Expert system applications in marine technologies

Sebnem Helvacioglu *, Mustafa Insel

Faculty of Naval Architecture and Ocean Engineering, Istanbul Technical University, Istanbul, Turkey

ABSTRACT

Expert system approach is one of the most suitable methods to model human expertise in computers, which was introduced into marine technology to design marine vehicles three decades ago. Even though there are several applications by expert system approach, only some of them can be used effectively in this area. Hence, a number of expert system applications in marine vehicles are examined in detail to understand the state of the art in this paper. Related tools, methods and subjects are discussed to evaluate the advantages and disadvantages in this discipline for the future developments.

© 2008 Elsevier Ltd. All rights reserved.

1. Introduction

Scientific and engineering disciplines seek new techniques to solve problems, which cannot be solved by currently available methods. A transition from deterministic to stochastic or from procedural to heuristic methods is used recently to tackle various problems. In this connection, Artificial Intelligence (AI) techniques including expert systems (ESs), artificial neural networks (ANNs), fuzzy logic, etc., became attractive worldwide. Perhaps, ESs are among the most fertile areas for scientific research in the field of AI. ES solutions are based on reasoning by using problem domain knowledge and heuristics. Hence, ES approach is the most suitable methodology for simulating human experts. Most of the ESs for ship design is aimed at development of assistance to deal with the complex characteristics of design problem.

Several tools are utilized to develop an ES from procedural programming such as FORTRAN 77 or logic programming languages and PROLOG or programming shells including CLIPS. Various techniques are utilized for user interface, knowledge representation, inference and explanation.

As ESs communicate with a user through an interface facility, some of them are built in and others are adopted from some procedural programming languages such as DELPHI or VISUAL BASIC.

ES projects deal with knowledge elicitation and representation techniques. The former is used to extract human or expert knowledge from several sources whereas the latter stands for modelling the knowledge in the computer environment. Interviews with experts, forward scenario simulation and acquiring the knowledge from source books are mostly utilized methods for knowledge elicitation. Knowledge is mainly represented by rules or objects.

The inference engine decides about the rules which are satisfied by facts or objects and executes these rules with the highest priority. Explanation facility is a part of ES whose shells and logic programming languages support the facility. Some ESs have no explanation facility which is a shortcoming of the system.

As knowledge is extremely valuable, the sample ESs in this paper have attempted to develop such systems. The aim of this paper is to review the literature about the subject and encourage scientists to use ESs in marine technology. Also, a number of ES applications is examined to find out the recent developments in the marine technology problems. The tools and the methods such as reasoning, representation, inference techniques, knowledge elicitation, explanation and user interface are examined closely.

2. Structure of an expert system

The structure of a typical ES is shown in Fig. 1 which includes the following major components:

- **User interface**—the mechanism by which the user and the ES communicate.
- **Explanation facility**—explains the reasoning of the system to a user.
- **Inference engine**—makes inferences by executing rules which are satisfied by facts or objects according to a priority scheme.
- **Agenda**—a list of rules by the inference engine, whose patterns are satisfied by facts or objects in working memory.
- **Automatic knowledge acquisition facility**—an automatic way for the user to enter knowledge in the system rather than by having the knowledge engineer explicitly code the knowledge.

---

* Corresponding author. Tel.: +90 212 285 64 93; fax: +90 212 285 65 08.
E-mail addresses: helvaci@itu.edu.tr (S. Helvacioglu), insel@itu.edu.tr (M. Insel).
Knowledge-base—consists of two parts, the domain knowledge, which represents some rules about the problem domain, and working memory where facts and generated facts are hold.

It is worth to mention about the advantages and disadvantages of ESs (Helvacioglu, 2001). A typical ES may have some of the following attractive features:

- The domain expertise can be available on any suitable computer hardware.
- The cost of providing expertise per user is greatly lowered.
- Unlike human experts who may retire, quit or die, the ES's knowledge will last indefinitely.
- The knowledge of multiple experts can be made available to work simultaneously and continuously on a problem at any time.
- ESs can explain the reasoning that led to a conclusion in detail.
- Fast or real time response may be necessary for some applications. An ES may respond faster and be more available than a human expert.
- An ES is steady, unemotional, and gives complete response at all times.

Although ESs have considerable advantages to offer, they also do have the following disadvantages:

- Some applications are difficult to use by another person who has not generated the knowledge-base.
- Some systems are very slow when compared to the human expert.
- The knowledge systems' ability tends to end abruptly.
- Sometimes, it is difficult to extract knowledge from an expert and to put it into a format that the ES can deal with and the size of the ES domain must be limited.
- The inability of ESs to exhibit common sense limits the effectiveness of present ES applications.

3. Application areas and tools

ESs can be applied in every field provided that expert knowledge is acquired. Unfortunately, ES application has not been used yet widely in marine technologies. This has been observed from the number of scientific publications. Automotive industry and aerospace industry has attracted 70 and 170 article publications, respectively, in a year. Meanwhile, the average number of articles in shipbuilding industry is about 1.4 articles per year, and none of them is commercialized (Park and Storch, 2002). There are a number of reasons for such a low interest; integration of ES into conventional CAD systems, knowledge elicitation and representation problems and uniqueness of ship designs.

Although ESs constitute a branch of AI, there are specialized languages for them that are quite different from the commonly used AI languages such as LISP and PROLOG (Giarratano and Riley, 1994). Recently, ESs have been utilized in combination with other technologies such as database, case-based reasoning and conventional programs to overcome knowledge management problems.

Although there is little work in the field, some subjects in the marine technology have attracted researchers for application of ESs. Some of the sample applications are examined and represented in Table 1, which indicates also the aim of the system, in which stage the system has been applied, and the application area in addition to different tools and programs that have been used to develop these systems. From this table, it is observed that some researchers use some AI programs such as PROLOG, the others developed their own ES shells such as INCODES, as well as general shells such as LEONARDO, ECHIDNA and CLIPS. On the other hand, some other CAD and conventional programs are used to support ESs.

4. Methods

Any ES structure includes knowledgebase and inference engine of the system in addition to explanation and user interface as shown in Fig. 1. Various methods used in the structure are examined here for some sample ESs, where methods of elicitation, representation and reasoning are given in Table 2 and inference, explanation and user interface in Table 3 in order to assess the potential development areas in shipbuilding industry ES.
Table 1
Sample ES applications

<table>
<thead>
<tr>
<th>Expert system</th>
<th>Aim of the system</th>
<th>Application stage</th>
<th>Application area</th>
<th>Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPOPS (Green, 1989)</td>
<td>The creation of a spatial layout representation, expressed in commonsense</td>
<td>The early stage of</td>
<td>Spatial layout design</td>
<td>Prolog</td>
</tr>
<tr>
<td>SPACE (Green, 1989)</td>
<td>Allows a commonsense model of an arrangement and directed more specifically as a</td>
<td>The early stage of</td>
<td>Spatial layout design</td>
<td>Prolog</td>
</tr>
<tr>
<td>Container ship ES</td>
<td>Over all design system concerned with the generation of vessel dimensions and hull</td>
<td>Concept design</td>
<td>Ship design</td>
<td>INCODES (Intelligent Concept Design System) is based on FORTRAN 77. Author developed a knowledge representation language (KRL) in INCODES that enables the shell to represent various types of knowledge</td>
</tr>
<tr>
<td>OSV (Mainal, 1993)</td>
<td>The preliminary design and operation of offshore supply vessels</td>
<td>The preliminary design</td>
<td>Offshore supply vessel design</td>
<td>LEONARDO is an ES shell, uses rules and an object-oriented frame system. It contains procedural language and includes support for Bayesian statistics, fuzzy logic and certainty factors</td>
</tr>
<tr>
<td>OSVDP (Mainal, 1993)</td>
<td>An interactive program to design offshore supply vessels including hull form</td>
<td>The preliminary design</td>
<td>Offshore supply vessel design</td>
<td>LEONARDO is an ES shell, uses rules and an object-oriented frame system. It contains procedural language and includes support for Bayesian statistics, fuzzy logic and certainty factors</td>
</tr>
<tr>
<td>OPTOSVD (Mainal, 1993)</td>
<td>An optimization program for determining hull parameters of OSV</td>
<td>The preliminary design</td>
<td>Offshore supply vessel design</td>
<td>LEONARDO is an ES shell, uses rules and an object-oriented frame system. It contains procedural language and includes support for Bayesian statistics, fuzzy logic and certainty factors</td>
</tr>
<tr>
<td>MOSVOP (Mainal, 1993)</td>
<td>A program for operation transporting the required materials</td>
<td>The preliminary design</td>
<td>Offshore supply vessel design</td>
<td>LEONARDO is an ES shell, uses rules and an object-oriented frame system. It contains procedural language and includes support for Bayesian statistics, fuzzy logic and certainty factors</td>
</tr>
<tr>
<td>MOSVCF (Mainal, 1993)</td>
<td>A program for the selection of the main engine and propulsion incorporating Certainty Theory</td>
<td>The preliminary design</td>
<td>Offshore supply vessel design</td>
<td>LEONARDO is an ES shell, uses rules and an object-oriented frame system. It contains procedural language and includes support for Bayesian statistics, fuzzy logic and certainty factors</td>
</tr>
<tr>
<td>MOSVBR (Mainal, 1993)</td>
<td>A program for the selection of the main engine and propulsion incorporating Bayes’ Rule</td>
<td>The preliminary design</td>
<td>Offshore supply vessel design</td>
<td>LEONARDO is an ES shell, uses rules and an object-oriented frame system. It contains procedural language and includes support for Bayesian statistics, fuzzy logic and certainty factors</td>
</tr>
<tr>
<td>Fishing vessel design (Akıntürk, 1997)</td>
<td>The preliminary design of fishing vessels, which includes some ergonomic rules in order to improve living and working conditions hence crew safety on-board fishing vessels</td>
<td>The preliminary design</td>
<td>Fishing vessel design</td>
<td>Echidna is an ES shell that supports constrained, hypothetical and model based reasoning, logic programming, and intelligent backtracking</td>
</tr>
<tr>
<td>Compartment layout design (Lee and Lee, 1997)</td>
<td>Compartment layout design for tankers. To change the tankers design to double sided according to the rules and regulation for marine pollution</td>
<td>The early stage of</td>
<td>Changing tankers into double skin type</td>
<td>Rules are represented in a general-purpose ES development shell. The integration between the knowledge base, database and the application programs</td>
</tr>
<tr>
<td>MADES (Lee et al., 1998)</td>
<td>A tool for extending the capability of existing CAD systems. The knowledge base is implemented in actual CAD environment of a ship engine room</td>
<td>The preliminary design</td>
<td>Machinery Arrangement Design</td>
<td>Knowledge is represented by object-oriented concept. CAD system, a graphical user interface, a database system are used to deal with the system</td>
</tr>
<tr>
<td>ALDES (Helvacioğlu, 2001)</td>
<td>Container ship design ES</td>
<td>The preliminary design</td>
<td>Accommodation Layout Design Expert System</td>
<td>CLIPS is used as an ES shell and DELPHI is used for visualization and user interface</td>
</tr>
<tr>
<td>Ship systems operation (Kowalski et al., 2001)</td>
<td>To prepare a knowledge base for ship power system automation</td>
<td>The preliminary design</td>
<td>Ship power system automation design</td>
<td>EExsys Developer is used as a shell. MATLAB is used for simulation and MS Access is for the database handling</td>
</tr>
</tbody>
</table>

4.1. Knowledge elicitation

Knowledge is probably the most valuable part of current technology. Knowledge sources can be categorized in four groups:

(a) Regulations originating from national or international bodies such as IMO, or from class societies.
(b) Company procedures, guides, open literature.
(c) Experience hidden in past cases.
(d) Knowledge of domain experts acquired through practice of work over the years.

The knowledge acquisition from first two groups is straightforward, but knowledge from the previous cases or from expert is difficult to extract. Different approaches have been applied in the ESs reviewed here.

Interview technique is used efficiently in SPACE ES to acquire knowledge from experts. It is possible to provide a textual description of the connections between individual items in a spatial layout without resorting to precise geometry. Also the way in which people describe the spatial layout verbally is investigated.

Welsh (1989) used forward scenario knowledge elicitation technique to acquire container ship design knowledge. Although the technique adopted to acquire container ship knowledge productively, the size of the container ship design knowledge prevented the author to use some other knowledge elicitation techniques and only some of the knowledge could be used in the system to keep the system manageable.

A preliminary design knowledge-base for OSV ES contains a considerable amount of information gathered through intensive studies on the characteristics of 20 pure supply vessels and 20 anchor handling/tug/supply vessels built since 1980 (Mainal, 1993). This domain of knowledge is expressed in the knowledge-base in terms of empiricisms, factual declarations and design parameters.
Lee and Lee (1997) modelled the ship compartment design processes, which the expert performs as temporary design, design evaluation, design change and repeat the processes. In this case, changing compartment of a ship depends on the shipyard’s size. So, the ES is designed according to a specific shipyard. The knowledge is extracted from rules and regulations such as MARPOL 73/78, IMO regulations and classification societies to redesign ship’s compartments.

The knowledge-base for ship power system automation is developed a database representation and MS Access to store the data. Rule-oriented knowledge representation rules and frames are used in the system for the environment changes. Non-monotonic reasoning is applied for the system according to the rules.

Table 2
Knowledge elicitation representation and reasoning methods in sample ESs

<table>
<thead>
<tr>
<th>Expert system</th>
<th>Knowledge elicitation</th>
<th>Knowledge representation</th>
<th>Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPOPS and SPACE</td>
<td>Interview by questioner</td>
<td>Object-oriented classification to define the entities of space, PROLOG convention to represent relationships and attributes</td>
<td>Logical deduction reasoning</td>
</tr>
<tr>
<td>Container ship ES</td>
<td>Face-to-face interview</td>
<td>INCODES knowledge representation system</td>
<td>INCODES provides synthesis and analysis procedure</td>
</tr>
<tr>
<td>OSV–OSVDP–OPTOSV–MOSVOP–MOSVCF–MOSVBR</td>
<td>Data of past vessels built since 1980</td>
<td>Leonardo package program facilities such as production rules and frames</td>
<td>Induction to get empirical equations for the main dimensions</td>
</tr>
<tr>
<td>Fishing vessel design ES</td>
<td>The source books and domain experts</td>
<td>ECHIDNA supports object-oriented representation system</td>
<td>The partial design proposed and checked with the system according to the rules</td>
</tr>
<tr>
<td>Compartment layout design</td>
<td>Rules and regulations to redesign compartments of a ship</td>
<td>Pre defined objects are used in IF–THEN rules to represent knowledge</td>
<td>Non-monotonic reasoning allows the ES to make decisions and take actions based on incomplete information and make revisions to the environment changes</td>
</tr>
<tr>
<td>MADES</td>
<td>Knowledge not only depends on an experienced designer but also has design constraint and regulations</td>
<td>Object-oriented concept is used to represent knowledge</td>
<td>Non-monotonic reasoning is applied</td>
</tr>
<tr>
<td>ALDES</td>
<td>Interview with several experts, source books, rules and regulations</td>
<td>Productions rule have been used to represent knowledge in computer</td>
<td>Induction adopted to find mathematical formulas from past cases, deduction applied to reach goals from rules and cases.</td>
</tr>
<tr>
<td>Ship systems operation ES</td>
<td>Classification societies, shipping companies and shipyards</td>
<td>Rule-oriented knowledge representation and MS Access to develop a database</td>
<td>Decomposition is utilized Case based reasoning to search existing ships and match appropriate results</td>
</tr>
</tbody>
</table>

Table 3
Explanation and user interface facilities in sample ESs

<table>
<thead>
<tr>
<th>Expert system</th>
<th>Inference</th>
<th>Explanation</th>
<th>User interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPOPS and SPACE</td>
<td>PROLOG forward chaining mechanism</td>
<td>Written description of the each step and graphs to illustrate the spatial layout</td>
<td>System returns the information of boundaries, if it is asked</td>
</tr>
<tr>
<td>Container ship ES</td>
<td>Backward chaining is used with a depth-first search mechanism</td>
<td>User is able to question the reasoning</td>
<td>Advice can be given to the user to provide design</td>
</tr>
<tr>
<td>OSV–OSVDP–OPTOSV–MOSVOP–MOSVCF–MOSVBR</td>
<td>Backward chaining for design and backward chaining for repeat the activity</td>
<td>Leonard ES shell answers why and how questions</td>
<td>Program permits to interact and control design. Corrects the user if incorrect data is input manually</td>
</tr>
<tr>
<td>Fishing vessel design ES</td>
<td>Searches the system for a solution to the problem, backtracks if necessary</td>
<td>ECHIDNA interacts with the user and explains its reasoning</td>
<td>Warns the user if a major rule was broken by the user</td>
</tr>
<tr>
<td>Compartment layout design</td>
<td>Forward chaining for design and backward chaining for repeat the activity</td>
<td>Facilities of the shell</td>
<td>Application of programming interface module allow user to communicate with the system</td>
</tr>
<tr>
<td>MADES</td>
<td>It is a design problem, starts to set most important objects and ends with less important ones</td>
<td>Facilities of the shell</td>
<td>All kinds of jobs are visualized and defined by graphical user interface</td>
</tr>
<tr>
<td>ALDES</td>
<td>Uses CLIPS forward chaining mechanism</td>
<td>CLIPS facilities</td>
<td>CLIPS and DELPHI facilities</td>
</tr>
<tr>
<td>Ship systems operation ES</td>
<td></td>
<td></td>
<td>Different program facilities</td>
</tr>
</tbody>
</table>

Most of the ESs reviewed here have utilized the knowledge freely available in the regulations. The format of such knowledge sources is not suitable for ES development. Hence, main bottleneck with such sources is how to derive the required knowledge and convert into a useable format. Additionally, most of such knowledge is in the form of performance requirements or final product attributes, this enforces the ESs into organize in a backward chaining inference. There is a large amount of research need on how such regulative knowledge can be converted into ES knowledge-base.

Knowledge elicitation from past cases is utilized quite frequently. Most of the literature work utilizes past cases by employing empiricism. The attributes of the previous designs are converted into empirical form and readily utilized afterwards. There is very little about the how previous cases have been conducted, and experience with the process of design rather than product has not been fully explored yet.
Main bottleneck in ES development is knowledge elicitation from the experts. Interview is a common form of publication reviewed here. However, there is no information available on the difficulties and techniques of how such interviews are conducted. Considering the variety of product types and experience depth of individual experts, this method is open to serious setbacks. The problems associated with cooperation of the experts, the expression ability of the expert, utilization of multiple experts to complete required knowledge, conflict resolution for a single or multiple experts are still to be solved. There is a need for further research on the techniques of knowledge elicitation for design process of large engineering units which are usually unique and designed by different designers due to long process of the activity.

4.2 Knowledge representation

Knowledge representation means organization and storage of the knowledge for ES usage to solve the problem in the computer. The choice of technique used to represent the knowledge associated with a subject depends largely on the nature of the problem under consideration, on the format and on the structure of the available knowledge. Knowledge representation is a substantial subfield in its own right, which shares many concerns with both formal philosophy and cognitive psychology. It is concerned with the ways in which information might be stored and associated in the human brain, usually from a logical perspective (Jackson, 1999).

Knowledge obtained from regulations such as SOLAS, MARPOL, etc., are in the form of required attributes of the system such as performance limits, or required equipment related to the size and function of the product. Such product attributes can be defined as goals, and cannot be readily used in the design process. Meanwhile, knowledge from experts is in the form of production rules which shows how such goals can be obtained from the current state of product attributes. The knowledge from previous cases is usually expressed as empirical formulation or frames of knowledge. Due to variation of knowledge types from the knowledge elicitation techniques, a difficult process of knowledge representation for each ES has to be performed.

In SPACE ES, different type of knowledge is used to define the model such as commonsense spatial knowledge, the spatial arrangement designation and the operators to create and manipulate the model. All these knowledge seek different representations. Object-oriented classification is used to define the entities of a space. There is a relationship between objects of the same class and the attributes of objects may be numerical values or symbols.

The relationships and attributes of the commonsense spatial knowledge is defined as general as possible in order to infer new instances based on the existing knowledge. PROLOG convention is used to represent relationships and attributes in the computing environment. In SPACE ES, the spatial arrangement model is implemented as a number of multi-argument atomic clauses, each of which represents an instantiation of an object, attribute or relationship. In the system, some operators are defined to create and manipulate the solution model and provide the user with information about it. The operators themselves contain a body of knowledge, which defines how to perform a sequence of actions on the spatial arrangement model (Green, 1989). Operators include assumptions about an object.

The knowledge representation language is developed to form part of the INCODES shell, which provides a user-friendly means of representing various types of knowledge (Welsh, 1989). The structure and syntax of INCODES knowledge representation language provide a high degree of flexibility in the knowledge-base creation applications. The representation system permits the user to customize the syntax of the knowledge representation language.

OSV designed ES uses the knowledge representation facilities of ES package, Leonardo, which has two main knowledge representation facilities as production rules and frames. The rules represent procedural knowledge and they are used to assign values to text, numeric and list objects; invoke screens and execute procedures written in Leonardo's procedural programming language (Mainal, 1993). A frame is associated with each object that is used in a rule. The information held in a frame specifies the source of the object's value, its certainty in addition to any associated text including prompts and explanations. Objects can be organized into classes with user-defined attributes.

The artifact can be seen as a complex system with an inherent hierarchical structure. The top level represents the entire system whereas the bottom level has the parts and pieces, which make up the various components (Akunturk, 1997). Concerning these points ECHIDNA supports object-oriented programming for easy design modelling. Objects are used to represent both physical identities such as the vessel itself and its components. In Echidna ES, shell represents the collection of bottom level objects instead of the whole object. It also allows the general constraint representation inequalities, which are different from traditional ES programs that allow usually only representation of equalities. Declarative representations such as the length of the ship in metres are common in design knowledge representation.

Usually, hybrid representation techniques are utilized in ESs. Lee and Lee (1997) divided compartment layout design knowledge into four categories, which are knowledge for initial value determination, section type determination, design evaluation and design change. The main part of the knowledge is represented by IF-THEN rules, which are based on the pre-description of objects These rules contain some kind of information and application programs to perform the design evaluation (Lee and Lee, 1997).

On the other hand, design knowledge is represented by an object-oriented concept in MADES ES, where the objects are classified in three types and the model is based on these types. They are physical objects, spatial objects and design constraints. Physical objects are the actual objects such as the main engine and the equipment. Spatial objects are the whole or part of the space in which the physical objects are arranged. Finally, design constraints include the conditions, which must be satisfied by the topological relations between the spatial and the physical objects (Lee et al., 1998).

A container ship design knowledge-base can be extracted from domain experts. The rules and regulations from the source books are used to complete the knowledge-base. The heuristic knowledge of experts is represented as production rules.

ES for computer aided design in ship system automation is adopted as a rule-oriented knowledge representation technique, which is supported by the ES program. On the other hand, MS Access software is used to develop a database of equipment, elements and systems automation of ship and requirements of classification societies.

Common forms of knowledge representation are heuristic production rules, objects sometimes arranged as classes, and facts defining current state of the attributes. There is some difficulty combining the knowledge represented with such forms and procedural knowledge required in the maritime design process such as stability calculations, powering calculations, strength assessments. Most of the publications reviewed here combine an ES language or shell with a procedural calculation platform such as FORTRAN, Pascal routines. Such an interface appears to be a necessity of the domain. The interface and division of process
between inference system and procedural system should be further investigated as it may move ES into more procedural approach if procedural process is more pronounced. The opposite approach would make ES more heuristic and unrealistic if procedural knowledge is ignored. The knowledge representation for procedural and heuristic parts are usually different due to the nature of the problem, this also bring another unsolved issue such as how knowledge representation can be synchronized.

4.3. Reasoning

There are three different logical reasoning mechanisms as deduction, induction and abduction. Logical deduction is the principle mode of reasoning and if cases and rules of the system are known, then the result can be achieved. Logical induction solves the problem starting from result and cases to find out the rules. Finally, abduction can be used to find out cases from rules and results.

Historical data from existing ships are used in statistical analysis forms. Induction reasoning method is adopted to improve some mathematical formulas from cases to derive the main dimensions in ALDES. Deduction reasoning method is used to achieve goals from cases. Decomposition is applied to divide the ship into manageable parts to be coded on the design point of view.

On the other hand, there are three types of knowledge in SPACE, namely, domain knowledge, problem solving knowledge and commonsense knowledge. They are represented in a formal way in the computer environment and requirements are inserted into the system as facts. The knowledge is defined to allow the model towards a spatial arrangement to be represented in non-geometric terms in a way, which allows some reasoning to occur (Green, 1989). The system reaches at a solution in a spatial layout problem by employing logical deduction reasoning.

INCODES system provides a unique combination of synthesis and analysis procedures, which enable design proposal developments at a detailed level, where the system is considered as unique. This is achieved by structuring the various procedures in such a way that the underlying theory is transparent to the user. MAINAL (1993) generalized OSV data to get empirical equations to estimate the main dimensions. This type of logical reasoning is induction, where the cases and results are used to find out rules for the problem, which includes the calculation of the main dimensions of offshore supply vessels in OSV ES program. For the problem solution, he considered the vessel into manageable decompositions and developed different programs to solve each one of them. If the rules and the cases are used to calculate the main dimensions then such a logical reasoning is referred to as deduction. In the offshore supply vessel design ES, optimization of the design is added to the system to calculate main parameters.

In ECHIDNA system, partial designs must be proposed first, then integrated into the evolving solution and their suitability is evaluated under design constraints. The system must be able to investigate proposed solutions and return to an earlier solution if a proposal is infeasible. The integration of partial design is controlled by rules.

Non-monotonic reasoning in ESs allows the systems to make decisions and take actions based on incomplete information and makes revisions according to the environment changes (Lee and Lee, 1997). This reasoning uses If-Change (IC) method in this system and it lists a series of actions to be performed after the slot value change (Lee and Lee, 1997). The same reasoning enables the system for design changes according to the design conflicts satisfaction.

In the performance of many functions of the ES for the design of ship system automation requires the use of information stored in the database of existing ships (Kowalski et al., 2001). Here, case-based reasoning method is adopted to search for the existing ships in order to match the case.

Reasoning mechanisms are well established, but utilization of such approaches has not been documented in detail.

4.4. Inference

The inference engine is a mechanism in the ES which uses the knowledge stored in the knowledge-base in order to solve a specific problem. The inference engine contains two components—the inference and the control. The inference component works on the simple assumption that if the condition of a rule is true then the associated conclusion must also be true. The term ‘control’ is used collectively to describe the procedure which an ES uses to find its next piece of information. The inference engine uses one of two methods of reasoning, backward chaining or forward chaining. The another facility of inference engine to achieve a goal is the search strategies. There are several common strategies used in ES.

An ES is developed in a logic programming environment, which takes the advantage of inference engine and control mechanism of the language. A human designer starts to design an artifact from temporary design; evaluates the design prior to any change, and repeats the above process for the completion. The process requires forward chaining for design and backward chaining for repeating the activity.

In SPACE, PROLOG inference mechanism is used to infer new values for attributes and relations. The general definition of attributes is allowed to use the computer program. The system uses the facts and knowledge, in other words starts from the facts and ends up with a solution or finds the goal state. This type of reasoning in an ES is called forward chaining.

The INCODES ES shell controls the methodology of the design process and decides which information is required from the user at any given time. The system gives the opportunity to the user to make every required modification. Any assumption can be overruled and new values are supplied. The ability of INCODES to interface easily with graphical procedures greatly increases the effectiveness of any application (Welsh, 1989). The system permits access to external routines written in high level languages, which increases considerably the application capabilities.

Leonardo ES package supports backward or forward chaining but the default inference mechanism is backward chaining. The system looks for the rules with the goal objects as the final conclusion and attempts to satisfy them in a depth-first manner. Iterative processing of rules is available and the uncertainty in rule processing is treated by either Bayesian probabilities or certainty factors. With Leonardo, applications can be developed in stages, since rules can be written and tested in discrete sets and they are merged subsequently (Mainal, 1993).

The ECHIDNA system searches for a solution but upon any failure it backtracks to the most recent choice point and selects a different alternative, which may not resolve the problem (Akintürk, 1997).

In MADES, the layout design problem is defined as assigning physical to spatial objects under given constraints. This system works starting from facts and objects and ends up with a product based on the forward inference method. It is also able to go back during the design stage and do the required modifications such as changing the location of main engine.

ALDES system is developed for design assistant where the design achievement is possible from the case to an end product by forward chaining search strategy.

Ship system automation ES program is based on a shell that supports backward and forward chaining, which handles
uncertainties by reasoning through fuzzy logic and possibility of co-operation with other software and databases.

As it is discussed in the previous parts, the knowledge acquired from different sources are different forms, e.g., goals from regulations, production rules from experts, facts from requirement specifications. It is not a straightforward choice to utilize a forward chaining or backward chaining system.

The inference about geometric attributes of a product especially geometric arrangement with hard and soft boundaries may present an ill-conditioned layout process. The priority and conflict resolution scheme is extremely important and needs further research.

4.5. Explanation

Explanation facility gives the reasoning of the system by a user on the basis of the rules. In SPACE system, at each step during the model development, a written description of the application result is followed by actual interaction between the system and user (Green, 1989). On the other hand, an appropriate graph is illustrated to improve understanding of the spatial layout development. In the INCODES system, the user is able to question the reasoning behind the assumptions and to examine the various lines of reasoning. Leonardo ES package is able to answer how? and why? which are expected from an ES program. ECHIDNA system interacts with the user and explains its reasoning. CAD provides graphical interface facilities, which are used as explanations in MADES. ALDES ES is based on CLIPS and its explanation facility. Every ES shell should have an explanation facility. ESs with several programs must have a very powerful user interface and explanation facility. The user must understand the reasoning of the system properly (Kowalski et al., 2001).

The regulations must be satisfied with a maritime ES in addition to heuristic rules. Such requirement is an expected attribute of the explanation facility, but most of the reviewed ESs do not satisfy this requirement due to complexity and frequent updates of the maritime regulations.

4.6. User interface

It is the mechanism by which the user and the ES can communicate. User can ask questions about the space in SPACE system and facts about the boundaries and the system will return the information.

Advice can be given to the user who is involved in the knowledge-base to provide guidance. The graphic capability of the INCODES enhances both flexibility and user interface aspects of the design system.

OSV program has several facilities that permit the designer to interact with and control the optimization process. The user can go back in the program to any previous design or manually input a new trial design. The software also identifies and helps the user to make corrections in the case of improper responses (Mainal, 1993).

ECHIDNA system allows the user to interact with the program in the design process. Additionally, the system warns the user if he/she breaks a major design rule.

Structural model definitions for the layout design of ship engine room can be prepared by the user through graphical user interface (GUI) in MADES, which helps to visualize all kind of jobs such as ship hull generations. The generated location of design objects are transferred to the CAD system for display.

Ship compartment layout design program is a complex system including a case base, a knowledge-base and a ship basic calculation program. All these programs communicate with each other and the user might understand the system. Application programming interface module allows the user and the programs to communicate each other in compartment design ES (Lee and Lee, 1997).

The objectives of MADES are effective accumulation and usage of the machinery layout design knowledge in general purpose CAD system environments (Lee et al., 1998). So, the user is able to communicate with the ES by using CAD program visual facilities.

In ALDES system, the communication of the program with the user is provided by using DELPHI, Pascal-based visual programming program.

Ship systems automation ES uses a number of computer programs to achieve the goal. User interface facility of the program interferes with the user for better designs, where the application thus created is a convenient and user-friendly tool (Kowalski et al., 2001).

Most of the ES in maritime field involves geometric layout problems which in turn require CAD capability of the ES. Some of the ESs interfaces with CAD programs to satisfy this requirement, this is a very important facility to check whether hard and soft boundaries are complied with.

5. Conclusions and recommendations

ES applications are a broad category of research issues and attracting much attention and efforts of academic and practical. Some of ESs are presented in Liao (2005), not including marine technology applications, showing how broad the application area is. Several sample ESs are investigated in this paper in order to assess the suitability of ES in marine technology field.

The application of ESs into ship design is not thoroughly investigated, because of its complexity in knowledge representation. In engineering disciplines in which the work breakdown structure can standardized and utilized several times, ESs are utilized successfully such as automotive, aircraft industries. Ship as a product is not standard, every ship type and size requires different work breakdown structure. This can be overcome by class-oriented tools rather than object-oriented tools. Once classes of ship equipment are defined new instances, objects, can be derived from the classes. This morphology has not been applied successfully to ship design ESs as yet.

In addition to design problem, design approval can be dealt with ESs. The complexity of current rules and regulations is very large for a single person to apply. Instead of teams of expert checking individual parts of rules and regulations, ESs can be utilized. However, such ESs requires the full design to be represented in computer environment in detail to check whether the required rules and regulations are satisfied for a given design. Lack of standards on design representation is the main obstacle for such development.

Knowledge elicitation is probably the greatest problem for the ship design ESs. Case-based reasoning methods (CBRs) have been found very efficient way of knowledge elicitation. However, the application of CBR has been very limited due to the lack of standard representation of ship designs.

Shipbuilding centres have been shifted from developed countries, such as Germany, UK, etc., to newly developing countries such as China, Vietnam, and Turkey, etc. Such movement has resulted in a loss of expertise especially on production planning, detail design, work instructions, etc. These tasks are performed by experts and labour intensive. Automated generation of these tasks from design description can facilitate shipbuilding in the newly developed areas.

ESs are useful to develop multiple solutions; several methods such as fuzzy logic could be adopted into these systems to solve...
the selection or optimization problems. Robust design approach is becoming more important than ever as fuel, steel prices are very volatile. Mathematical optimization solutions are very sensitive to these issues. Hence, ESs can lead more robust compromised design solutions instead of ill conditioned optimized solutions.

Shape generation and location is another problem which could be integrated to improve ESs. Geometrically defined ESs with hard and soft boundaries would increase the efficiency of ship design systems. Visualization tools such as VRML (Virtual Reality Modelling Language) could be integrated to ESs to represent the end product.

Different works in the literature suggest that ES can be applied to several subjects in marine vehicle design. Unfortunately, there have been a number of difficulties originating from the nature of highly regulated, one-off design features of the maritime domain, resulting in very few works in the field as it is pointed in this paper. In fact, knowledge acquisition, representation of knowledge from multiple sources, assembling of different types of knowledge, interfaces with CAD facilities, coordination with procedural knowledge/programming are the main bottlenecks of developing an ES in maritime domain. Such setbacks have slowed down the development of ES in maritime field. However, development of ESs has large potential effect in the field, as knowledge management is becoming a tremendous task due to large number of regulations, and loss of expertise with globalization.

References


