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On application of the Case-Based Reasoning methods in ship automation design

INTRODUCTION

Contemporary designing, to be effective, requires application of the up-to-date information techniques. An important stage of the process is the preliminary one containing the conceptual and contract designs in which main parameters of a ship as well as its cost are estimated. Imperfections and errors made in that stage may result in serious technical and economical consequences both for building and operation of a ship. Therefore when designing a new ship it is important to make use of information comprised in designs of existing ships.

This is possible by making use of the artificial intelligence methods, particularly the Case-Based Reasoning (CBR) ones, expert systems and a relational database with intelligent interface.

In order to implement the CBR method the authors elaborated its application for aiding ship automation design with the use of the Exsys Developer shell expert system cooperating with the Access database. It contains information about automation objects and systems used in existing ships, that comprised in catalogues, as well as data dealing with current and completed designs.

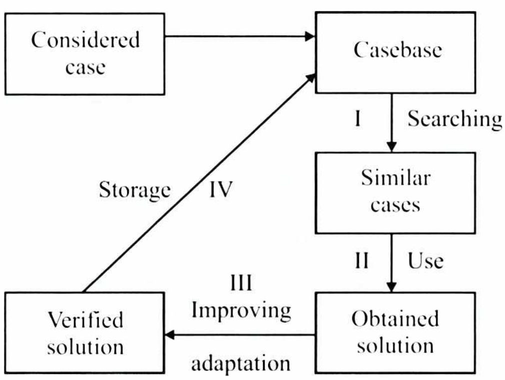

Fig.1. Schematic cycle diagram of Case-Based Reasoning method

CASE-BASED REASONING METHOD

The CBR method is a relatively new way of solving problems dealing with databases and knowledge bases, which consists in generating solutions of novel problems by using solutions earlier applied in similar situations. To this end a similarity is calculated between a new case and each of the stored cases. The approximate solution this way obtained can be adapted by using rules of an expert system, genetic algorithm or by taking part of an expert directly.

The area of application of the method is wide and it can contain e.g. diagnosing, classification, decision-making supporting, planning, designing etc.

On defining a given case problem the application of the method in question amounts to the four-phase cycle of the following operations [1,6] :

I – search - out of a database of realized solutions – similar ones to the case to be solved,
II – use of the found solution and its verification, if necessary,
III – adaptation of the elaborated solution,
IV – storage of the obtained solution in the database (casebase).

The cycle is schematically shown in Fig.1.

In the literature sources [3, 5, 7] examples of the following methods for case similarity determination can be found :

- investigation of identity of text parameters with taking into account their weights (identity test)
- use of a symmetrical similarity function of lower limit of numerical parameters.

The identity test related to a given parameter yields 0 or 1 in compliance with the following relationship :

$$S(p_1, p_2) = \begin{cases} 1, \text{ for } p_2 = p_1 \\ 0, \text{ for } p_2 \neq p_1 \end{cases} \quad (1)$$

where :
p_1 – parameter value for a designed case
p_2 – parameter value for a preceding case.

The symmetrical similarity function with lower limit, witch is also related to single parameters, is defined as follows [7] :

$$S(p_1, p_2) = 1 - \frac{|p_1 - p_2|}{\max(p_1, p_2) - P_D} \quad (2)$$

where : P_D – lower limit of a parameter value.

It is self-evident that the formula yields values from the [0,1] interval.

APPLICATION OF THE CBR METHOD TO DESIGN OF SHIP AUTOMATION SYSTEMS

The design process and integration of ship automation systems require to analyze a large amount of information dealing with various systems and objects, taken from many sources, and to gather it into one or several integrated computer controlled systems. Handling such large and continuously increasing set of information requiring to take into account many different factors, becomes more and more time-consuming and complex process.

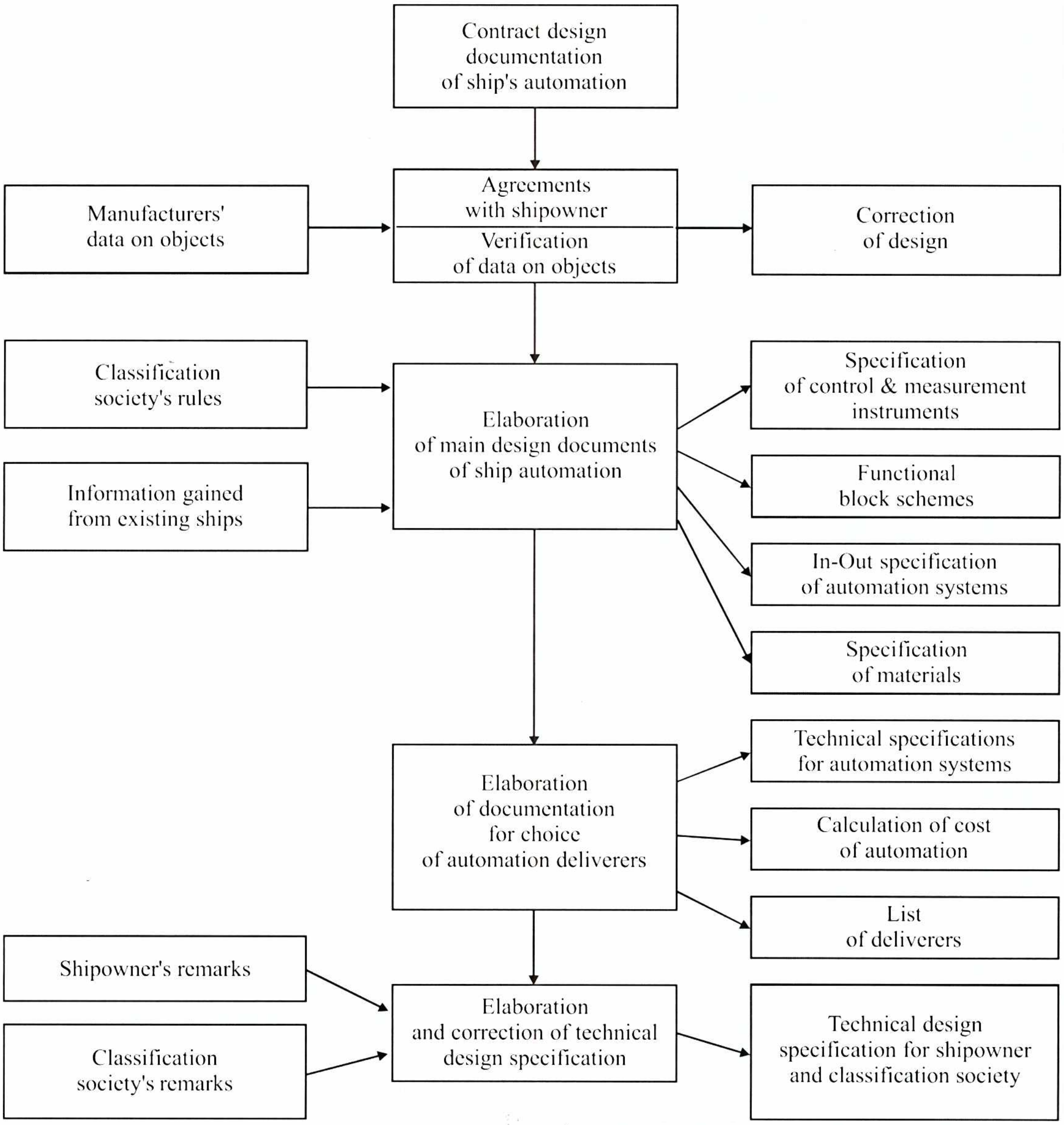

***Fig.2.** Schematic diagram of ship automation design process at technical design stage*

The schematic diagram of the ship automation design process in the technical design stage is presented in Fig.2. The scheme shows the sequence of realized tasks and the main sources of information (initial documents) as well as the final documents, i.e. the results of the design process which are obtained with the use of the CBR method applied in the expert system for aiding design of ship automation systems [2].

In the system in question a case is identified with a ship automation design and it consists of : overall data on a ship and its automation, data for technical specification of automation, specification of control & measurement points on a ship, as well as functional block schemes of systems.

In the task of aiding ship automation design the similarity is related to the features characterizing the existing ship power plants; as it is assumed that solutions dealing with automation are conditioned on some selected features of a ship's power plant. The ship's similarity is determined in relation to certain groups of the features because of a large number of the features to be accounted for.

The set of the considered ship's features (parameters) was divided into the subsets related to : the entire ship, its main propulsion, electric power plant, as well as the following shipboard installations : fuel oil, lubricating oil, fresh water, sea water, compressed air, steam and boiler, bilge and ballast systems, and other.

The similarity calculation results within the range of those subsets are considered as partial similarities. At the beginning, in the database the single parameter similarities are calculated with accounting for field weights. On their basis the partial similarities are calculated for the above specified groups, and finally , the similarity of the entire ships as a weighted sum of the partial similarities.

The so-calculated similarities in the database system are transferred to the Exsys expert system where they are fuzzyfied, together with the parameters whose similarity is calculated by using the fuzzy logic directly. From the Exsys the resulting maximum partial similarities are transferred to the database, together with the identifiers of relevant ships as well as the maximum total similarity of the entire ship. On this basis the database system searches out data of that ship as a similar one. In the case that the entire automation system of the found similar ship does not satisfy expected requirements, its particular elements may be taken from other ships on the basis of the maximum similarities of the appropriate systems (installations).

In Fig.3. an example scheme of searching for a similar ship is presented.

The adaptation of a similar object can be made for entire systems (installations) or it can deal with a single objects of an arbitrary system. This makes it possible to get access, especially as regards the functional block schemes, not only to objects of automated systems

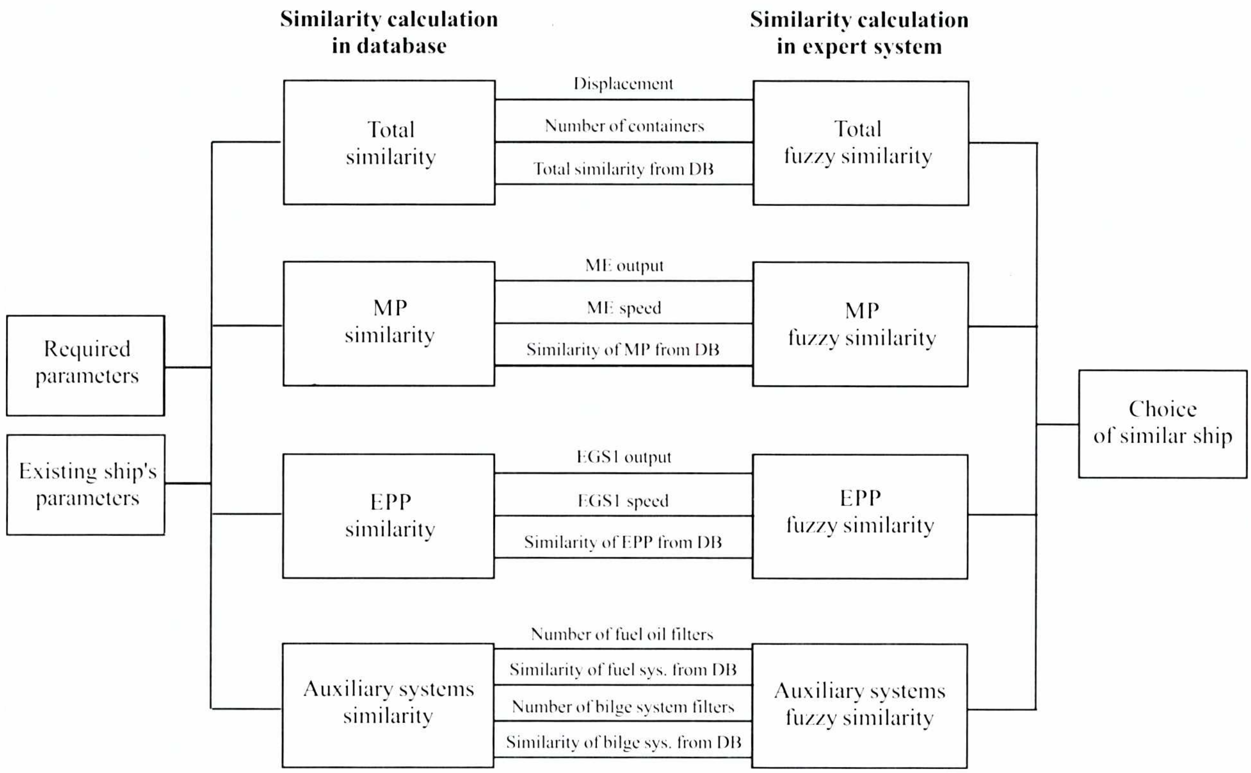

Fig.3. *Example scheme of searching for a similar ship*

where : *MP – ship's main propulsion, ME – main engine, EGS1, EGS2 – electric generating sets, EPP – electric power plant, DB - database.*

but also to links between them. Such adaptation of an existing ship can be realized on the basis of :

- other designs of existing ships
- a domain model.

The latter method [4] may be used if in the database no sufficiently similar ship is found, or a found ship is of a relatively low similarity and the designer gives adjusting of an existing ship up in favour of independent designing.

If partial similarities of particular systems of a similar ship (that of the largest total similarity) are smaller than those of the particular systems of other ships, then the design of the automation system of the similar ship may be verified on the basis of designs of other ships.

In the computer aided design (CAD) system for ship's automation, elaborated by the authors the similarity calculation methods were based on :

- adaptation of the identity test and symmetrical similarity function with lower limit
- application of the fuzzy logic [8] for selected numerical parameters
- application of the trapezoidal, triangular and Gaussian functions of similarity, elaborated by the authors [9].

The identity test is applied to the text parameters such as : ship's type, classification society, automation class, ME type, propeller type, type of EGS1 and EGS2, shaft generator type, as well as some numerical parameters such as number of propellers, transmission gear and EGS.

The symmetrical similarity function with lower limit is used for the numerical parameters such as : number of ME, number of EGS, as well as selected parameters of example installations such as e.g. : number of fuel oil pumps, separators and filters, number of bilge pumps.

The fuzzy logic - in contrast to the classical expert systems - can be applied for reasoning on the basis of uncertain, inexact data with the use of approximate rules, i.e. in a way characteristic for man. It can be used simultaneously to an arbitrary number of parameters, making it possible to pass from numerical quantities to linguistic ones (of a natural language) by which logical reasoning can be performed easily [8]. This way, decision making is independent of an importance and range of numerical values of considered parameters.

In the CAD system in question the fuzzy logic is applied to such parameters as : ship displacement, number of refrigerated containers, main engine (ME) power and speed, number of electric generating sets, as well as number of valves of selected installations (of fuel oil and bilge).

The fuzzy logic is applied to similarity calculation of differences between values of atributes of a designed ship and those of relevant atributes of particular existing ships, as well as of partial similarities calculated in the database.

RECAPITULATION AND FINAL REMARKS

- At realization of most design tasks of ship automation an important drawback is the lack of application of formal methods, mathematical models and advanced computer aiding techniques. Taken decisions and accepted solutions are often based only on knowledge resulting form experience and intuition of designers.
- The presented expert system elaborated to aim ship automation designing makes transformation of the knowledge into formal rules and improvement of design results, possible.
- The system is an intelligent, user – friendly tool which can effectively aid the ship automation design process in its preliminary (offer and contract) and technical stages.
- The elaborated application of the database can support the design process in the area of the most time-consuming operations.
- In the presented CAD system the unconventional determination methods of ship similarity are applied for design purposes, namely the fuzzy logic and trapezoidal, triangular and Gaussian similarity functions. They provide a better similarity measure making it possible to select a similarity function in accordance with relevant requirements and type of a considered parameter.
- Examples of practical applications of the presented CAD system for ship automation will be soon published by the authors.

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Conference

Explo – diesel & gas turbine '03

On 5 ÷ 9 May 2003, under this heading, held was 3rd International Technical Scientific Conference devoted to the problems associated with :

Keeping Diesel Engines and Gas Turbines in Movement with Regard to Environmental Protection

The Faculty of Ocean Engineering and Ship Technology, Gdańsk University of Technology, and Alfa Laval AB, Lund, were its main organizers.

The Conference was aimed at arranging a wide forum for exchange of opinions on cognitive and utilitarian issues in the field of designing, manufacturing and usage of diesel engines and gas turbines as well as the devices which make it possible to keep them operating at possible high efficiency.

52 papers were approved for the Conference, including the following invited ones :

- *An assumed reliability structure - redundant in a safety aspect* by J. Jaźwiński (Airforce Technical Institute, Warsaw), Z. Smalko (Warsaw University of Technology)
- *System reliability and availability related to its operation process* – by K.Kołowrocki (Gdynia Maritime University)
- *On operational features of technical objects - with turbine engines as an example* – by J. Lewitowicz (Airforce Technical Institute, Warsaw) Kamila Kustroń (Warsaw University of Technology)
- *System background of exploitation* – by L. Powierża (Warsaw University of Technology)
- *A model of technical object operation, based on three - - processor approach* – by L. Będkowski and T. Dąbrowski (Military Technical Academy, Warsaw)
- *Problems of ship system design for safety* – by A. Brandowski (Gdańsk University of Technology).

The enumerated papers were read during the first two sessions. Next three sessions were devoted to :

⇨ Session III – Operation (7 papers)
⇨ Session IV – Reliability, Safety and Tribology (7 papers)
⇨ Session V – Diagnostics (6 papers).

The first five sessions were held in a hotel conference hall at Międzyzdroje.

Session VI of 8 papers on various topics, had place onboard the ferry POLONIA during its voyage from Świnoujście to Ystad (Sweden).

Sessions VII and VIII were held in the headquarter of Alfa Laval AB, Lund (Sweden). At first, representatives of the firm presented, to the Conference participants, the firm's history, its achievements and potential for developing the production technology of heat exchangers; next, two following papers were read by their authors :

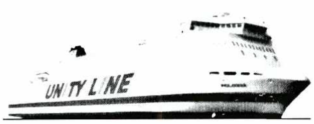
- *Numerical simulation of gasdynamical processes within a turbocharging system of a marine engine* – by Z. Korczewski (Polish Naval University)
- *State of the art of electronically controlled engines* by A. Krupa (MAN-B &W).

Two last sessions, held again at the hotel in Międzyzdroje, were devoted to the following issues :

⇨ Session IX – Operation (8 papers)
⇨ Session X – Tribology (8 papers).

Apart from the papers concerning directly the main topics of the Conference, its organizers arranged also some papers on more general issues of inter-disciplinary scientific merits, which also contribute to developments in the broad area of designing, manufacturing and utilization of the piston and turbine internal combustion engines and equipment cooperating with them.

The Conference participants, apart from exchange of their scientific experience, had the opportunity of having the sea trip onboard the ferry, of being acquainted with its power plant, as well of visiting some spots of interest in Ystad, Malmoe and Lund. In the latter town they were acquainted with the manufacturing process of the plate heat exchangers signed with the Alfa Laval trademark.



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