Integrating various types of knowledge represented in (possibly) different knowledge representation formalisms. For instance, given a device D we may have to deal with (i) the knowledge of D's domain, (ii) D's topology, (iii) D's structure, (iv) D's function and (v) D's behaviour, (vi) diagnosis-strategy knowledge, (vi) heuristic knowledge related to D and (vii) control knowledge.
(3) Some criteria of assessment so that it can be decided whether or not the Knowledge Base (KB) is appropriate to the system being employed. There are many aspects according to which a KB may be assessed. Some of the criteria are, (1) assessing the present state of a KB for completeness and for information/knowledge content, and (2) comparing different KBs about the same domain but with different knowledge acquisition techniques and/or KR formalisms and so on. It is important to note that these criteria are not independent. With regard to completeness of a KB, there generally is no *clear* specification that has to be met. One way of representing knowledge in a KB is by means of *rules* (cf. [7]). *Rules* in a KB, are usually gradually refined until we reach a point when we may judge that they are quite appropriate for the intended task. However, even then, completeness is a matter of judgment; one way of measuring completeness (e.g. a set of rules for a diagnosis system), is by applying a diagnostic system to a set of test performance tasks, if there are any, and checking that they have optimum expected outcomes (e.g. correctly diagnosing faults). The information/knowledge content of a knowledge base could be a reflection of the type and quality of queries it can intelligently support. Querying a KB is one way of uncovering its knowledge capability. However, this cannot be interpreted outside a context where other important concepts, such as relevance, usefulness, helpfulness may need to be considered. Comparing and evaluating different knowledge acquisition techniques and various knowledge representation schemata might help in deciding which techniques are better for certain tasks.

8. TOWARDS INTEGRATION

To be effective, the proactive and integrated multidiscipline of COMADEM needs a sound decision-making capability to efficiently resolve complex and uncertain conditions to which modern dynamic systems are constantly exposed. Knowledge Management offers the key to prosperity.

The success is highly dependent upon the availability and accessibility of knowledge acquired and employed by the organizations. It is difficult, if not impossible, to make available a comprehensive knowledge base about a dynamic system. Model-based diagnosis employs deep knowledge of the topology, structure and normal function of a system. Knowledge of abnormality (fault models) about a system can never be complete. With international cooperation, COMADEM can play an important role in creating a new information/knowledge library to help the condition monitoring community to get actively involved in diagnosing and prognosing all types of failures associated with dynamic systems. We urgently need such a deep knowledge based reasoning and analytical capability to effectively resolve various ongoing issues related to systems failures and its consequences. Understanding failures is a very exciting multidiscipline in its own right. Knowledge discovery, generation, dissemination and management offer great long term prospects for the economies as a whole.

9. CONCLUSION

This paper has highlighted the importance of condition monitoring fault diagnosis and prognosis in modern dynamic systems. The authors have argued the central role of Knowledge Management in enhancing the quality/reliability/safety aspects of such systems in today's global environment.

REFERENCES

1. Brooking, A. (1999). *Corporate Memory: Strategies for Knowledge Management*. International Thomson Business Press, London.
2. Console, L., Dupré, D. and Torasso, P. (1989). A Theory of Diagnosis for Incomplete Causal Models, *Proc. Eleventh International Joint Conf. on Artificial Intelligence*, Detroit, 1311–1317.
3. Console, L., Portinale, L., Dupré, D.T. and Torasso, P. (1992). Combining Heuristic Reasoning with Causal Reasoning in Diagnostic Problem Solving. *Second Generation Expert Systems*, Springer-Verlag, Berlin, 46-68.
4. Davenport, T.H. and Prusak, L., (1998), *Working knowledge: how organizations manage what they know,* Harvard Business School Press, Boston, Mass.
5. Davidson M., (1996), *The Transformation of Management*, Butterworth-Heinemann.
6. Davis R., Shrobe H. and Szolovits P., (1993). What is a Knowledge Representation? *AI Magazine*, Vol. 14, No. 1, 17-33.
7. Davis, R., Buchanan, B. and Shortliffe, E., (1977). Production Rules as a Representationfor a Knowledge-Based Consultation Program, *Artificial Intelligence* 8, 15–45.
8. Harrington J., (1979), Computer Integrated Manufacturing, Malabar, Florida.
9. Obeid, N. and Rao, B.K.N., (2005), Temporal Aspects in Condition Monitoring & Root Cause Failure Diagnosis of Modern Complex Systems. *International Journal of COMADEM.* Volume 8, Issue 4, 10 – 23.
10. O'Leary, D.E. (1998). Enterprise Knowledge Management. *Computer*, Vol. 31, 54– 61.

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