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Document based knowledge base engineering method for ship basic design

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ABSTRACT

We propose a basic ship design knowledge-model for information storage and retrieval using a knowledge-based engineering (KBE) system and develop a semantic inquiry function that allows users to use the retrieved information immediately. Our aim is to merge the repetitive access and calculating tasks and data such as the principal dimensions required during the basic ship design process into a single database, so that this information remains available for future construction projects. However, the concept of linking a design knowledge base and inference engine requires the combining of ship design information with the KBE system. This research enhances the flexibility, extension, and operation of the inference mechanism of the KBE design methodology through the establishment of a user interface, knowledge base, and inference engine. The design information is managed a document-based approach, which requires the conversion of the original documents into the XML (eXtensible Markup Language) format, and compiles rules for the basic design process. This system uses the KBE method attempts to reduce the double workload of design and modeling at the commencement of a new project with the document-generating integration work.

1. Introduction

Ship design is a complex task based on expertise and is iterative in nature. It also requires a knowledge base. Because of the complex characteristics of ship design, it is suitable for a knowledge-based engineering (KBE) approach. Basic ship design aims to determine the major ship characteristics affecting cost and performance. This basic design work includes the selection of the ship's dimensions, hull form, power, machinery arrangement, and primary structure. Proper selections ensure the attainment of the mission requirements, which might include good seakeeping performance and maneuverability, as well as a specific speed, endurance, cargo capacity, and deadweight. Furthermore, it includes checks and modifications of the achievement of required cargo handling capability, quarters, subdivision and stability standards, and freeboard and tonnage measurements, which are usually defined as constraints (Helvacıoglu and İnsel, 2001).

The decisions made at the basic ship design stage are fundamental to the entire design and production process of ship construction. Decisions at this point have a continuous and profound influence during the ship product life cycle (Nowacki, 2009). Particularly in the hull-form generation stage, following the selection of the primary dimensions, there are many complex elements that combine to create design constraints, including the hull form design, performance coefficients, and geometric characteristics, which require a skilled designer's knowledge and experience (Noy and Musen, 2004). However, because the available information is limited, and there are many design elements that require multiple revisions, making decisions about such design elements is not easy. The trend in recent design methods has been toward a more interactive information flow, rather than an one-way information flow. Accordingly, a key function for the shipyard's engineering technology is to improve the efficiency of the basic design stages. The engineers use the information in each design stage, as it changes gradually from soft information to hard information (Helvacıoglu, 2001).

Bronsart developed a knowledge-based model for ship design that used semantic web techniques (Bronsart and Zimmermann, 2005). The model integrates knowledge, geometric models, and manufacturing information through a semantic web. The integration of KBE methods into computer-aided design (CAD) systems allows for automatic quality assurance. Knowledge acquisition is the process of extracting human knowledge and expertise and recording it in some convenient form for subsequent representation as a computer compatible knowledge base (Picard et al., 1999; Golabchi, 2008). Zimmermann examined the use of knowledge-based applications for the structural design of a ship (Zimmermann et al., 2005). Based on a formal introduction to knowledge and quality, they illustrated the use of KBE in knowledge querying and quality assurance. They also described both the knowledge reasoning method and the knowledge-based structure of information in a networked environment.

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Basic ship design follows the planning design stage; it covers regulations and descriptions of the basic design calculations, hull structure, outfitting, machinery, and electrical aspects, which define the performance, materials, equipment, layout, and manufacturing standards (Hiekata et al., 2007a, 2007). The shipyard's engineers send the basic design layouts to the classification societies and various administration organizations for review, and afterward these become the major basis for manufacturing design tasks (Abersek and Popov, 2004). Another paper proposed a methodology to articulate design knowledge using a design template and proposed a software system to support the proposed methodology. The system is both a kind of design navigator and a design data storage technology (Hiekata et al., 2008). With the globalization of business activities, the core competence of a manufacturing enterprise increasingly depends on the quality of its intellectual capital and how this capital is used. Intellectual capital is usually presented in the form of various kinds of documents.

There are several general methods used to create hard information in basic ship design. One of these is the use of the accumulated knowledge and organized data collected by experienced engineers, or information acquired from journals and theses, to judge the accuracy of design data. In this paper, we apply the KBE method to manage the design experience and information mentioned above and uses an XML-based protocol to organize the documents. This integrated concept will help domain experts output new construction projects, based on former cases, and at the same time enhance the interoperability of the shipbuilding environment. This issue will be publication in next articles (Wu and Shaw, in preparation).

This research involves more than simply establishing a knowledge-based engineering system; the purpose of this research is to develop a support interface for an intelligent rule inference system with two contributing parts. One is the collection of shipbuilding classification and routine design regulations and formulas. The second set of contributions comes from documents that, after conversion, form XML-based rules (here we used shipbuilding specifications) and refer to previous, similar construction cases. An additional application of the KBE method merges the revised and sequenced log files as information feedback. These are then regarded as knowledge resources for later design cases. This research discusses an approach toward a document-based KBE for use in global engineering and manufacturing projects. Knowledge can be captured into documents at many stages in the project lifecycle, and the nature and value of the reusable content and contextual knowledge vary with the project stage.

This paper is organized as follows. In the next section, we analyze the design flow advantage after applying document-based KBE and discuss the advantages and disadvantages of using a document-based system. Section 3 explains knowledge gathering, section four is about knowledge reasoning methods, and the development of a framework for a document-based KBE system is detailed in section five. Finally, the last section of this paper presents our conclusions.

2. Design flow analysis

A comparison analysis was made between the present and proposed basic design work flows, expressing the time cost benefit and advantages of enhancing the interoperability by improving the inner design system processing model (in the center squares in Figs. 1 and 2). Figs. 1 and 2 represent the original and improved design workflow models used in shipyards. Essentially, all activities in a large engineering organization are related either to winning contracts or fulfilling the requirements of existing contracts. Aside from the contractual documentation that states the requirements that drive the project, there are major bodies of information and knowledge that must be managed, related to design, production, and documentation.

2.1. Present design flow analysis of shipyard

In the shipbuilding industry, ships are built in small numbers with many different designs depending on the owner's requirements. To secure orders, designers have to design efficient, high performance ships within a fixed time period. In ship design, the data from existing ships are largely used because the available data are limited and the design freedom is very high. During the conceptual stages of a design, for example, the principal particulars and major performance of the ship are estimated by comparison with ships of a similar type or from coefficients derived from existing ships. Therefore, designers should closely study, analyze, and organize the design data from similar ships that have been built in the recent past. These data can be implemented as a database and utilized to improve the quality and shorten the time needed for the design. Engineers who compile the requirements of the ship owners from the sales department determine the design conditions.

Fig. 1 shows how the owner's designers and the shipyard's sales department and engineers discuss and transfer the owner's requirements into design conditions and specifications. The engineers input design conditions to the basic design program and marshal the calculation results with tools such as Microsoft Excel. Although a document editor then helps to transfer the data to documents (specifications) using a document editor program, normally the engineers are still responsible for the work. Finally, the editor completes the documents (specifications) using a document editor program such as Microsoft Word. The engineers store these design documents in a public document database such as web-shared folders, while the sales department simultaneously delivers the specifications to the ship owners for approval. After signing the contract, the data stored in the database will flow downstream, for access by detail design programs like Excel, TRIBON (AVEVA, 2006), PDMS (Plant Design Management System) (AVEVA, 2010), and so on.

As seen in the knowledge path at the top of Fig. 1, engineers consult references, journals, and theses, and share their expertise with others. Then, domain experts work on generating common usage designs or design methodologies by data mining a body of data, after which the engineers develop program coding based on this knowledge.

In the shipbuilding industry, engineers spend most of their time collecting and transferring data to documents or software. Moreover, engineers must redevelop program coding based on this knowledge when the domain experts find new technology or a more appropriate design method.

2.2. Document-based KBE model for design flow

The establishment of the following elements in the basic ship design knowledge-based engineering application system might result in positive effects on the current design flow, as seen in Fig. 2.

We adopt a knowledge-based basic design system in place of the basic design program. We use an XML-based protocol that integrates documents provided for basic design and adopts the same format and document-storage ontology structure in order to save work, while delivering messages across multi-platforms. Furthermore, it provides superior access to knowledge bases such as the rule base and document base. Ship designers select appropriate existing ships from the database based on their