Knowledge-based System Development Processes in a Maritime Regulatory Domain

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ABSTRACT

Application of knowledge-based technology in maritime domain will help us in information management, capturing experience and provide a shorter learning time for new skill acquirements. A pilot project using this technology is recently undertaken by Det Norske Veritas and Maritime Technology & Transportation Department of Singapore Polytechnic. This paper describes the initial experience of the development team.

1. INTRODUCTION

Over the years, classification rules, the SOLAS Convention, its Protocol and Amendments, have become increasingly complex and elaborate. Prior to actual building of a ship or undertaking of a conversion/ retrofit, the relevant designs are submitted to Det Norske Veritas (DNV) for approval. The approval engineers use their expert knowledge, developed over a number of years of training to check through the submitted drawings and documents against compliance to these regulatory requirements. This is a demanding task, where information management and past experience are key issues influencing the job performance. We have identified a need for a knowledge-base system (KBS) interface to enhance such guidance and information management. This software tool is envisaged to improve experience transfer at the DNV's approval centres. A knowledge-base system, “KBS for Design Approval of SOLAS Elements in Oil Tankers” has been selected as a pilot project to investigate the viability of developing large scale KBS for information management in the maritime regulatory domain. The work is jointly undertaken by DNV and Maritime Technology and Transportation Department of Singapore Polytechnic (MTT). The project is at it initial stages and is sponsored by National Science and

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Technology Board of Singapore, Singapore Polytechnic and DNV. This paper describes some of the preliminary work done to establish the KBS framework and the associated risks and risk-management plans for the development .

2. A KBS for Design Approval of SOLAS Elements in Oil Tankers

For this pilot project the scope of KBS development is restricted to SOLAS Regulations relating to tankers. The KBS would be providing performance support at task level for the DNV's approval engineers. The knowledge-base developed would include the following:

a) computer-based information with access to reference information and case history databases wherever relevant,
b) learning experiences with access to realistic scenarios,
c) guidance/ support for decision making processes,
d) user-friendly interfaces providing proactive and reactive support to assist users in completing their approval tasks.

The project takes a two pronged approach for the KBS structure.

- Task segmentation to Regulation level. All approval tasks would be broken down to compliance of related SOLAS regulations. This is illustrated in Fig.1.

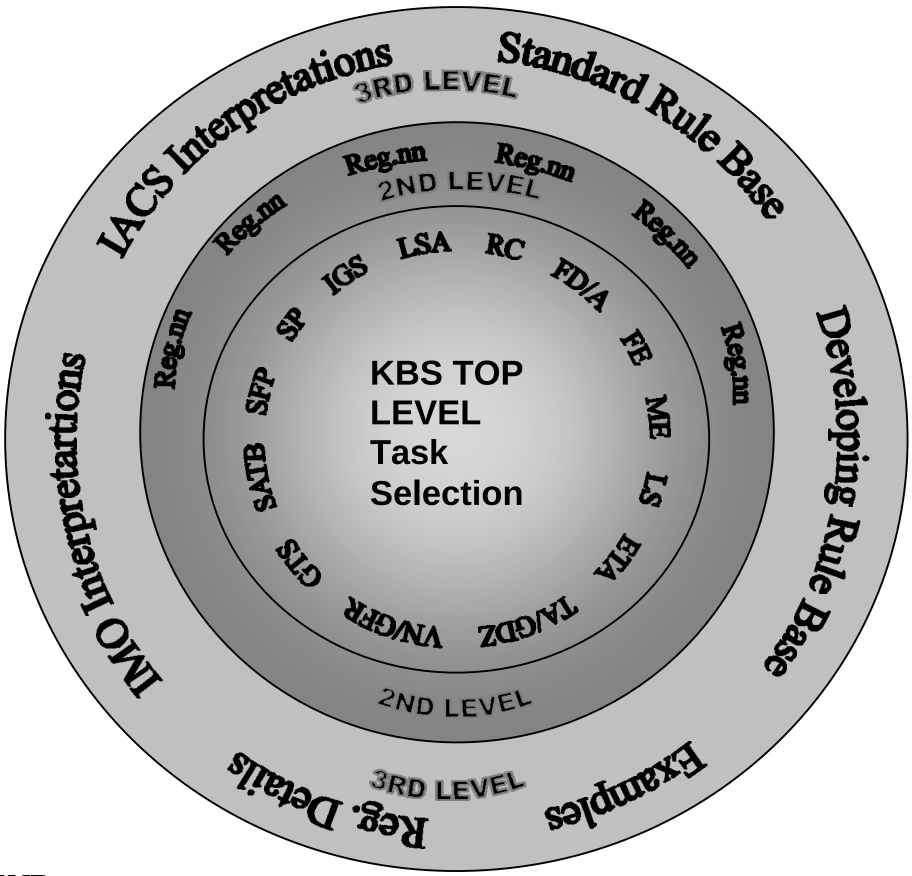
SOLAS related approval task for an oil-tanker

- Subtask 1
- Subtask 2 (Example: Structural Fire Protection)
  - Regulation 1
  - Regulation 23
  - Regulation 57
  - "
  - "
  - Regulation N
- Subtask 3 (Example: Means of Escape from different compartments)
- Subtask N

Figure 1. Task segmentation

- Additionally, approval tasks could also be processed using a rule-base. This rule-base is to be based on past approval experience. The rule-base would be called the STANDARD RULE-BASE. A dynamic component to the rule-base would also be available, which would capture the new problems and their approval processes as encountered over time. This would be called the DEVELOPING RULE-BASE. The components of the DEVELOPING RULE-BASE would be transferred manually to the STANDARD RULE-BASE from time to time after vetting.

The overall structure of the KBS at three levels is shown in Fig.2 below. Approval work is initiated at the top level by choosing one of the tasks (task details are given in the legend to Fig.2).



LEGEND
(Details of tasks at the top level)

LSA	Life saving appliances
RC	Radio communication
FD/A	Fire detection and alarm
FE	Fire extinction
ME	Means of escape
LS	Location of spaces
ETA	Emergency towing arrangement

TA/GDZ	Tank Arrangement/Gas dangerous zones
VN/GFR	Ventilation/ Gas freeing
GTS	Gas tight seals
SATB	Safe access to tanker bow
SFP	Structural fire protection
SP	Safety plan
IGS	Inert gas systems

Figure 2. KBS Structure at three levels

Once a particular task is selected, the related SOLAS regulations are identified at the 2nd level. At the 3rd level of KBS, the user can access the following for each regulation:

- Regulation details - these represent the surface level information and are called declarative knowledge. Declarative knowledge equates to "knowing that". This is book-based knowledge [SOLAS regulations] and it may not be directly related to the experts' cognitive foundations and concepts that they use to relate the information in a meaningful fashion for approval processing.

- IMO/IACS interpretations - these may represent semantic knowledge, providing inter-relationships which could help in identifying decision making procedures. Alternatively, they could also be declarative.

- Standard rule-base - these would form a rule base, attempting to capture the established procedures, which is already standardised in DNV's approval centres. These would most likely be procedural knowledge identifying routine procedures or tasks undertaken during approval processing.

- Developing rule-base -- these would form the dynamic component of the KBS, attempting to capture the new knowledge as it evolves while the approval engineers tackle and solve new problems during their day-to-day work. The approval engineers would be encouraged to enter the rationale for their decisions and relate the premises to the actions opted for. This developing knowledge-base would have to be vetted from time-to-time and the items found justified would be included in the standard rule-base. The KBS structure would be planned to allow for sharing of this developing knowledge-base among the approval engineers even before the vetting takes place. This could provide the following:

    - a conducive environment for capturing new experience,
    - a platform for cognitive interaction between approval engineers and
    - an opportunity to critique the new knowledge during the development stage.

This will make the new knowledge more robust by the time it is put up for vetting. Knowledge type for developing rule-base could be procedural, semantic or episodic.

- Examples-- provides past cases with diagrams, calculations and necessary support material. Examples would form the episodic information, relating past events and associating them with relevant aspects of the regulations.

3. KBS DEVELOPMENT STRATEGY

3.1 COMPARISON OF STRUCTURED DEVELOPMENT LIFE CYCLE PROCEDURES AGAINST PROTOTYPING APPROACH AND ASSOCIATED RISKS

The KBS project is being developed using a prototyping approach. In this section we relate the differences between traditional software engineering development strategies against prototyping and how we are planning to handle risks during the development stage. Major risks are envisaged during planning, knowledge acquisition and failing to exercise the re-use strategy.

Traditional methodology of developing of information systems is to use a linear structured development lifecycle (SDLC) as illustrated below.

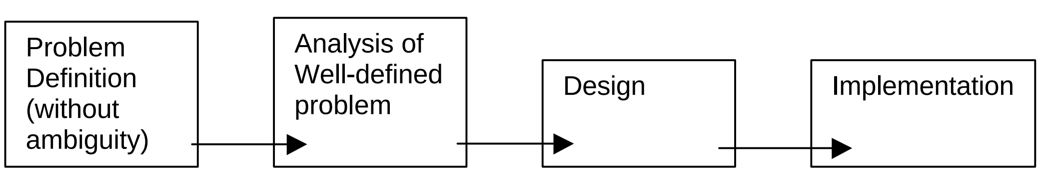
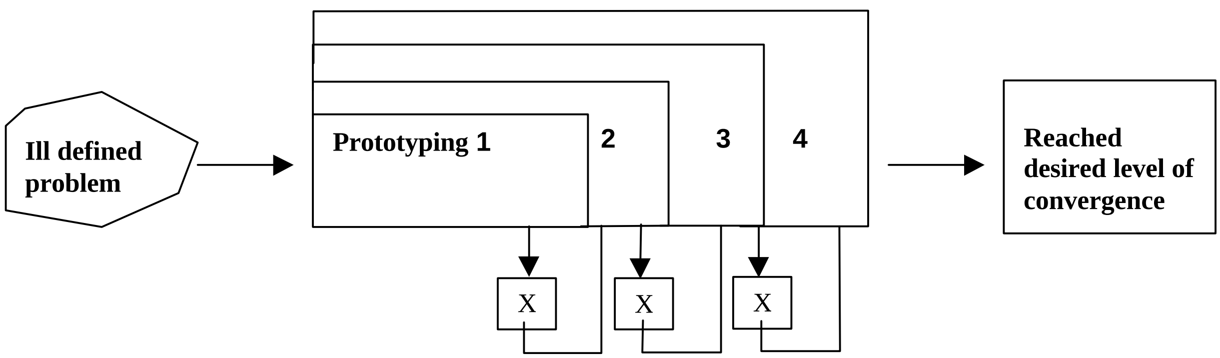


Figure 3. Linear structured development lifecycle

The fundamental assumption for the above lifecycle depends on the assumption that the system requirements are well defined and in the short term they are considered to be static. Based on these assumptions project milestones are planned and intermediate project deliverables are produced. The deliverables are then verified and evaluated for meeting the objectives as stated in the *clearly defined* requirement specification. Thus, these deliverables, delivered after completion of various intermediate stages, provide the necessary control and the management of the overall risk in the system development.

In KBS development, the requirements are not well defined. In such cases, a linear development methodology is not suitable. Instead a prototyping approach is normally undertaken. In a prototyping development process the system evolves through multiple stages of interaction between the KBS builder and the domain experts. This is shown in the following diagram.



Prototyping: CONCEPTUALIZE → FORMALIZE → IMPLEMENT → TEST

Conceptualize: KNOWLEDGE EXTRACTION → KNOWLEDGE REPRESENTATION

$\boxed{X}$: NOT REACHED THE DESIRED LEVEL OF CONVERGENCE

Figure 4. Iterative development process during prototyping

3.2 KNOWLEDGE ACQUISITION FOR CAPTURING DIFFERENT KNOWLEDGE ATTRIBUTES.

It is acknowledged that knowledge acquisition is the primary bottleneck for KBS development. Hence, techniques used for knowledge acquisition become important criteria for a successful KBS development. We are planning different techniques for capturing the various attributes of the knowledge. A description of our plan is given in Table 1.

Knowledge attribute	Declarative	Procedural	Semantic	Episodic
Scope of knowledge segment	SOLAS Regulations (considered as surface level information)	Heuristic task sequences and procedures undertaken by approval engineers	Concept based decisions in approval processes. (Interpretations based on relationships between concepts)	Experiential information that has been grouped or chunked by episodes. (Case-based decisions.)
Intended technique	1) Capture directly from public domain information 2) Interviews	1) Structured interviews 2) Process tracing 3) Simulations	1) Task analysis 2) Process tracing	1) Could be obtained from past records. 2) Process tracing

Table 1. Knowledge acquisition matrix

3.3 RE-USE OF COMPONENTS DURING KBS BUILDING

It is recognised that one of the main reasons for lack of dominance of KBS technology in information system development is lack of re-use during KBS building. To promote re-use as an integral process of our KBS development we have chosen a development platform of Microsoft Visual Basic (VB5) and Visual Rule Studio (VRS) of Rule Machines Corporation. Instead of using proprietary expert system development environment, this VB5+VRS platform provides an open architecture and lends itself to package rules into components reusable objects called RuleSets. By fully utilizing OLE and COM technologies, RuleSets act as COM Automation Servers, exposing RuleSet objects to any COM compatible client. RuleSets are presented not by static, cumbersome API, but are exposed as COM automation objects derived from the objects created within each individual RuleSet. Thus, each RuleSet exposes a unique object signature, which directly models the object behaviour of the specific RuleSet. Implication of this platform is the emphasis on reuse, e.g. re-use of SOLAS RuleSets for the tanker KBS being used for other types of vessels or re-use of the RuleSets for developing teaching software.

3.4 RISKS AT THE KNOWLEDGE REPRESENTATION STAGES

Knowledge extracted during elicitation stage is to be eventually represented into a meaningful knowledge structure. This is also seen as an area of considerable risk. The risks and risk reduction strategy is shown in the following table.

RISKS	INCURRED BY	RISK REDUCTION
Wrong formalisation to store elicited knowledge	Knowledge engineer	To be identified during testing of prototypes. Could be minimised by better interaction between knowledge builder and domain experts.
Right formalisation of knowledge, but not flexible enough to accommodate future structural changes in knowledge	System design engineers	To be identified during planning of prototype. Could be minimised by better interaction between knowledge engineer and system design engineers.
Right formalisation of knowledge, but not generic enough for reuse.	System design engineers	To be identified during planning of prototype. Could be minimised by better interaction between knowledge engineer and system design engineers.

Table 2. Risk management during knowledge representation

Additionally, the effectiveness with which the KBS meets the needs of the users will also be important criterion for assessment during prototyping.

3.5 REDUCING RISK DURING PROTOTYPE TESTING PHASE

In KBS development, the degree of convergence or divergence between the decisions made by an expert and while using the KBS should be carefully assessed during testing phases and the consequences evaluated as illustrated below. The process will identify the degree to which system captures the knowledge.

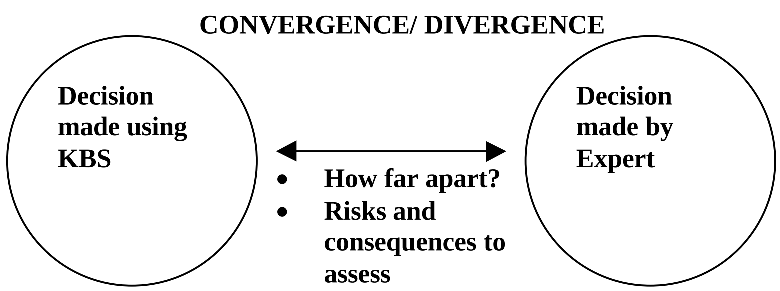


Figure 5. Risk assessment during prototype testing

4 CONCLUSION

Use of KBS technology in the maritime regulatory domain is seen as a possible trend to manage information influx, which is becoming increasingly complex and voluminous. Success of this trend would depend on how appropriately we apply this new technology to this regulatory domain and manage the associated risks. The pilot project described in this paper is an experiment in this direction. Experience gained from this pilot study could be used to develop a full scale maritime regulatory domain KBS or expert systems in other areas, e.g. heuristic fault-finding of machinery systems or ISM code management etc.

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