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Reutilization of diagnostic cases by adaptation of knowledge models

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ABSTRACT

This paper deals with design of knowledge oriented diagnostic system. Two challenges are addressed. The first one concerns the elicitation of expert practice and the proposition of a methodology for developing four knowledge containers of case based reasoning system. The second one concerns the proposition of a general adaptation phase to reuse case solving diagnostic problems in a different context. In most cases, adaptation methods are application-specific and the challenge in this work is to make a general adaptation method for the field of industrial diagnostics applications. This paper is a contribution to fill this gap in the field of fault diagnostic and repair assistance of equipment. The proposed adaptation algorithm relies on hierarchy descriptors, an implied context model and dependencies between problems and solutions of the source cases. In addition, one can note that the first retrieved case is not necessarily the most adaptable case, and to take into account this report, an adaptation-guided retrieval step based on a similarity measure associated with an adaptation measure is realized on the diagnostic problem. These two measures allow selecting the most adaptable case among the retrieved cases. The two retrieval and adaptation phases are applied on real industrial system called Supervised industrial system of Transfer of pallets (SISTRE).

1. Introduction

This study is a part of our research work realized in the European project SMAC. The goal of this project was to develop a distributed cooperative knowledge oriented platform that proposes a set of maintenance services (Karray et al., 2009).

These services offer support to the maintenance operators in their daily tasks. The platform is composed of several modules like the equipment model for instance, and a functional analysis and resource management unit that is interconnected by domain ontology (Karray et al., 2011) to ensure an intelligent maintenance policy within a company. The knowledge models are used in this platform to solve practical problems such as fault detection, fault diagnosis, etc. in industrial applications.

The paper aims at building an intelligent application based on a case based reasoning system that is dedicated to industrial diagnostic and repair in the context of maintenance services.

Althoff and Bartsch-Spörl (1996) assert that case based reasoning (CBR) is the most appropriate technology to implement a knowledge based system. Moreover, CBR is frequently proposed as a methodology for knowledge management applications, in particular in experience based system technologies. It presents the expert knowledge as past and real experiences that are easily understandable by human users. It is a problem solving and learning method that uses similar past problems formalization to solve new ones by adapting them to the context. This method is suitable for diagnostic applications, because fault diagnostic is a domain based on the experience of human experts, where problems are recurrent and can be reused. In addition, diagnostic by case-based reasoning is one of the methods preferred by the industrials. Indeed, reasoning in this method, and unlike machine learning methods where the learning phase has a significant cost and requires time, can start with an incomplete case.

Therefore designing a diagnostic knowledge oriented system requires time and availability of experts to explicit their practice. However, the cost of this service is very high, and thus this phase needs to be optimized. Indeed, the challenge in knowledge management is the knowledge gathering. Jacobson and Prusak (1996) studied the knowledge management in organizations, their prediction on the knowledge cost for the year 2010 was € 2.6 billion. Their statistical study involved more than 200 knowledge workers of different organizations. Fig. 1 shows that 37.7% of the time of knowledge workers is dedicated to the elicitation phase and 45.9% to the knowledge adaptation phase.

Our problem is to develop a knowledge based diagnostic system for SISTRE a supervisor industrial system of pallet transfer (see Appendix A) while minimizing development costs, this can be achieved thanks to the use of an existing method. To reuse an adequate method, we briefly review some of the CBR industrial diagnosis system.

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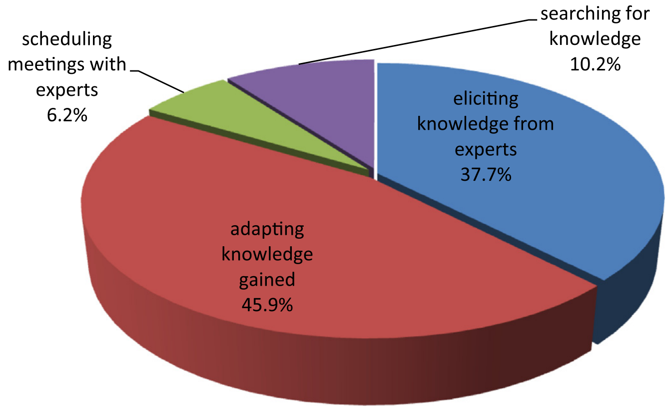

Fig. 1. Percentage of knowledge workers time spent (Jacobson and Prusak, 1996).

Industrial systems developed in the CBR diagnosis, can vary from a car studied in a diagnostic technique system named CREEK (Aamodt, 2004) to a locomotive defined for remote diagnostics (Varma, 1999), to aircrafts (such as Boeing 747 aircraft developed in CaseLine (Watson and Marir, 1994) and used as a demonstrator by British Airways or Boeing 737 in CASSIOPEE (Bergmann et al., 2003) owned by CFM International). There are also industrial printers studied by Domino UK Ltd in CHEKMATE and presented in Grant et al. (1996), gas turbines studied in a fault system of General Electric Energy in Atlanta (Devaney and Cheetham, 2005) and complex machine like Patdex (Richter and Wess, 1991) and Nodal CBR (Cunningham and Smyth, 1994). There is a wide variety of methods ranging from classification problems when there is just a weak domain theory, to knowledge based systems. More knowledge-oriented systems such as Gas Turbine, Creek, Cassiopee, Pad'im, NodalCBR, Patdex, use models of knowledge different from each other. In most systems, a case characterizes a diagnostic experience.

We note that there is no common method for building a CBR system. The construction depends crucially on the representation of cases and knowledge models of the application domain. That is phases of CBR cycle. Actually, authors provide us just with the cases representation of the system and without any associated methodology.

Very few authors defined the design methodology in the case based diagnosis system. Lamontagne and Lapalme (2002) represent a generic model of case based reasoning system in which they combine the CBR online cycle composed of 4 phases (elaborate, retrieve, reuse, retain) with knowledge container defined by Richter (1995) (vocabulary; case base; similarity metrics; adaptation knowledge) making it possible to preserve and exploit the past experiences.

In the same way our team (Rasovska et al., 2008) combines the CBR reasoning "capitalize" and "actualize" phases with the knowledge "detection" and "preservation" in the knowledge capitalization cycle defined by Grundstein (2000). The elicitation step is not defined by interviews with experts but by a methodology based on engineering safety tools, and reliability concepts such as FMECA and failure history (Rasovska et al., 2008). The creation of knowledge models is carried out by the analysis of the equipment and its decomposition (approach modeled on the practice ground of Cegelec company).

The idea developed in this paper is similar to Rasovka's methodology, where a CBR system is built from knowledge models used by maintenance experts like functional and dysfunctional equipment models that are accessible on all equipments and easy to build when not available (Rasovska et al., 2008). This choice minimizes the cost of experts.

To elaborate an oriented knowledge CBR system, we must conceive first the different knowledge containers of CBR and secondly the CBR reasoning phase.

(i) In the knowledge elicitation, our proposal is to build
  a. An appropriate case base (a case formalization based on the definition of the diagnostic taking into account the indicators used by the maintenance users).
  b. Similarity measures taking into account missing values and adaptation measures reflecting the adaptation cost.

(ii) In the reasoning process, our proposal is to develop a reasoning process suitable for this model. The reasoning process is dedicated to retrieve the similar case and adapt it to solve problems in other contexts. This adaptation phase is complex and is usually designed for a specific application.
  a. The first challenge in this reasoning phase is to propose an algorithm based on the model and independent of the specific application.
  b. The second challenge is to minimize the adaptation cost in the retrieve and reuse phases by proposing an "adaptation-guided retrieval phase".

Our objective in this work is to minimize the cost of designing the knowledge diagnostic system. To evaluate the design cost of our diagnostic method we define in Section 6.4.2 three indicators; the adaptability of the method, the reuse cost and the creation effort.

The paper is organized as follows. We first describe the principle of the elicitation approach which defines the knowledge containers of CBR system. In Section 3, we focus on the retrieve step of the reasoning phase. One might think that the most similar case is always the best candidate. However, the literature reviews of the retrieve phase show that this is not always the case (Smyth and Keane, 1993, 1995, 1998; Cordier et al., 2006). Consequently, we propose an adaptation-guided retrieval method applied to the industrial diagnostic based on two measures: the first one is similarity and the second one is adaptation. Section 4 deals with the adaptation phase, which is applied to the best adaptable retrieved case.

To define a general adaptation method on symbolic data in the field of industrial diagnostic, we are interested in the adaptation approaches in all applications of CBR.

Some studies of the "memory-based reasoning" (Kasif et al., 1995) avoid this step because the wealth of the case-base can compensate for the adaptation phase (Stanfill and Waltz, 1986). However, other authors, like us, develop this phase to enrich the case-base. In this context the adaptation step is the core of CBR (Chebel-Morello et al., 2011; Lieber, 2007). Furthermore, prior works on adaptation were dedicated to a given application. To avoid this specificity, three axes have been explored: (i) Adaptation Knowledge Acquisition (AKA) aims to define general principles of clarification in the studied field. A complete state of the art concerning these methods can be found in Lieber (2007). (ii) Catalogs of adaptation strategies are applied in several domains and are given in Riesbeck and Schank (1989). (iii) Unifying approaches are studied in order to find a general adaptation model as proposed by Fuchs et al. (2000). These authors propose a general adaptation algorithm independent of the application scope. It is applied to digital data as an interval that can be extrapolated. Therefore, we were inspired by the unifying approaches of Fuchs et al. (2000).

We propose a method based on the dependencies between the problem and the solution of a solved case and uses two knowledge models. Three relations of dependencies are defined and exploited to adapt a retrieved case within an adaptation algorithm described in the same section. The matching carried out at the time of the