Intelligent Semantic Case Based Reasoning System for Fault Diagnosis

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ABSTRACT: *Case-Based Reasoning (CBR) often shows significant promise for improving the effectiveness of decision support systems. Previous research in decision making has proposed the use of a CBR approach to accumulate, organize, preserve, link and share diverse knowledge coming from past experiences. However, existing CBR systems lack semantic understanding, which is important for intelligent knowledge retrieval in decision support systems. In order to overcome the limitation of existing CBR and develop an intelligent CBR system which can not only carry out data matching retrieval, but also perform semantic associated data access, and improve the traditional keyword-based search, this paper integrates ontology technology into a CBR system and proposes to combine semantic retrieval method and numerical measurement in case retrieval. Ontology technology is an ideal selection for realizing our system thanks to the good semantic understanding offered by ontology. The resulting ontology based CBR system is applied in fault diagnosis of industrial machines, a semi-structured decision-making environment involving multiple attributes. The case illustrates the use of proposed semantic CBR system, and shows the feasibility of our approach and the benefit of the ontology support.*

Subject Categories and Descriptors
[H.3] Information Storage And Retrieval; [I.2] Artificial Intelligence

General Terms: Semantics, Information Search, Ontology, Case-Based Reasoning

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1. Introduction

Several organizational decision problem solving situations are critical and recurring in nature. In this kind of activities a solution is realized by modifying a prior solution (or solutions) to meet new requirements, and knowledge capitalization is of a considerable contribution during the problem solving; it would be easier for the decision maker to reuse the solution corresponding to a similar problem already solved than to solve it which would require a whole analysis of the problem. Therefore, mechanisms to capture the experiential knowledge of experts can be of significant value to the organization in general, and the decision makers in particular.

Previous research in decision making has proposed the use of a case based reasoning approach to accumulate, organize, preserve, link and share diverse knowledge coming from past experiences, and thus support such activities [1]. Moreover a shared meaning of the conflict resolution scheme that has worked in the past may get developed and used in the current situation [2]. The development of a shared repository that stores the knowledge of expert members and their experience invoked in prior solutions, retains the rules, policies and procedures of an organization and acquires relevant data and knowledge from the external environment can be useful for subsequent groups engaged in similar problem solving activities, and will clearly assist them.

Case-based reasoning (CBR) often shows significant promise for improving the effectiveness of decision support. However, existing CBR systems lack semantic understanding, which is important for intelligent knowledge retrieval in decision support system [3]. While there has been substantial research in decision making and case-based reasoning systems, the explicit use of ontology based reasoning to support repetitive decision problem solving activities has received less attention.

To develop an effective CBR system, two issues are critical: the first is how to find an effective method for case representation, which ensures domain knowledge can be acquired in an accurate easy manner, thus laying a good foundation for case retrieval; the next is how to find an appropriate method for case retrieval, which assures the right knowledge can be retrieved to solve a specific problem when a new task takes place.

Ontologies can serve as the semantic support for conceptual modelling, guiding and constraining the intended meaning of the conceptual models of the decision system.

The objective of this paper is to construct an intelligent CBR system with the support of semantics. The system can not only carry out data matching retrieval, but also perform semantic associated data access, and improve the traditional keyword-based search. In order to get it, an effective case representation method, as well as an appropriate case retrieval approach, must be found. Through the semantic search capability, the hidden, but previously defined relations among data and concepts could be shown and represented if needed. These relations allow the user to understand the knowledge behind the stored data. Semantic technology could lead to the improvement in knowledge extraction, dissemination and management. Moreover, the use of a common and unified domain ontology can improve the decision making process where most of the decisions are dependent on individual experiences and domain knowledge of relevant managerial personnel.

The integration of an ontology within a CBR system is likely to provide additional information processing support. We use ontology as a means to acquire domain knowledge and construct a case-base and use ontological semantic retrieval method as the case retrieval. Besides the case base, the proposed system uses three ontologies: decision domain ontology, task ontology related to fault diagnosis of the given equipment, and domain ontology related to the industrial equipment. This system will allow a more efficient searching in the case base by exploiting the semantic relations which exist between the cases, and uses the semantic relations (intra-ontology) existing between the concepts within each of the ontologies, as well as the relations (inter ontology) which existing between the concepts that belong to different ontologies.

We experiment the resulting system in fault diagnosis domain, a semi-structured decision making task involving multiple attributes, to illustrate the use of the proposed CBR system.

The remaining part of the paper is organized as follows. First, we present the case study. In section 3 related works on integrating ontology to CBR are described. Then, we present our ontology approach to improve the CBR system in section 4 and the ontology CBR process in section 5. Finally, we present an application relating to fault diagnosis domain before concluding.

2. Case Study

In industrial plants, the presence of abnormal events generates risks. To avoid such risks, safety barriers are set up. However, barriers may not work properly, and thus abnormal events may arise. In such a case, industrial technicians intervene to diagnose the failures basing mostly on past failure experiences occurred in similar situations.

We apply our approach in fault diagnosis domain. Fault diagnosis deals with the detection and isolation of abnormal events. It consists of interpreting the current state of the machine from sensor readings and process knowledge. Fault diagnosis is of crucial importance in terms of safety and also of economics, because of the influence of abnormal events in yield and quality of products.

A fault may be defined as an abnormal change in the characteristics of a system which gives rise to undesirable performance. Equivalently, the change of performance could be due to performance deterioration or malfunction. Hence, the operators should know the cause(s) of the change. In such cases the diagnosis system should be able to identify the cause(s).

The application concerns the company EMETAL which is an Algerian company offering a wide range of sheet bending machines built for years of operation at full capacity. The machines are manufactured for the automotive industry, outdoor and indoor furniture, supermarkets and household electrical appliances, etc. The machines are numerically controlled tools that bend and fold sheets and tubes, precision and industrial sheet metal, steel sheet and strip. The controllers perform a variety of functions including protecting the machine from damage by performing an automated shutdown when dangerous conditions are detected and archiving sensor data.

As of 2016 there are thousands of these machines in use by EMETAL’s customers national wide. EMETAL has contracts to service more than a thousand of machines and that number has been growing by hundreds every year. Different types of machines are manufactured in this company. Each machine is identified with two parameters: the number of axes and the diameter of the tube to be bent. The FS Series machine is a folding machine with three axes: feeding and folding. This machine can bend wires with diameters up to 7 mm. The FS Series machine is a combination of 13 different components. The Parvex drive in the switch cabinet is a particularly critical component. The Parvex drive consists of a set of drives.

A statistical study was carried out on the failures encountered in the company. Some of the failures are common between the different machines. In most cases, the failure is due to the electrical problem. The Parvex drive is the component the most affected by the failures. The duration of repairing can last up to a few weeks for complex problems.

Currently, the machine diagnosis process was as follows: When a machine has broken down or a malfunction of a machine is detected, the on-site operator will call the company and will send a message. The breakdown will be assigned to a company technician for analysis. The technicians take into account the information provided by the customer, will access the data from the machine, review key values, draw on their previous know-how and experience, create a hypothesis about the breakdown cause, create plots specific to the breakdown type hypothesized, confirm the cause of the breakdown as best as can be done using the available data, then call the site to provide assistance and confirm the breakdown cause. Each repairing is recorded. The saved records are not well formalized and thus unexploited. These sheets should be used as a basis of experience for use in future repairs.

The goals of the service are to improve machine and system reliability, reduced machine operating and maintenance costs, and produce the greatest possible sustained availability from the machine. For the company, it is a matter of better formalizing the experiences of the business experts on breakdowns and repairing, using reasoning from cases. The CBR system is to be used to automate the data review, hypothesis generation, and hypothesis confirmation portions of this process whenever possible and assist the user when it does not have confidence in a single cause.

In order to contribute, we determine in a base of reference cases (maps of problem solving and their solutions), which cases are closest or similar to that studied or to be treated. Business experts will be able to study these analogous or similar cases in order to deliver their diagnosis and propose a repair. This case base will represent a tool for decision-making when solving future industrial problems. The objectives are to reduce the diagnosing and problem solving time, quickly analyze the breakdown, provide technicians with tools to help them be more effective at the diagnosis stage, and to transfer knowledge on unformed trades and train people for more efficiency and performance. The company wants to reduce the diagnostic time for more frequent breakdowns.

3. Related Work

The core of any decision support system is knowledge from which, and of which, decisions are made. Knowledge management encompasses various practices of managing knowledge such as knowledge generation, capture, sharing, and application. Within these practices, effective sharing and use of knowledge depends – to a large extent – on the organization's ability to create and manage its knowledge. This knowledge can be described as the way organizations store it from the past to support present activities [4].

Knowledge management and Case-Based Reasoning (CBR) as computational problem solving method are two intertwined topics that have increasingly attracted more and more attention and grown in importance for businesses and academics over the past few years. The main principle of CBR is: *similar problems have* similar solutions.

Case-based reasoning is a problem solving paradigm an alternative reasoning paradigm that in many respects is fundamentally different from other major AI approaches. Instead of relying solely on general knowledge of a problem domain, or making associations along generalized relationships between problem descriptors and conclusions, the case-based reasoning formalism was proposed as a way of storing human experiences and retrieving stored cases similar to the current item through a process of analogical search. It draws its knowledge from a reasonably large set of cases contained in the case library of past problems and by adapting their solutions solves new problems rather than only from a set of rules. Furthermore, case-based reasoning systems are claimed to "learn" through addition of further significant cases to the case-base and by forms of abstraction which may then be applied to this collection of cases [5].

Reasoning by re-using past cases is a powerful and frequently applied way to solve problems for humans. However, one of the drawbacks of CBR is the lack of flexibility of the knowledge representation. Indeed, the structure of the case is considered as constraining and strict which does not allow dealing with a carried out experiment in its semantic context, really limiting the performances of the system.

Among existing AI technology, ontology technology is an ideal selection for realizing this kind of system because ontology has not only powerful ability of knowledge representation, but also good semantic understanding. Ontologies provide a semantic based approach to explicitly represent information in a computable manner so that information can be automatically processed and integrated. Ontology also provides shared understanding of a domain to overcome differences in terminology from various sources [6].

In Artificial Intelligence, one of the most accepted definitions has been stated in [7]. Gruber specifies: "an ontology is an explicit specification of a conceptualization". This definition was then refined in [8]: An ontology is "a formal, explicit specification of a shared conceptualization”. It helps modelling a world phenomenon by strictly defining its relevant concepts and relationships between the concepts. Two dimensions can be considered in any ontology: the pragmatic dimension to express its application to a certain domain with an intended use, developed following a specific methodology or design method; and the semantic dimension as a representation mechanism that structures, organises and formalises a particular content, according to a level of granularity.

The ontology-based approach has its advantages in: (1) Facilitating knowledge sharing by providing a formal specification of the semantics; (2) Supporting for logic reasoning based on the defined classes and properties; (3) Enabling knowledge reuse by use of existing and mature ontology libraries without starting from scratch.

Several studies have given empirical evidence for the dominating role of ontologies integrated with specific, previously experienced situations (what we call cases) in human problem solving. The importance of incorporating an ontology into a system architecture has been well recognized, in the context of intelligent decision support, as the means of knowledge representation and management and to assist decision makers with complex problem-solving. Ontology could ease the representation and sharing of domain knowledge through providing knowledge sharing infrastructure. Adopting such an approach could help users to understand the knowledge of the desired domain besides their data presentation features.

Overall related research consists in searching the solution of a problem similar to the target one. Ontology is used to bring semantics to the attributes describing the target problem, and upon which the retrieving step can be realized in the case base. Semantic enrichment of the attributes of target problem thanks to ontology enhances source case retrieval.

In [9] the authors present a method that uses semantic information to improve relevant case retrieval in casebased reasoning systems. The method overcomes conventional case-based reasoning (CBR) systems depending on word knowledge to index and search cases from its memory.

[10] consider domain ontology as the basis of knowledge structure and the concrete case knowledge to share knowledge of different systems. This strategy is represented as the instance of relevant concept of domain ontology, through which knowledge of different systems is shared. Knowledge management becomes more flexible and simple, and case retrieval becomes more precise and reasonable

[11] propose an ontology-based fuzzy CBR support system for ship’s collision avoidance to prevent the cumbersome tasks of creating a new solution each time a new situation is encountered. The first level of the ontology-based CBR identifies the dangerous ships and indexes the new case. The second level retrieves cases from the ontology and adapts the solution to solve the new situation for the output. The CBR’s accuracy depends on the efficient retrieval of possible solutions, and the proposed algorithm improves the effectiveness of solving the similarity to a new case.

A proposal presented in [12] aimed at knowledge reuse, during the decision activities by means of interwoven concepts from the knowledge management, CBR and ontologies research.

In [13] the constructed decision support CBR prototype system of marketing strategy contains more than 600 cases. The evaluation shows that with the support of semantics, they can not only carry out data matching retrieval, but also perform semantic associated data access.

[14] construct domain ontology of mold design and propose an ontology-based search model with semantic distance measures to improve the traditional keywordbased search for the mold design domain. The ontological search is compared against traditional keyword-based search in the mold design domain and shows more fault tolerance and flexibility in maximizing the accuracy and number of detected matches.

To facilitate decision making within collaborative design, a Decision Support Ontology (DSO) is proposed in [15]. The structure of the information model developed reflects a priori knowledge of decision making and supports the communication of information independent of any specific decision method.

A case-based reasoning system for the Semantic Web called Tuuurbine is presented in [16]. Tuuurbine is built as a generic CBR system able to reason on knowledge stored in RDF format. It uses Semantic Web technologies like RDF/RDFS, RDF stores, SPARQL, and optionally Semantic Wikis. Tuuurbine implements a generic case-based inference mechanism in which adaptation consists in retrieving similar cases and replacing some features of these cases in order to obtain one or more solutions for a given query.

A knowledge-based approach to support decision making in human resource management is proposed in [17]. The appropriate support of decision making is implemented using case-based reasoning and ontology. The problems of knowledge and case representation are considered, as well as the algorithm of case retrieval.

Many research efforts for decision modelling and support have been systematically applied to the field of ontologies. However, there is no complete approach that would define how to model decisions in ontologies, and a few isolated cases in which an established decision making method was used in ontology for a specific domain where the reasoning procedure is based only on domain ontol ogy.

In our approach, we consider particularly the case where the reasoning process is enriched by exploring ontology. Thereby the purpose is to retrieve and provide a set of possible solutions relating to source case showing the semantic relations between them. Afterwards, it is the duty of the decision-maker, according to his/her expertise, to opt for the decision which will seem to him appropriate to the target problem. An important goal of our work was to structure decision model in such a way that the problem solution can be obtained by reasoning upon three ontologies (domain, task, and decision). The ontologies with reasoning support can be used in the function of a case base reasoning system.

4. The Ontology-Based CBR System

We consider decision making to be a process involving used and, the object concerned by recommended solution a sequence of decisions informed by the current state of information. As such, the decision process developed is structured to reflect the conceptualizations of decisions with a particular emphasis on semantically capturing decision rationale.

The frame of our work is to integrate a knowledge capitalization tool in a Group Decision Support System (GDSS) that will be exploited by the actors (facilitator and/or decision makers) for the purpose of decision support [18] [19]. We are in the context where typically incidents are not entirely identical to each other (some symptoms are not observed) but the knowledge of past incidents enables decision makers to recognize a similar situation and tailor their strategies by taking a course of action that experience has shown is effective and successful. This can happen when there is failure at some sensors so that lights or alarms cannot be triggered. The search in the database of cases can then be disoriented.

A CBR problem-solving approach is used to solve a new problem (target case) by remembering a previous similar situation (source case) and by reusing information and knowledge of that situation. The effectiveness of this approach is further improved by the application of ontologies as a mechanism for reasoning about the domain concepts and dealing with the inconsistencies that can arise in the applied vocabulary when multiple decision makers are involved.

The proposed system will assist the actors involved in a group decision making session by offering them a set of decisions for the new problem and it is for the actor to situate each solution in its semantic context and then choose a particular solution based on his expertise.The benefits of using the system is to provide a more convenient retrieving process in information retrieval system in order to reach conclusions and give recommendations based on knowledge from previous cases (experiences) and ontologies.

Knowledge considered in our CBR system is represented by cases and ontologies. Our approach proposes the use of ontologies to build models of general domain knowledge. Although in a CBR system the main source of knowledge is the set of previous experiences, our approach to CBR is towards integrated applications that combine case specific knowledge with models of general domain knowledge. The more knowledge is embedded into the system, the more effective is expected to be. Semantic CBR processes can take advantage of this domain knowledge and obtain more accurate results.

4.1 The Case Base

Case representation is essential in the realization of a CBR system since on this presentation depends the effectiveness and the fastness of the system case retrieving mechanism. It is therefore necessary to well identify information to be stored in each case and to choose the more efficient representation scheme of this information. A case in our system represents a diagnosis experience, and thus consists of three main parts: a problem part describing the failure, a *cause* part describing the different possible causes of this failure, and a solution part. Each of both parts is represented by a set of simple or complex descriptors among which some are defined in a dedicated ontology:

Problem part**:** the task to be solved; *Cause part*: the problem causes and its symptoms; *So lution part*: the solution, the problem solving method used and, the object concerned by recommended solution

The case base is composed of all the structured cases which will be explored during retrieving step (recall stage). Every case consists of a breakdown problem already experienced and solved. Figure 1 shows the UML classes diagram relating to the modelling of the case base. The descriptors are entries to the ontologies (e.g. Id-Task, Id-Symp and Id-Cause are entries for the task ontology; the descriptors Id-Object is an entry for the domain ontology, and the descriptor Id-Solution-Id is an entry for the application ontology).

4.2 Ontologies Modelling

The ontology development methodology is usually composed of several strategies on defining classes and class hierarchy, defining properties and naming considerations. We used METHONTOLOGY [20] to create and develop the ontologies.

As all the potential decisions that might be made by the decision makers are listed in an appropriate documentation, the ontologies are created based on resources included technical reports describing body of knowledge.

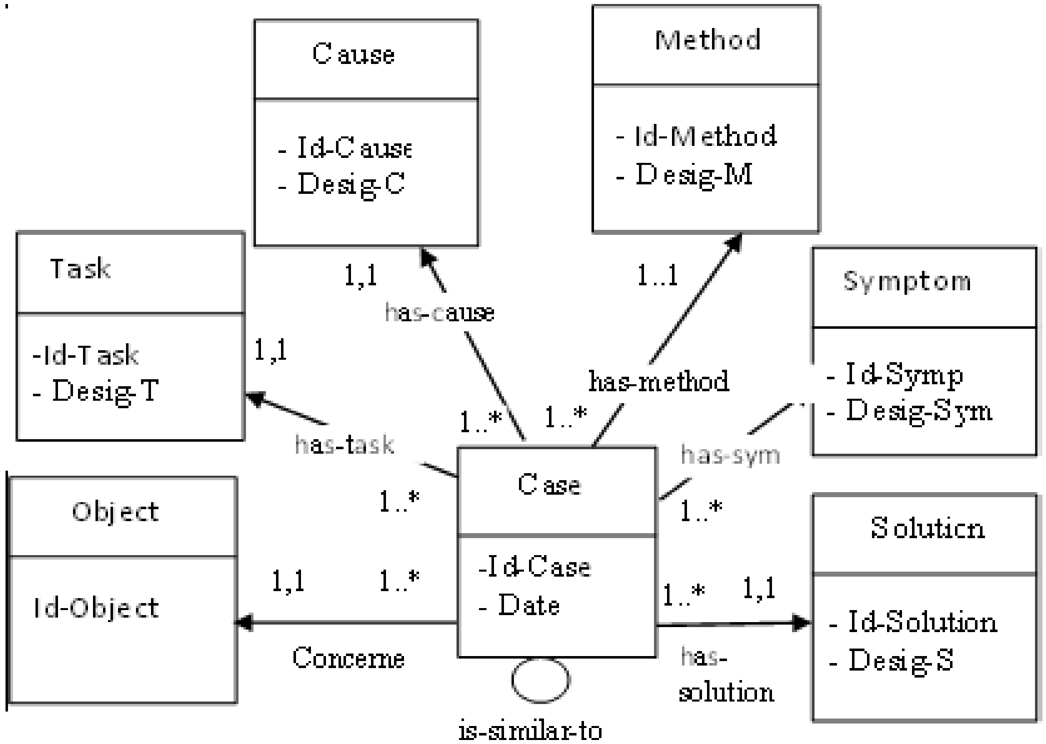

Figure 1. UML Class Diagram of the Case Base

Documents have been analysed to come up with existing terminology and definitions for the different domains, subdomains, applications and aspects considered in the ontologies structure. Similarly, the description of the equip ment to be maintained is get from specific documentation while the specification of the task ontology is built with the support of an expert in industrial maintenance.

METHONTOLOGY provides guides for constructing ontology in specific domains through several activities. These activities encompass, among others, the conceptualisation,the formalisation, and the operationalisation of the ontology:

4.2.1 Ontologies Conceptualization

A conceptualization has to be understood as a simplified view of the world we wish to represent for some purpose. Conceptualization activity consists of creating a glossary of domain terms to determine which terms are included in the ontology, identifying the binary relations among classes of the ontology, build the concept classification tree to indicate support-classes and sub-classes, and create concepts dictionary containing meanings of concepts, and description of instances, and attributes.

The proposed approach is based on the three ontologies. Figures 2, 3 and 4 present respectively UML classes diagrams of Application Ontology, Domain ontology and task ontology.

Domain ontology: It consists of the vocabulary used in expressing decisions in terms of equipment components. The ontology constitutes a specification of the concepts relating to the equipment to maintain as well as the semantic relations between these concepts The latter are principally aggregation and composition relations between the equipment components. The obtained conceptual model simply machine-readable and understandable.

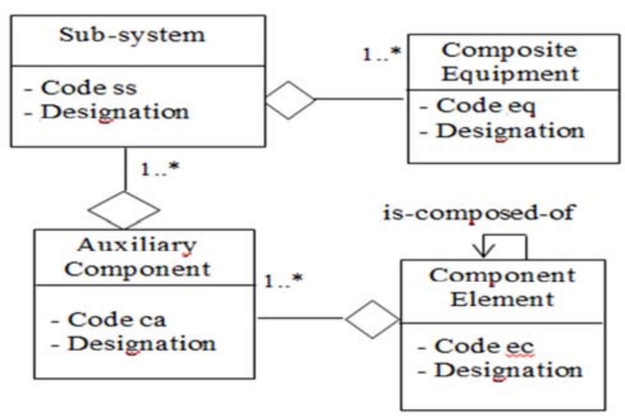

Figure 2. Conceptual model of the domain ontology

Application ontology: Represents the domain of decisions in terms of concepts which are decisions, equivalent decisions, main decisions, as well as objects related to the decisions and, semantic relations between decisions in relation to considered application:

• **“Contradiction Link” Relation:**It links a main decision with all the main decisions which are incompatible to it within the breakdowns diagnosis application context;

• **"Generalization Link" Relation:** It specifies the relation of subsuming between main decisions. This relation is transitive;

• **"Is Synonymous of" Relation:** It links an equivalent decision to a corresponding main decision.

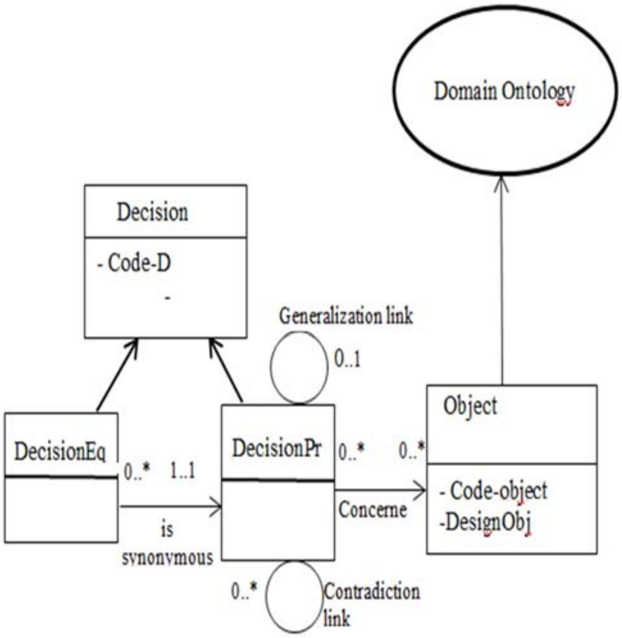

Figure 3. Conceptual model of the application ontology

Task ontology: This ontology described all the faulty diagnosis problems related to the machine (equipment) in terms of task, symptom, cause and solution concepts, and the relations between them.

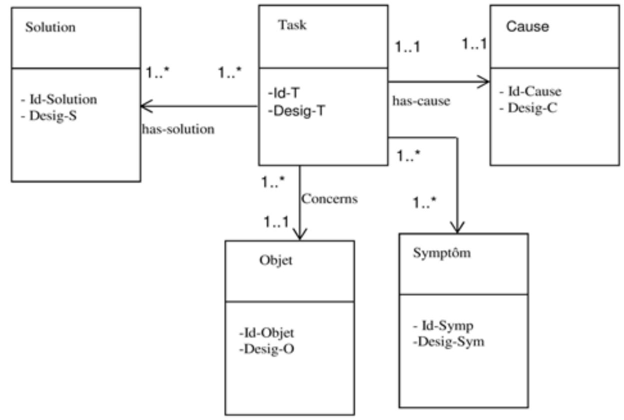

Figure 4. Conceptual model of the task ontology

4.2.2 Ontologies Formalization

The formalisation activity has as goal to transform the conceptual model into a formal model by using ontology editors. The Web ontology language (OWL) [21] has become the widely used ontology language for its benefits of the well-defined syntax, efficient reasoning support, formal semantics and the full expression ability, and so on. OWL provides a semantically rich and sufficiently broad specification of decisions capable of supporting the application of any specific decisionmaking method.

We believe that OWL ontologies are well suited for representing information within decision making applications. We have thus created the ontologies using Protégé before their generation in OWL format. The terminology of our domain is represented through classes, properties and logical axioms, whereas the observations are asserted through instances of classes and properties. Figure 5 illustrates a partial view of the decision ontology.

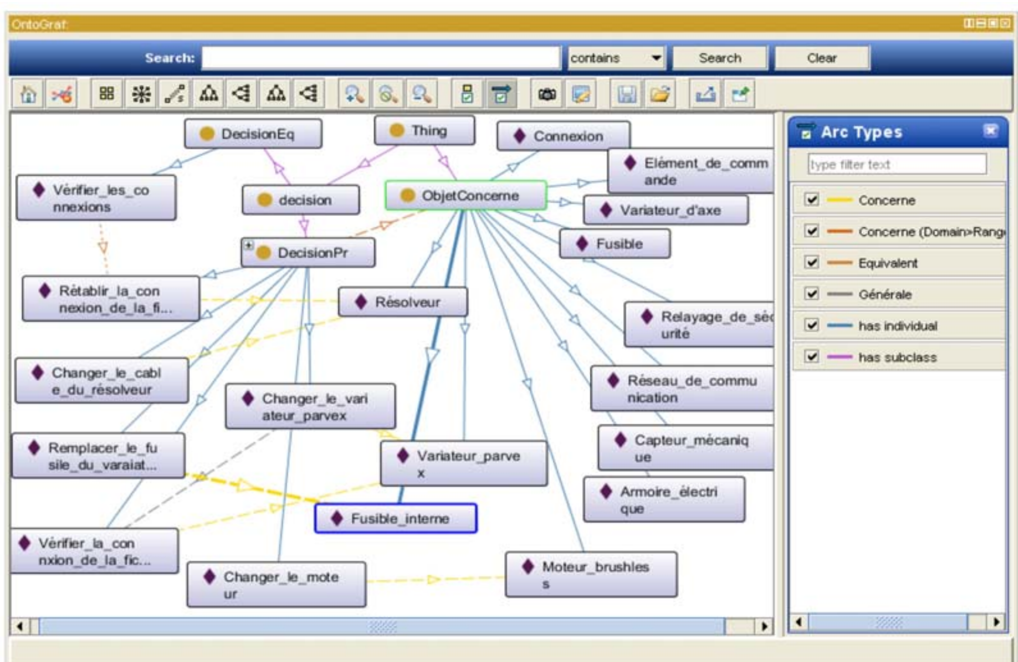

Figure 5. Partial view of the decision ontology

4.2.3 Ontologies Operationalization

An operationalized ontology is expressed in an operational language and endowed with operational semantics. In this sense the ontology operationalization consists of a computer specification of all the operations made on concepts in an operational language. The use of an operational ontology assumes its representation in an operational but also formal language, i.e. providing reasoning mechanisms appropriate to the targeted knowledge manipulations. To do this, we used the NetBeans developing environment associated to Java language [22].

Furthermore, we used the Jena framework [23] to manage the ontology. Jena provides a programming environment for RDF, RDFS [24] and OWL as well as a query engine allowing SPARQL queries execution (Simple Protocol And RDF Query Language) [SPARQL, 2008] which is a RDF query language.

OWL language is used to represent the case base. This would allow managing the case base as a knowledge base upon which inferences may be made. It is possible to define semantic relations between cases as for instance the transitive relation "is-similar-to" which relates the source cases already identified as being similar. Furthermore, as the remained knowledge (i.e. the ontologies) is also expressed in OWL, this would allow having to some extent compatibility between languages formalizing the different knowledge manipulated by the system, as well as, the knowledge operating tools such as SPARQL.

Example of case T3 in the case base:

```
<owl:NamedIndividual
rdf:about="http://www.basedecas.org/
ontologycases#
3">
<rdf:type rdf:resource="http://
www.basedecas.org/ontologycases#Cases"/>
<has-as-task rdf:resource="http://
www.basedecas.org/ontologycases#T3"/>
<has-as-cause rdf:resource="http://
www.basedecas.org/ontologycases# Failure to
turn up
the variator"/>
<has-as-method
rdf:resource="http://www.basedecas.org/
ontologycases
#M1"/>
<concerns
rdf:resource="http://www.basedecas.org/
ontologycases
# Internal fuse"/>
<has-as-solution
rdf:resource="http://www.basedecas.org/
ontologycases
#change internal fuse"/>
<possesses
rdf:resource="http://www.basedecas.org/
ontologycases
#display variator off"/>
<possesses
rdf:resource="http://www.basedecas.org/
ontologycases
# Failure to turn up the variator, the
machine is shut
down"/>
<is-similartordf:
resource="http://www.basedecas.org/
ontologycase
s#15"/>
</owl:NamedIndividual>
```

5. The Ontology-Based CBR Process

The proposed case based system should reflect human knowledge by storing data about previous significant events as "cases" within a computerized system. In this regard, the system uses the case base to retrieve similar cases to the problem to be solved. But, when the retrieving process fails or the cases retrieved are not satisfactory for the decision maker, the system uses ontologies. It makes use semantic relations between concepts within the same ontology or entries from an ontology to another to derive other solutions to the problem. By making use of the decision ontology, the system derives more specific or more general decisions to that or those made by the retrieving process. It can also set the solution relating to the equipment by visualizing the concerned component. Then, it uses the equipment ontology to set the involved component relating to the neighboring ones or to the component in which it's comprised. Similarly other case descriptors may be used as entries to ontologies to enlarge or reduce solution space. When a solution is retained, then tested and validated, it is stored in the case base as a new case (with all its descriptors).

The reasoning process consists of the following steps (Figure 6):

- **Problem Description:** The participant describes the problem to be solved. This description can be made of different ways: by providing the task to be solved, the observed symptoms, or the faulty object, etc.

- **Retrieving:** It consists to search in the case base and retrieve similar cases to the problem to be solved. Here, we consider the usual local and global similarities measures to retrieve similar cases to the targeted problem.

- **Reasoning:** This step consists of the use of ontologies to enlarge or to reduce the solution search space. According to the object of widening, one of the three ontolo

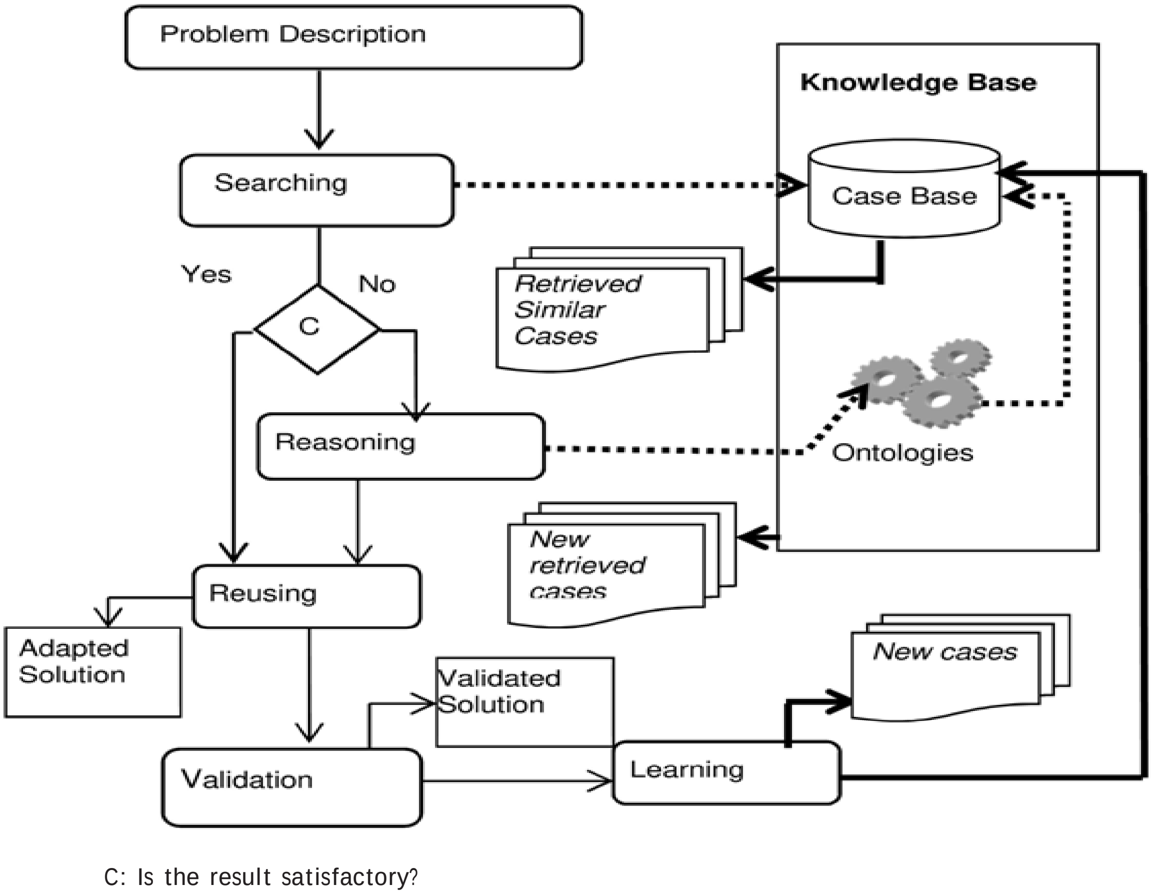

Figure 6. Ontology-based CBR Process

gies is used.

For example when the object of widening is a task or a symptom, the task ontology is used; when the object of widening is a faulty component, the equipment ontology is used, but when the object of enlargement is the problem solution then the decision ontology is used.

• **Validation:** Once the decision is made, executed and validated the process will skip to the next step.

• **Learning:** The new case is added to the case base. It referees to all the similar source cases if exist.

The reasoning step is useful as it allows revealing semantic knowledge from ontologies between the different parameters of the problem to be solved. Given a problem to be solved, this would allow:

• Converging to the semantically close case in the case base, or

• Retrieving first a structurally close case from the case base then, according to the case descriptors, exploiting ontologies in order to derive other possible solutions to the problem. The participant will choose among the sug

Id-T	Task	Cause	Method	Object	Solution
1	T1	Resolver break	M3	Resolver cable	Check the resolver cable
2	T2	Breaking of one or more wires of the encoder	M2	encoder	Changing the Encoder
3	T3	Operating cycle incident	M1	Brake Relay	Changing the brake relay
4	T4	Internal drive incident	M4	Dimmer (drive)	Changing the drive
5	T5	High temperature	M6	Radiator	Clean the radiator
6	T6	Excessive engine speed	M5	Engine	Changing engine
7	T7	Drive power incident	M1	Internal fuse	Changing the internal fuse
...	...	...	...	...	...

Table 1. The case base

gested solutions that he considers being the most appropriate one to the problem.

6. Application

We consider the following description of the problem: "Operation incompatibility between the resolver and the engine".

This problem is characterized by the followingsymptoms: Symp 4 (at the moment of automatic start the orientation head moves downwards) and Symp 10 (Default 4 appears on the taxis drive display).

At this level, we do looking for similar cases to the problem occurred. Referring to the example, the case sought is that relating to task T3.

Id-T	Symptoms
1	Symp 3 (default 2 appears on the axis drive display)
1	Symp 1 (impossible to power on the machine, it is stopped)
2	Symp 2 (No information at the encoder display)
3	Symp 4 (At the time of automatic start the orientation head moves downwards)
3	Symp 10 (fault 4 appears on the display of the axis drive)
3	Symp 20 (electrical axis incident, drive power incident)
4	Symp1 (cannot be powered up, machine is shut down)
4	Symp 20 (electrical axis incident, drive power incident)
4	Symp 21 (absence of "READY" (Power E1)) (Symp displayed on the computer screen)
5	Symp 7 (default 4 appears on the display of the axis drive)
5	Symp 20 (electrical axis incident, drive power incident)
5	Symp 21 (absence of "READY" (Power E1)) (Symp displayed on the computer screen)
6	Symp 9 (high engine temperature)
6	Symp 18 (drive display off)
6	Symp 1 (cannot be powered up, machine is shut down)
…	…

Table 2. The list of related symptoms

The similar case retrieved from the case base is presented to the decision maker. The latter may want to expand the search. The broadening of research is therefore to seek a more general solution from the solution of the retrieved case. An example of expansion consists of considering the solution of the case, then, going to seek from the decision ontology, the decisions more general than the retrieved solution. Considering the decision ontology, the retrieved solution is: "Changing engine" more general than "Changing the brake relay". By searching in the case base the cases related to the more general "changing engine" solution, we obtain:

Id-T	**Task**	**Cause**	**Method**	**Object**	Solution
6	T6	Excessive engine speed	M5	Engine	Changing engine

Table 2. The obtained solution

This result corresponds to a new source case retrieved after broadening the search using the semantic relation "decision more general" which exists between the decisions in the decision ontology. The role of the decision maker is to opt for one of the delivered options.

7. Conclusion

In this paper, we proposed to integrate ontology in case-based reasoning system. The used CBR approach to search in a case base of faulty diagnosis problems already solved a similar case to the problem to be solved. In this context, we considered that the latter may be not fully defined. The purpose in that case is not to retrieve one case similar to the target problem, but rather to provide the decision-maker a set of source cases with their solutions and it is the duty of the decision-maker, based on his expertise, to opt for a solution to the target problem. To develop this tool, we used jointly a case base and three ontologies representing each an aspect of the domain knowledge of faulty diagnosis problem.

A case study is presented to illustrate the feasibility and applicability of our approach. The main purpose of this is to provide fault diagnosis decision for industrial machines. Knowledge reuse is achieved by communicating diagnosis decision rationale and facilitating semantic-based retrieval of knowledge. The study is still in its initial phase. We need to collect much information to use quantitative indices for performance evaluation of our method. In the future further experiments are to be organized to evaluate the system performance and we will try to evaluate the performance of our method with fault coverage rate, diagnosis effectiveness ratio, and other quantitative indices.

We believe that our approach is useful in several aspects. First, it enables to formalize the case base in OWL what allows managing it as a knowledge base. Indeed, by exploiting the semantic relations within the case base such as “is-similar-to”, it is possible to derive new knowledge from those stored. Also, as a result of memorizing a source case base on its descriptors, the ontologies exploration will allow deriving new knowledge which will serve for a new research cycle in case base. The final result is the presentation of a set of source cases which solutions are presented in semantic context evidence the relations between them. Other semantic relations are also evidence those existing between objects involved in the provided solutions.

We claim that ontologies have an important role in the context of CBR systems because they allow the knowledge engineer to use knowledge already acquired, conceptualized and implemented in a formal language reducing considerably the knowledge acquisition bottleneck. The effectiveness of CBR can be further improved by the application of ontologies as a mechanism for reasoning about the domain concepts and dealing with the inconsistencies that can arise in the applied vocabulary when multiple decision makers are involved. Moreover, the reuse of ontologies from a library also benefits from their reliability and consistency.

8. References

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