Knowledge Management for Fault Diagnosis of Gas Turbines Using Case Based Reasoning

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Abstract

Fault diagnosis of industrial equipments becomes increasingly important. Developing a fast and reliable diagnosis system presents a challenge issue in many complex industrial systems. The major difficulties therein arise from the unavailability of experienced technicians for support. This study is oriented to explore a knowledge management approach by capitalizing the expertise which serves on one hand, to build an ontology used in gas turbines maintenance domain, and on the other hand, to develop a case based reasoning tool for helping users to make decisions in diagnostic and maintenance.

Keywords: Knowledge management, domain ontology, fault diagnosis, case based reasoning.

1. Introduction

Construction of automatic maintenance systems, especially diagnosis systems is one of means to optimize reliability and availability of equipments. Indeed, Diagnosis is an intelligent act which is hardly programmable with classic techniques. Several studies have been made for the development of the diagnosis methods based on artificial intelligence (AI) methods and techniques. Expert systems [5] provide a useful means to acquire diagnosis knowledge directly from key personnel (experts) and transform their expertise into production rules. However the knowledge acquisition and verification processes are difficult and complicated and sometimes experienced technicians even have no idea of how to express their strategies explicitly and accurately. Rule induction and neural network [10] are the means that can be applied to find out fault classification knowledge using previous known examples. These methods are demonstrated robust but requires a sufficiently large training set to ensure promising outcome. Case based reasoning (CBR) [1] offers another alternative to implement systems of intelligent diagnosis for real applications. This alternative is motivated by the idea that the similar situations lead to similar outcomes. The main strength lies in the fact that it enables directly reusing concrete examples in history and consequently eases the knowledge acquisition bottleneck. It also creates the opportunity of learning from experiences but skipping the step of data training.

We believe that CBR techniques are of particular application value for diagnosis in real industrial environments where the acquirement of adequate training examples in advance is mostly not realistic if not possible.

The paper is organized as follows: section 2 gives an overview of knowledge management. Concepts of ontology, CBR and gas turbines are given in the section 3, followed by the explanation of the gait adopted for the conception and the implementation of the ontology as well as an explanation of the use of the principle of CBR for the diagnosis in gas turbines in section 4. We conclude our work in the section 5.

2. Knowledge management

Facing the needs increased of the enterprises to preserve and to share knowledge of their employees, knowledge management began to occupy, since the beginning of the years 90, a more and more important place in the enterprises [13]. Several definitions of the concept of knowledge management have been proposed in the literature: [13]; [6]; [7]. Two extreme ways exist to conceive knowledge management systems. On one hand it is considered like a simple process of communication that can be improved with certain tools (electronic mail service, Groupware, Intranet, workflow, System hypertext, etc). On the other hand it is about capitalizing knowledge with the help of a corporate memory by analogy with the human mind that allows us to construct on past experiences and to avoid the repetition of errors; the corporate memory must capture the information of the different sources of an organization and make it available to do different tasks.

According to our perception knowledge management can be defined as: "a set of tools used for structuring and preserving a capital of knowledge in an organization, facilitate access to these knowledge and sharing it while assuring the survival of this capital by the update and the creation of new knowledge"

According to Grundstein [7], generic processes of knowledge management answer the problematic of knowledge capitalization This problematic is characterized by five facets and their interactions : to mark the crucial knowledge, preserving, valorising, actualizing and managing this knowledge, each of the facets refer to some processes intended to solve the problems concerned: Identify, localise, Modelling, conserving, diffuse, exploit, evaluate, organize ,….etc.

3. Modelling knowledge

3.1 Ontology

Knowledge capitalization process consist in marking the crucial knowledge (know and know-how) that are necessary to the processes of decision. So it's important to identify; then to formalize and model the explicit knowledge in order to memorize them. One of the proposed methods is the construction of the ontology [4].

The following definition has been given to the ontology in [4] "to make ontology, is to decide of the individuals who exist, the concepts and properties that characterize them and the relations that link them". So, the ontology contains the terminological primitives of the domain (the conceptual vocabulary structured in a set of concepts and a set of existing relations between these concepts).

3.2 Case based reasoning (CBR)

The processes that make up case-based reasoning can be seen as a reflection of a particular type of human reasoning. In many situations, the problems that human beings encounter are solved with a human equivalent of CBR. When a person encounters a new situation or problem, he or she will often refer to a past experience of a similar problem. This previous experience may be one that they have had or one that another person has experienced. If the experience originates from another person, the case will have been added to the (human) memory through either an oral or a written account of that experience. The idea of CBR is intuitively appealing because it is similar to human problem solving behaviour. Therefore, CBR involves reasoning from prior examples [1]: retaining a memory of previous problems and their solutions and solving new problems by reference to that knowledge.

Descended of the research in artificial intelligence on the problems resolution, this principle of resolution can be described as follows [8]: Generally, a case-based reasoner will be presented with a problem, either by a user or by a program or system. The case-based reasoner then searches its memory of past cases (called the case base) and attempts to find a case that has the same problem specification as the case under analysis. If the reasoner cannot find an identical case in its case base, it will attempt to find a case or multiple cases that most closely match the current case.

In situations where a previous identical case is retrieved, assuming that its solution was successful, it can be offered as a solution to the current problem. In the more likely situation that the case retrieved is not identical to the current case, an adaptation phase occurs. During adaptation, differences between the current and retrieved cases are first identified and then the solution associated with the case retrieved is modified, taking these differences into account. The solution returned in response to the current problem specification may then be tried in the appropriate domain setting.

At the highest level of abstraction, a case-based reasoning system can be viewed as a black box (Fig. 1) that incorporates the reasoning mechanism and the following external facets:

- The input specification or problem case.
- The output that defines a suggested solution to the problem.
- The memory of past cases, the case base, that are referenced by the reasoning mechanism.

In many practical applications, the reuse and revise stages (Fig 1) are sometimes difficult to distinguish, and several researchers use a single adaptation stage that replaces and combines them. However, adaptation in CBR systems is still an open question because it is a complicated process that tries to manipulate case solutions [12]. Usually, this requires the development of a causal model between the problem space (i.e., the problem specification) and the solution space (i.e., the solution features) of the related cases.

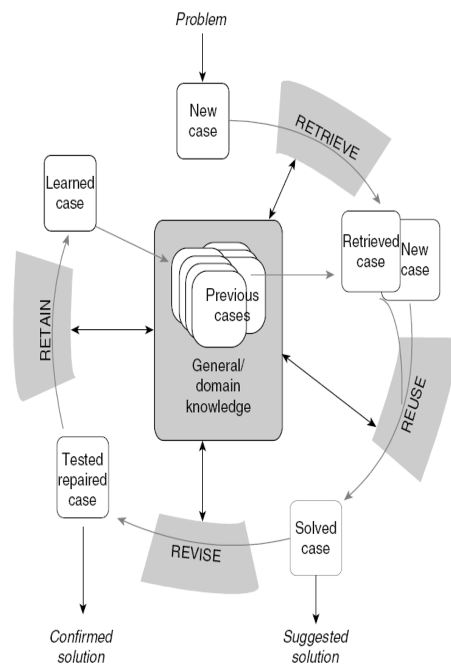

Fig 1. Case based reasoning phases [12]

The feasibility of the CBR for the decision support where the experience of past situations is reused to manage new situations, has been shown in the survey of the decision making process [8]. The deepening of this mechanism (CBR) brings us to see behind a knowledge management process. In fact, the CBR and the knowledge management follow the same objective of acquisition and reuse of experience or knowledge.

3.3 domain analyze

The diagnosis has for objective to determine the state of equipment or a process from observations [5]. It evaluate if the equipment functioning is correct, graduated, faltering and to determine the components that are breakdown or that require a maintenance action. The diagnosis takes support on two complementary analyses, one consists to a functional decomposition of the equipment, and a second consists to an analysis of failure style: for every failure, the expert identifies the symptom, the origins that provoke it and the actions that lead to its reparation.

3.4 The Gas turbines

The gas turbine [14] is a motor machine with rotary movement and internal combustion, provided with an air compressor and a combustion chamber in measure to produce a fluid under pressure and with very high temperature. This fluid, while relaxing in the floors of the turbine, produces the mechanical energy to the outside.

Because of the importance of the gas turbines in the process of the economic development, maintenance operation of these equipments is of a fundamental importance. It permits to reduce the inactivity time of equipments that is very expensive.

4. Steps of Work

4.1. Domain ontology for diagnosis and maintenance of gas turbines

After studying the maintenance process of gas turbines and the practice of experts in this domain we developed the ontology of maintenance domain. The role of this ontology is to describe the installation to maintain which is a gas turbine with all its components and all its information concerning its functioning method.

Step1: we focused our work on the identification of knowledge requiring an operation of capitalization (to Mark). We collected the crucial knowledge of the domain from the existing technical documentation (books, handbooks of manufacturers…) and with the help of key personnel (operator of maintenance, expert of the domain). The result of this stage is a set of knowledge judged crucial in the domain of the maintenance.

Step2: From the collected knowledge, we identify precisely the concepts and their relationships which constitute our ontology. Concepts are of various types: classes, properties and instances. We consider as classes equipments and their decompositions (e.g. instrument, thermocouple, pump, filter…). We associated every equipment with knowledge describing its characteristics which are considered as properties or slots (e.g. temperature, pressure, vibration, frequency…).

Other knowledge are also selected to specify relations between concepts. Some of these relations are:

Is-a: this relation allows leading taxonomy of concepts (e.g. thermocouple “is –a” instrument).

Part-of: this relation makes possible to determine subcomponents of a component. Every equipment is decomposed in sub-equipments which can be decomposed in elementary components (e.g. inlet guide vanes IGVs, inducer, impeller, a diffuser a scroll “part_of” centrifugal compressor). In addition, other relations are formalized describing functioning method of equipments (their main role and secondary functions, e.g. supervise, control…).We precise for every equipment the breakdowns style in other words the categories or failure kinds of this equipment (have-failure relation).

Step3: On the other hand another category of knowledge that we judged essential in this study and which are represented in our ontology consist on describing the procedures in the process of maintenance by describing some cases of dysfunction. The case is composed of two different parts that contains the description of the case through a set of symptoms (parameters or variable on the equipments) and its solution. These cases constitute the case base in our CBR system. For the mechanism of reasoning we associate to the set of variables the similarity measures that are based on the distance and the associated weight.

Step4: we have constructed the instance base of the designed ontology using a powerful ontology editor “Protégé" [15] (Fig2). Protégé is used as a tool of knowledge acquisition describing the considered installation. The ontology resulted can be exploited by other systems.

4.2. Case based reasoning system

In our study we focused two phases of CBR cycle: describe the new case and retrieve sources cases. Initially and following a demand of intervention we start by describing the problem by an equivalent case. So, the maintenance operator fills in a form. This form is composed of a hierarchy of questions with multiple answers permitting to localize the problem in term of system, equipment, component, and the nature of the problem: electric, mechanical problem... and to have some parameters on the failed components. From this form we extract the pertinent descriptors of the case. Once the target case (new case) is elaborated we retrieve the sources cases. In a first time the case base is filtered to k the cases sources that have the same nature of the problem represented by the target case. On this set of cases we compare by calculating the degree of similarity of the target case (T) with the different cases sources (S).

For the calculation of similarity, we consider that the descriptors of cases (p descriptors) have the same importance (w_i =1 for all descriptors). We take in account the presence or the absence of the descriptor ($sim_{presence:}$ 0 / 1 for absent or present) as well as the local similarity of the descriptors $sim(t_i,s_i)$ that indicates the variation of values between the descriptors. So the similarity is calculated as follows:

$$Sim(T,S) = \frac{\sum_{i=1}^{p} w_i \, sim_{presence} \, sim(ti,si)}{\sum_{i=1}^{p} w_i}$$

Then we reuse the solutions of the sources problems considered like similar to the target problem. The solution can be modified while changing the parameters and we speak here of a phase of adaptation. In some cases the solution is proposed without change. The operator of the maintenance executes the proposed procedure for reparation. If the result is satisfactory this new case is memorized in the case base and therefore in the ontology what refers to the last phase of the CBR cycle "Retain", on the other hand the facet "Actualize" is appeared here from our knowledge management system else if the proposed solution is not satisfactory we proposed the solution of the least similar case than the precedent one. We proceed thus until one of the proposed solution is kept or the operator applies his own solution that must be described so that it will be memorized with its problem in the case base.

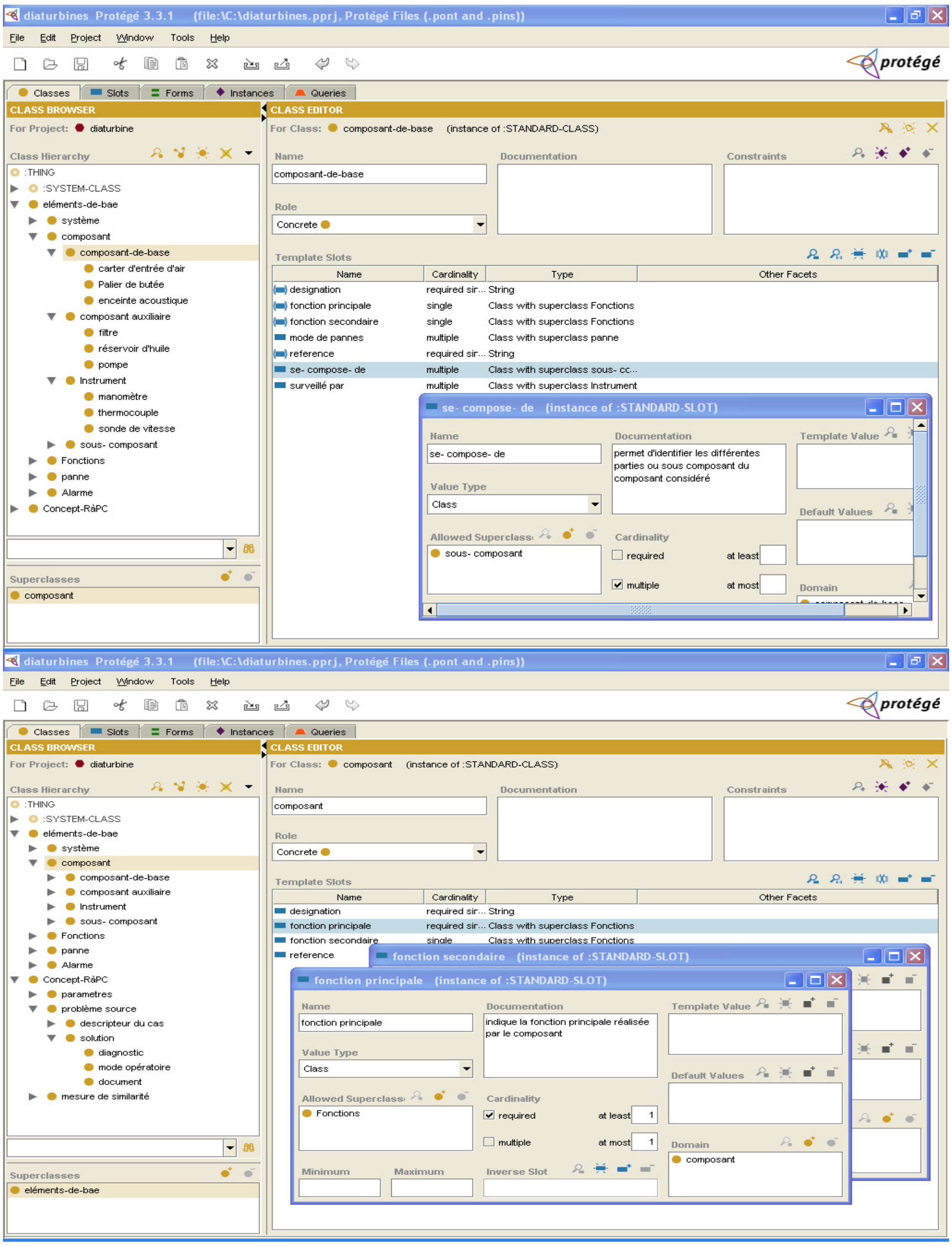

Fig2: overview of the ontology in Protégé

5. Conclusion

We studied the process of diagnosis and maintenance of the gas turbines. We have oriented our work toward the construction of a knowledge management system. Knowledge in this system are preserved as an ontology that regroups knowledge of the domain, and a case base used for reasoning. This ontology is implanted on the ontology editor "protégé". We have developed a method for the resolution of the diagnosis problem based on CBR approach. The validation of our system of diagnosis and maintenance by the experts showed that our ontology covers the entire domain. This ontology is extensible (modeling and instantiation). Currently we enrich the case base in order to cover a higher number of failure cases. We note that the validation and evaluation of this tool must be continued during its use in real situations. In prospect we are going to add other functionalities to this system notably the aid of the distant experts in the process of maintenance.

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