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An expert system using rough sets theory for aided conceptual design of ship's engine room automation

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Abstract

More and more complicated conceptual design of ship's engine room (CDSER) heavily depends on designers' engineering knowledge and existing ship data. To achieve intelligent design at the initial ship design stage, many researchers have made much significant progress in this field, however, most of them only focused on how to find the similar constructed ships. At present, how to utilize these existing data remains an untouched topic. In order to make good use of the existing data and reduce the dependence on designers' experience, a novel system named Expert System for Aided Conceptual Design of Ship's Engine Room Automation (ESACD), is elaborated in this study. With the support of the constructed Ship Data Warehouse System, two core subsystems Configuration Selection Assistant (CSA) and Design Scheme Decision Assistant (DSDA) are included in ESACD. A promising approach integrating Fuzzy *c*-means algorithm (FCM) and Rough Sets Theory (RST) to extract configuration rules from the stored data is adopted in CSA. According to engineers' proposals, RST is utilized to reason knowledge in incomplete scheme information systems for getting design scheme rules in DSDA, which are useful suggestions for engineers to get better schemes at this stage. Finally, the validity and necessity of this interactive expert system are demonstrated through the CDSER of a new 50,000 DWT Handymax bulk carrier. It is proved that ESACD can efficiently facilitate rapid and intelligent design in CDSER, and reduce the cost of a new ship design.

Keywords: Conceptual design of ship's engine room (CDSER); Rough sets theory (RST); Discretization; Configuration of engine room; Design schemes

1. Introduction

Conceptual design of ship's engine room (CDSER) is one of the most important tasks in ship preliminary design, in which many perplexing subsystems should be carefully considered, such as main propulsion system, electric power system, fuel system and piping-system. The early stage of ship development includes a lot of fuzzy problems and tolerates a high degree of uncertainty. At this stage, it is inevitable that it heavily depends on the experts' experiences and design cases of existing ships because available information is limited and the degree of design freedom is very high (Lee & Lee, 1999).

Ship design researchers have indulged themselves in the field of computer system for aided ship design automation. The method of using computer system for simulation and detailed design of the ship subsystem has been broadly investigated (Arendt, 2000, 2004; Arendt & Kowalski, 1999; Kowalski, Arendt, Meler-Kapcia, & Zieliński, 2001). On the basis of these systems developed for aided ship design, the integrated system for ship design has also received much attention (Kim, Lee, Park, Park, & Jang, 2002; Han & Lee, 1996; Parsons, Singer, & Sauter, 1999). These integrated systems provide the precondition of collecting and sharing of various data on built ships in the whole ship development process.

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Generally, the computer systems for aided conceptual ship design are relatively few, because knowledge of the design requirements and constraints in this early phase of a product's life cycle is usually imprecise and incomplete, making it difficult to utilize computer-based systems or prototypes (Hsu & Liu, 2000). However, with the rapid development of artificial intelligence, utilizing expert system technology in conceptual ship design has been accepted gradually, and researchers have made much progress in this field. For instance, the application of Memory-based learning (MBL) was proposed to access reference cases for a new ship design (Lee, Kang, Ryu, & Lee, 1997). Furthermore, an intelligent assistant system was developed based on the MBL method for ship design. (Lee & Lee, 1999). For the purpose of improving the result of using MBL and meeting designers' requirements better, fuzzy method with trapezoidal, triangular and Gaussian function was carefully studied (Kowalski, Meler-Kapcia, Zieliński, & Drewka, 2005). Whereas, all of these literatures are only concentrated on the methods of selecting similar constructed ships, none of them investigated the methods of handling the existing design information for getting a better design scheme under uncertain circumstances. Since conceptual ship design is a burdensome design process and lots of information should be carefully considered, it is unacceptable that expert system only provide similar built ships for the ship designers. Thus, constructing an expert system to deal with the multifarious data about the similar built ships, from which useful knowledge can be extracted for the engineer, is a new field that is worth to be deeply studied. In order to achieve the goal of mining useful knowledge for assisting design engineers in CDSER, an expert system based on Rough Sets Theory (RST) (Pawlak, 1982) is elaborated in this paper.

Pawlak (1982) first proposed RST, which has been extended and applied in many research fields, such as chemic analysis (Liu, Xiang, & Qu, 2007), customer relationship management (CRM) (Tseng & Huang, 2007), accident analysis (Wong & Chung, 2007), travel demand analysis (Goh & Law, 2003) and other uses (Pawlak & Skowron, 2007). The merit of RST is that, it neither needs additional information about the data nor is necessary to correct the missing or incomplete data of attributes. Instead, rules generated are categorized into certain rules and generalized rules.

In this paper, an elaborated expert system, Expert System for Aided Conceptual Design of Ship's Engine Room Automation (ESACD) is proposed. It is composed of Configuration Selection Assistant (CSA) and Design Scheme Decision Assistant (DSDA). In CSA, following the traits of CDSER, a promising approach that combines Fuzzy *c*-means clustering algorithm (FCM) and RST is utilized to mine configuration knowledge from similar previous ships' solutions. In DSDA, the method of using RST to compute rules in incomplete information systems, which can acquire optimal certain or optimal generalized rules, is adopted to get conceptual design scheme rules. The rules can substitute engineering knowledge to a certain extent, thus, ESACD effectively speeds up the CDSER process.

The remainder of this paper is organized as follows. The traits of CDSER are discussed in Section 2. The innovative system is established in Section 3. In Section 4, the detailed steps and application of integrating FCM and RST to capture configuration rules in CSA are discussed, then, applying RST approach to reasoning rules in incomplete information systems in DSDA is explained in Section 5. In Section 6, the CDSER of a new 50,000 DWT Handymax bulk carrier is taken as a case study to prove the validity and necessity of the expert system. Conclusions are given in Section 7.

2. Conceptual design of ship's engine room

The quality of conceptual design of ship's engine room (CDSER) has significant effects on the cost and performance of new ships, and plays the most crucial role in the whole ship development process. Fig. 1 illustrates the importance and complicacy of every design stage in the whole life cycle of ship design. It can be seen that the impact of decision and design freedom at conceptual ship design stage are the most important factors in the whole ship development process, but the development tools and design knowledge at this stage are much fewer. As mentioned earlier, knowledge of the design requirements and constraints in this early phase of a ship's life cycle is usually imprecise, incomplete and uncertain. Obviously, CDSER has all the traits of conceptual ship design, because it is one of the most significant tasks in conceptual ship design process. Not only the traits discussed above, it also has its own ones as below:

- *High complexity:* Several interrelated subsystems, dozens of devices and over ten thousand meters piping-system will be preliminarily designed in engine room.

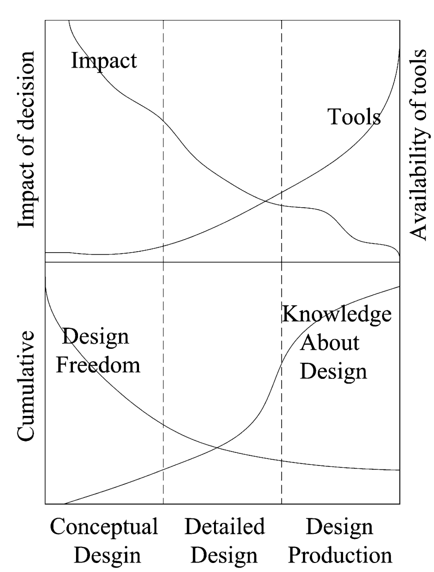

Fig. 1. Importance and complicacy of every design stage in the whole life cycle of ship design.