CAPTURING EXPERTISE IN MARINE REGULATIONS ON A KNOWLEDGE-BASED SYSTEM

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Knowledge based expert systems have wide applications in the fields of Engineering, Medicine etc. and have the capability of finding solutions to complex problems by searching or manipulating large knowledge bases. By using CLIPS Object Oriented Programming Language (COOL) a prototype expert system was developed to capture the regulations of Annex I of MARPOL 73/78 Convention. This will enable the user to find the regulations applicable for a particular case accurately and speedily.

INTRODUCTION

Conventions of the International Maritime Organization such as SOLAS, MARPOL, STCW, Load Line etc. play a very important role in various aspects of the marine industry. These conventions have become the basis for the Maritime Legislation of member nations of IMO, guidelines for the ship building, operation and manning and have the final objective of achieving the safety of shipping and environmental protection. To meet the increasing complexities of ship building, operation, manning and, additionally, due to the growing need for the prevention of marine pollution, the International Conventions are becoming elaborate and complex documents. As a result, finding applicable regulations in many cases is invariably, a daunting task for many who are not familiar with these regulations.

Lack of sufficient knowledge of Maritime Regulations has resulted in many problems in the shipbuilding industry, specially in the oil tanker building, and in the operational aspects of shipping. Shipbuilding yards who forward design plans to the classification society for approval sometimes commence the building activity because of the tight delivery schedule, before the design plans are approved but later find to their dismay that the plans require substantial changes as a result of new or amended regulations. This type of error can be very costly. Similar problems can occur in the areas of survey, operation and manning of ships.

Presentation of Maritime Regulations in an easily accessible manner by using a Knowledge-based Expert System will provide help to the personnel in the maritime industry in seeking the applicable regulations to a particular case or

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instance without screening through series of conventions. It must be pointed out that the Knowledge-based Expert System incorporates the expertise of the Expert(s) in various IMO conventions and his(their) ability to sort the regulations together with the knowledge-base which stores the regulations.

Annex I of the MARPOL 73/78 Convention, which is considered by many as one of the complex documents, was chosen for the development of the Prototype Expert System on an experimental basis.

Present status of MARPOL 73/78

The International Convention for the Prevention of Pollution ships, 1973, as modified by the protocol of 1978, widely known as MARPOL 73/78 Convention, deals with the aspects of pollution prevention by specifying the standards of construction and survey, types of equipment, documentation and the regulations concerning the operation of ships. The Convention consists of five annexes and these contain the regulations for the prevention of pollution by:

- Oil (Annex I)
- Noxious Liquid Substances in bulk (Annex II)
- Harmful substances carried in packaged form, freight containers, portable tanks or road or rail wagons (Annex III)
- Sewage (Annex IV)
- Garbage (Annex V)

All annexes except Annex IV are currently in force.

Subsequent to the adoption, several amendments to the convention have been made by Protocol I (Reporting of incidents involving the discharge of harmful substances), Protocol II (Establishment of an Arbitration Council) and by several other Marine Environment Protection Committee (MEPC) Resolutions.

Recent important amendments to the Annex I of the convention include:

- the requirement of double bottoms and double hulls extending the full length of the ship's side for tankers of 5000 dwt and above ordered after 6 July 1993;
- an enhanced programme of inspections that will apply to all tankers aged five years and above;
- mandatory fitting of double hulls or an equivalent design for tankers of 25 years of age and above;
- the requirement of an Shipboard Oil Pollution Emergency Plan approved by the Administration;
- new limits on the discharge of oily water mixtures.

Knowledge-based Tool Used and Method of Object-Oriented Implementation

A knowledge based expert system requires a storage of data (knowledge) to be used for the decision making and for the presentation of the required output.

The knowledge-base tool used was FuzzyCLIPS Version 6.04 (1995) of Institute for Information Technology, National Research Council, Canada. This is subset of the famous CLIPS Version 6.0 expert system shell, developed by NASA at the Software Technology Branch of the Johnson Space Center, Texas, USA in 1993.

Object oriented methods are used to represent the knowledge-base using COOL (CLIPS Object Oriented Programming Language). Object oriented programming (OOP) provides the natural way of representing real world objects, which is similar to a frame structure (Durkin, 1994).

Each object can have declarative knowledge to define the static characteristic of an individual object, while there is also scope for procedural knowledge representation in the form various message handlers (Giarratano, 1993; Lyndon B Johnson Space Centre, 1993). A message-handler represents the dynamic characteristics of an individual object. The knowledge is encapsulated in the object and its message-handlers. In the case of production system, the knowledge is scattered around in the form of various rules. Additionally, the use of inheritance greatly speeds up development process and pattern matching through the instances can handle the same class handlers. Use of polymorphism allows the same command to behave in a different way to suit the individual characteristics of a particular class. The knowledge is processed by messages sent by message-handlers.

The object-oriented method of knowledge representation is shown in Figure 1.0 Reference to the figure, slots and facets represent the declarative or static knowledge of the object. However, slots can also be written with messages and thus, quite capable of representing dynamic knowledge. Message-handlers 1 and 2 of abstract class A are inherited by sub-classes or child-classes B and C. Additionally, class B has its own message-handlers 3, 4 and 5 and class C has its message-handler 3 and 4. Class D has no super-class or parent class and has its own message handlers 1 and 2. Message handlers send or receive messages between instances and also communicate with the user (keyboard input, screen output) to process knowledge. Query system in COOL was also used to pattern-match from the set of instances.

The implementation of MARPOL ANNEX I is shown in figure 2.0, which shows the overall structure of the objects, their slots and message handlers, which define their properties and behaviours. The class instances are also shown.

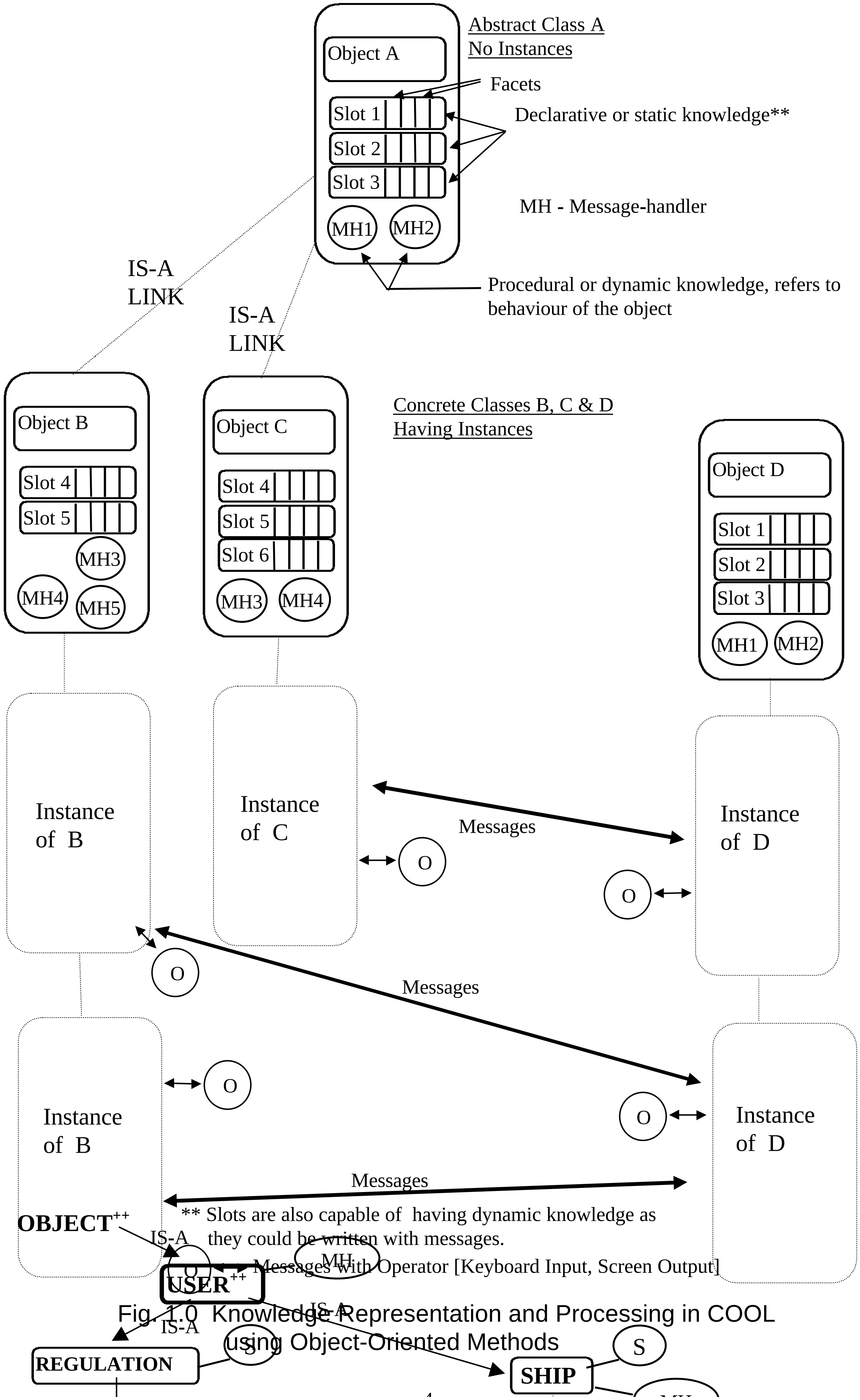
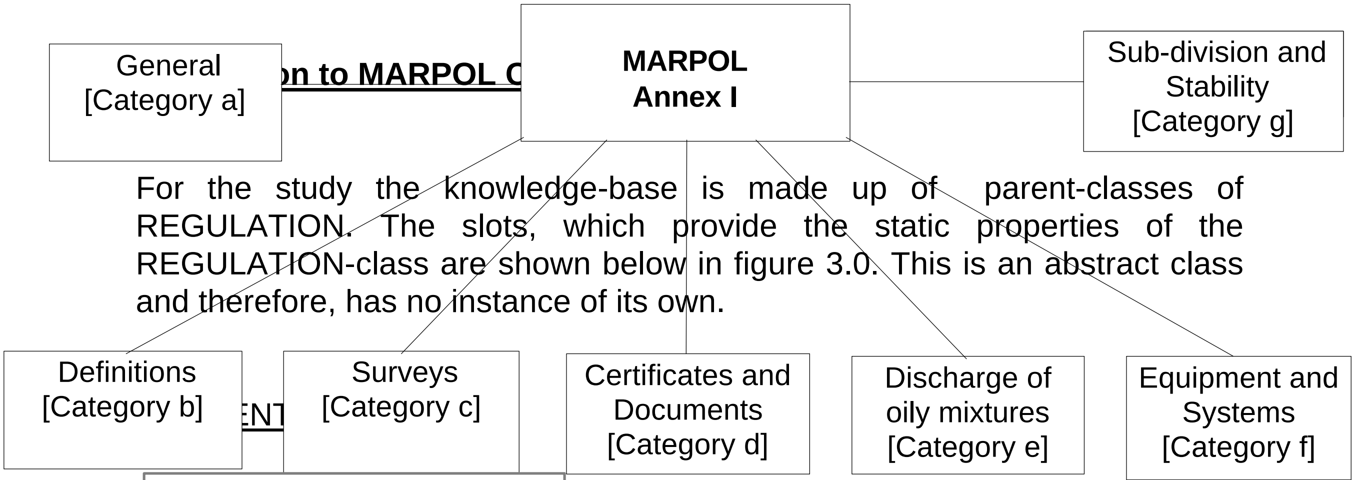


Fig. 1.0 Knowledge Representation and Processing in COOL using Object-Oriented Methods



For the study the knowledge-base is made up of parent-classes of REGULATION. The slots, which provide the static properties of the REGULATION-class are shown below in figure 3.0. This is an abstract class and therefore, has no instance of its own.

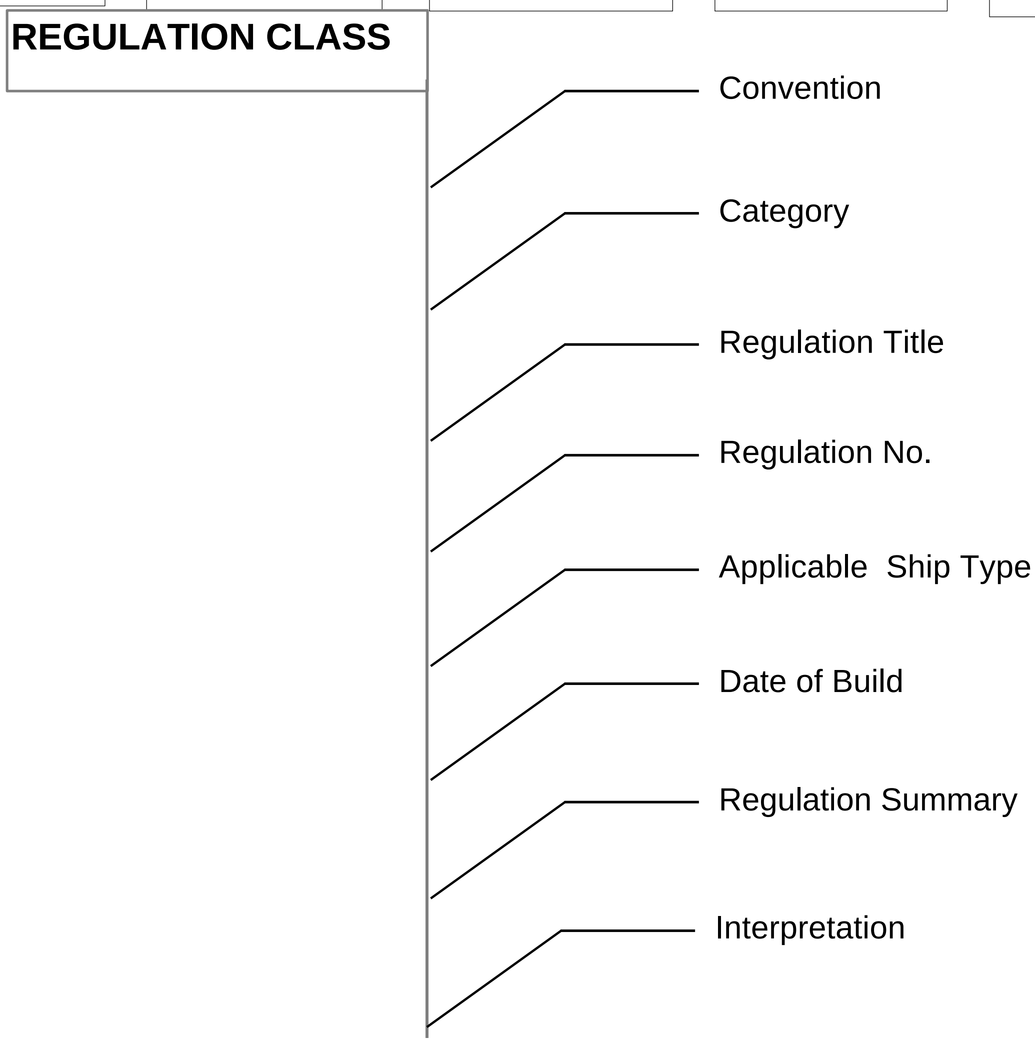


Fig. 3.0 Parent-class REGULATION with its slots.

REGULATION-class has seven child-classes of CATEGORIES as shown in the Figure 4.0. This essentially partitions the main search space of the knowledge-base, facilitating reduction of average seek time. This is a concrete class, which means it has its own instances.

Fig. 4.0 Child-class CATEGORY a, b, c, d etc. with its slots.

The child-class CATEGORIES have the instances, which store the summary regulations of ANNEX-I. For this study there are 48 instances. The instances under CATEGORY e, which is “Discharge of Oily Mixtures” are shown in figure 5.0.

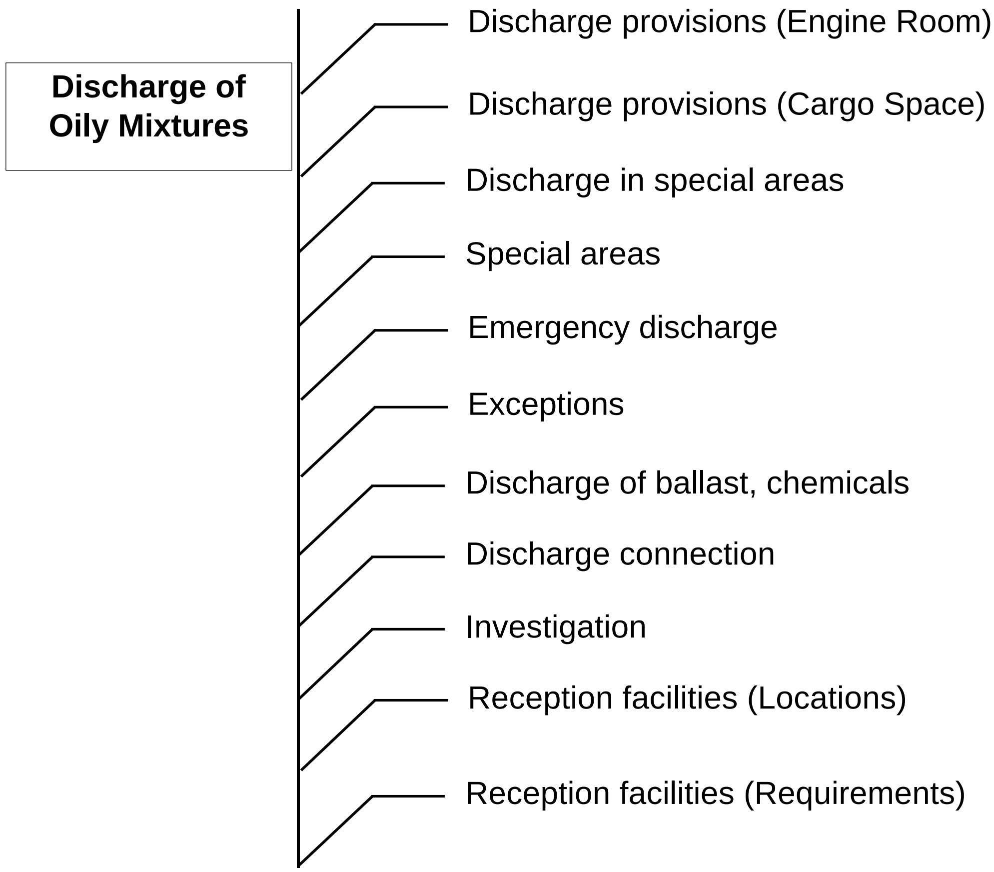


Fig. 5.0 Instances of CATEGORY e

MARPOL 73/78 Convention is applicable to all types of ships but the regulations applicable different types of ships may be different. Further, the applicable regulation may vary according to the tonnage, age, tank arrangements etc. Therefore, the ship is to be properly defined according to its type, tonnage, age etc. and the figure 6.0 shows the SHIP-class with its slots. The SHIP-class is a concrete class and instances of the SHIP-class provide the user-defined vessels, for which the applicable MARPOL ANNEX-I regulations are sought.

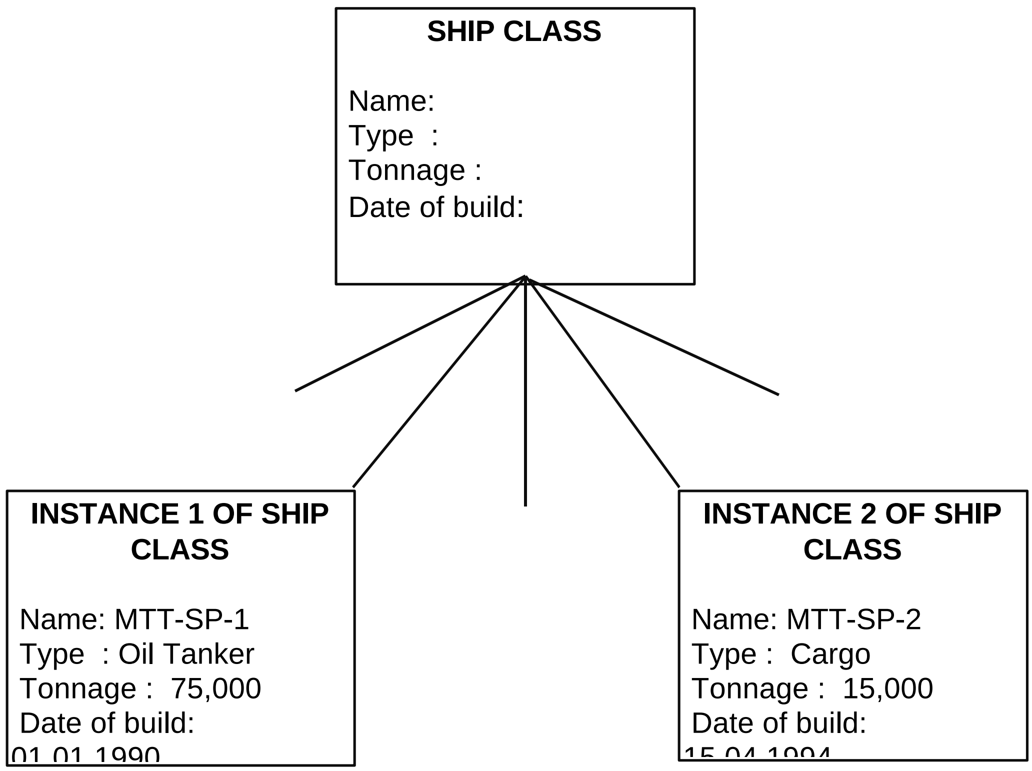


Fig. 6.0 SHIP- class and user-defined instances

User-input and Knowledge-Processing

The operation of the expert system will first involve the selection of the ship class instance from the data base by typing the ships name or inputting the data to create an instance of the ship class. Thereafter, the user is expected to select the category of the regulation out of the seven categories displayed on the screen. The screen will then display the regulation titles under the chosen category and the user can select the required title. The message handlers of the expert system have been then programmed to read the information in the instance of the ship class and the chosen regulation title and do the pattern matching with the instances of the regulation child-class under the chosen category. The summary regulation and its interpretation, if any, will then be displayed on the screen.

The complexities of regulations are captured in the regulation child-classes where a normal user of MARPOL will find it difficult to choose the applicable regulation. For example, regulation 13 of Annex I on SBT, DCBT and COW is applicable to oil tankers of different dead weight tonnage and different age, differently. One of the message handlers for the SHIP-class is shown in figure 7.0 below, handling the category c.

```
; Message_handler-8 {SHIP-class}          [primary]
        (defmessage-handler SHIP CATEGORY_c ()
                (printout t  crlf "Category  SURVEYS {choose from the following
list}" crlf crlf
               "For example, enter 'a' or 'b' or 'c' ..... and <Return>: " crlf crlf
               "a]  Type of Surveys and Intervals" crlf
               "b]  Ships below Convention Size" crlf
               "c]  Surveyors" crlf
               "d]  Conditions of  Survey and Certification " crlf  crlf)

                (bind ?CATEGORYc_key (send [User_Defined_Vessel] get-
CATEGORYc_key))

                (if  (eq ?CATEGORYc_key  a) then
                                (bind ?CATEGORYc Type_of_
Surveys_and_Intervals))
              (if  (eq ?CATEGORYc_key  b) then
                                (bind ?CATEGORYc
Ships_below_Convention_Size))
              (if  (eq ?CATEGORYc_key  c) then
                                (bind ?CATEGORYc  Surveyors))
              (if  (eq ?CATEGORYc_key  d) then
                                (bind ?CATEGORYc
Conditions_of_Survey_and_Certification))

                (printout t
               "{Present Default}" crlf  "Reg. in Suveys Category = "
?CATEGORYc crlf crlf)
              (printout t "{Enter change and <Return> or N and <Return> for no
change}: " )
                (bind ?CATEGORYc (read))

              (if (neq ?CATEGORYc  N)  then  (dynamic-put
CATEGORYc_key  ?CATEGORYc)
                crlf crlf)
                (send [User_Defined_Vessel] print-user-entry-form ))
```

Fig. 7.0 SHIP- class message-handler for an input routine

Conclusion

A knowledge based expert system by using an object oriented programming language can be successfully implemented in modeling complex documents such as MARPOL 73/78. Although, only the summary regulations in a concise form are incorporated in the expert system at present, full and accurate regulations can be included with improved sorting capabilities, so that the expert system on MARPOL will be a valuable tool to surveyors, shipbuilders and operators.

References

1. MARPOL 73/78 Convention, Consolidated Edition, 1991.
2. Durkin, J., 1994, *Expert Systems - Design and Development,* Macmillan Publishing Company, New York, USA.
3. Giarratano, J. C.,1993, *CLIPS User's Guide,* Houston, TX:NASA, Lyndon B. Johnson Space Centre, Information Systems Directorate, Software Technology Branch, Texas, USA.