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Ontology and CBR based automated decision-making method for the disassembly of mechanical products

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ABSTRACT

This paper proposes an ontology and CBR (case-based reasoning) based method which overcomes the difficulty for computers to understand complex structures of various mechanical products and makes the disassembly decision-making process of the products fully automated and cost-saving. In this method, (1) ontology concept is applied to the disassembly decision-making. This enables computers to understand and self-reason the CBR/RBR (rule-based reasoning) based disassembly decision-making process. Since ontology uniforms different kinds of disassembly-related knowledge from different sources, the integration and sharing of the knowledge could be achieved; (2) high flexible decision-making to various conditions with high quality is achieved by the combination of ontology and CBR; (3) to achieve the decision-making when CBR fails, an ontology based RBR method is designed to complement the shortage of CBR in the disassembly decision-making field. The paper also presents an application program to realise the proposed method. In addition, a case study is analysed to verify the validity and automation of the program.

1. Introduction

With the development of technology, on a global scale, quality of mechanical products keeps improving whilst the renewal cycles become shorter. Proper recovery of mechanical products can avoid wasting of resources and prevent environment damage.

For a mechanical product, disassembly is the first step of recovery and it determines the whole recovery plan. An automated decision-making system will lead the recovery process low cost. However, to achieve such a system, there are two obstacles:

(1) It is difficult to find a universal disassembly decision-making method for all mechanical products. Because the structures of mechanical products are diverse. Even for same type products, their components might be quite different due to factors such as customisation, maintenance or update during their lifecycles.
(2) It is hard to realise the automation of disassembly decision-making process. Because computers cannot directly understand the heterogeneous disassembly-related information from different sources.

Case-based reasoning (CBR) is suitable to overcome the first obstacle. CBR simulates the approach how humans solve problems: using the solutions of similar past problems (i.e. cases) to solve the new ones and stores the successful cases in the case base [1–3]. With the accumulation of new cases, the problem solving ability of the CBR system improves continuously.

Ontology is the solution for the second obstacle. An ontology is an explicit specification of a conceptualization [4]. Ontology can make non-ambiguous semantic explanation to domain knowledge and it can be understood directly by computers [5–7]; ontology can describe concepts with different granularity and it supports logical reasoning [8].

This paper combines ontology and CBR to build a decision-making method for the disassembly of mechanical products. The method has following contributions:

(1) Apply ontology concept to disassembly decision-making. This enables computers to understand and self-reason the CBR/RBR (rule-based reasoning) based disassembly decision-making process. Ontology uniforms different kinds of disassembly-related knowledge from different sources, thus realise the knowledge integration and sharing.
(2) The combination of ontology and CBR makes the decision-making system flexible to various conditions with high quality.

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(3) Combined with ontology, RBR is used to complement the shortage of CBR in the disassembly decision-making field, achieving independent reasoning when no existing case is available.

The rest of this paper is organised as follows. Section 2 is a literature review; Section 3 shows the complete structure of the decision-making system; In Section 4, a disassembly-ontology is constructed with the explanation of the generating of product semantic models; Section 5 describes the ontology-based CBR method in detail; Section 6 introduces the ontology-based RBR method; Section 7 presents the implementation of the decision-making system; Section 8 shows a case study which verifies the proposed method by applying it to a pair of fixtures; some discussions are carried out in Section 9; conclusion and further work will be presented in the last section.

2. Literature review

The following studies show the feasibility of applying CBR to the recovery decision-making, and they enlighten the study in this paper. Zeid et al. [9] proposed CBR as an approach to solve planning for disassembly (PFD) problems. Veerakamolmal and Gupta [10,11] used CBR to solve the problem of multiple-products disassembly. In these studies, two representation methodologies of accessing the case memory were proposed, and the disassembly tree was used to model a product's structural layout. Zeid et al. [12,13] suggested to use EMOPs (Eposodic Memory Organization Packet) memory model for the knowledge representation of the PFD plan. The memory model was able to save and retrieve disassembly plans in a CBR system. Shih et al. [14] proposed CBR based methods to determine product end-of-life strategy and conduct cost-benefit estimation. Rasovska et al. [15] introduced a mix method, which combined the CBR with the knowledge engineering techniques, to develop a decision support system for industrial equipments diagnosis and repair. Kuo [16] combined CBR and the analytical hierarchy process to simplify the calculation of the recyclability index for a product.

However, traditional CBR system are poor at semantics understanding ability [17,18]. Yang and Hsu [19] proposed a FAQ system. The system employed an ontology-supported CBR technique to propose adapted query solutions and utilised an ontology-supported RBR to generate possible solutions for the user. Assali et al. [20] presented a knowledge-intensive CBR platform for diagnosis. The platform integrated domain knowledge along with cases in an ontological structure. Tung et al. [21] developed a solution retrieval system based on the hybrid approach using CBR, RBR and ontology. Guo et al. [17,18] integrated ontology technology into the CBR system to develop an intelligent CBR system to meet the needs of injection mould design. Dendani-Hadiby and Khadir [22] aimed to develop a CBR application for fault diagnosis of steam turbines that integrated a domain knowledge modeling in an ontological form. Xie et al. [23] proposed a CBR system for hydro-generator design, and the case base in the system was constructed based on a domain ontology to improve retrieval efficiency. Ruiz et al. [24] used an ontology-based similarity measure for CBR.

Currently, applying ontology to CBR is few studied in the disassembly decision-making field and this paper is aimed to fill up this vacancy.

3. The overall method

The purpose of this paper is to combine ontology, CBR and RBR in a reasonable manner so as to achieve a flexible and fully automated disassembly decision making system. Fig. 1 shows the overall structure of the system. Information from mechanical products, external data sources and disassembly experts are formalised into a standard semantic expression and transferred to the CBR/RBR module. Then after the CBR/RBR based decision-making process, the disassembly solutions are generated and output to the users.

The following details the function of each module in the system.

- **Information collection module.** Because the disassembly decision-making of a product is closely related to its lifecycle information, this paper uses an RFID (Radio-frequency identification) based method to obtain the information (Note: Authors' another paper has studied the method in detail). In this method, a product is attached with a set of RFID tags, which records the lifecycle information of it (some data are stored in the tags directly, others are stored in form of URL—Uniform Resource

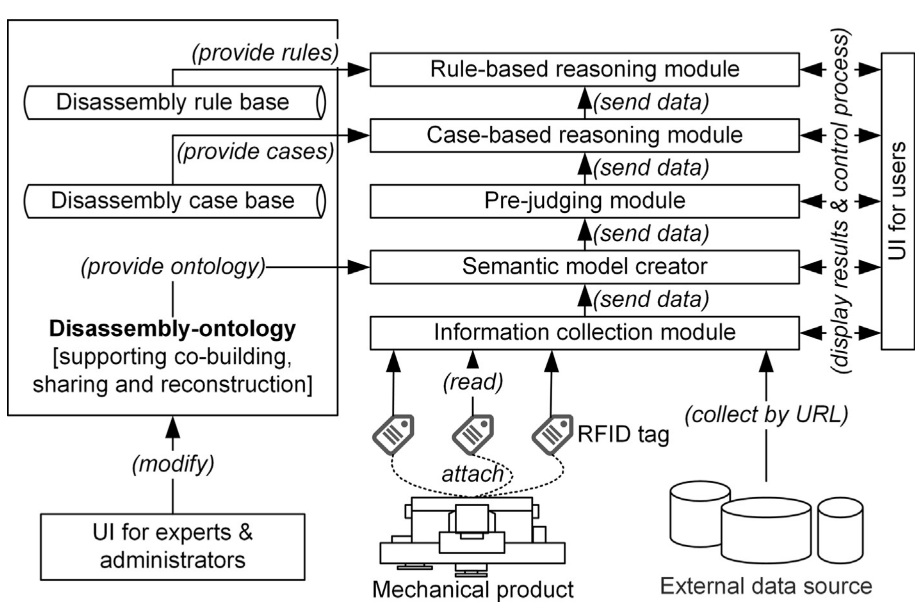

Fig. 1. Overall structure of the decision-making system for disassembly.