The Intelligent Tutoring System of an Engine Room Simulator

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Abstract

This paper describes an Intelligent Tutoring System (ITS) used for the DIS-based real-time Engine Room Simulator (ERS) at the Faculty of Maritime Sciences of Kobe University. In this ERS system, some specific models of ITS can manifest almost all the behavioural features of the real systems on board ships especially those relevant to the MET (Maritime Education and Training) goals. Its evaluation models can contain the appropriate handles, to enable a knowledgeable communication with the learner about the model contents. Therefore, the ITS can provide a basis for generating articulate simulation models to successfully evaluate the students behaviours and competences. The evaluation methods are especially described in detail in the paper. The evaluation methods are divided into 3 types: Type A, Type B and Type C according to the different interaction relationships among evaluated objects. Type A is used mainly for a linear Node Series, Type B is used mainly for a nonlinear Node Series, and Type C is used only for malfunction simulation.

Keywords: maritime education and training, engine room simulator, intelligent tutoring system, evaluation method

1 Introduction

The steady increase in Information Technology (IT) and computing power has in fact given marine simulators a solid position, within the area of MET, as indispensable tools. However, some studies have shown that marine simulators are only effective when proper guidance and evaluation are provided [1, 2, 3, 4].

Therefore, the Intelligent Tutoring System (ITS) and training functions are required to provide such guidance and evaluation.
Teaching trainees to act and think in a logical manner will provide them with the correct attitude to cope with unexpected problems. It has been shown that trainees who were trained in strict logical thinking performed significantly better compared to trainees who were not encouraged to solve problems logically in ERS training tasks [5]. In this paper, the training task and evaluation methods are described in detail, respectively. The training task is designed based on the Systematic Approach to Training (SAT) method. The evaluation methods are divided into 3 types: Type A, Type B and Type C according to the different interaction relationships among evaluated objects. It can avoid the human effect in evaluation, and can give a satisfactory score to realize automatic evaluation and self-training.

2 Training task

Simulator training can be used to provide a stimulating and challenging environment to the trainees. Providing a challenging and stimulating environment does not only involve the hardware, creating correct and challenging training scenarios is also an important factor. In this section a training method is given to create consistent and appropriate training scenarios.

2.1 Systematic Approach to Training

The Systematic Approach to Training method (SAT) is a well known method for defining and implementing training programs originated from the nuclear industry [5, 6, 7, 8]. Well-trained personnel are recognized as an effective means for prevention of accidents. The SAT method expresses the view that the training and the design of training courses is a cyclic process. The training program is constantly revised during the whole life cycle of a plant. Training demands change during time and training courses have to reflect these changes.
The SAT method recognizes five sequential steps in the design of a training program:

- Analysis of task and training needs
- Design of training program
- Development of training material
- Implementation of Training
- Evaluation of training effectiveness

2.2 ERS training task analysis

Task analysis is defined as: “A systematic examination of a task resulting in a time oriented description of tasks performed by an operator, showing the sequential and simultaneous activities”. The advantage of a task analysis is that it provides the training course designer with information about the training task in a structured manner. There are many different methods to analyze a task

[5,13,14,15,16,17,18]. During a task analysis the following aspects of a particular task can be analyzed and quantified:

- What is the desired final behavior
- What are the important conditions under which behavior will occur
- What are criteria for acceptable performance
- What to train
- How to Train
- How well to train
- How much time to spend on training

3 The final evaluation

With regards to MET, the direction in which simulator-based education and training appears to be heading these days, the time to develop appropriate strategies to evaluate trainees is long overdue.

4 The methodology

The steady increase in computing power has in fact given simulation a solid position within the area of educational systems. However, several studies have shown that simulations are only effective when proper training and evaluation methods are provided. In order to realize such a goal, automating tutoring and training functions require the simulator models to be articulate [9]. Two further requirements follow from this. Firstly, a specific simulation model should manifest all the behavioral features of the real system as far as those are relevant to the educational goals. Secondly, a simulation model should contain appropriate handles, by means of which these features are indexed, to enable a knowledgeable communication with the trainee about the model contents.

Automated handling of tutoring and training function in ERS training system requires the availability of articulate domain models. In this paper the qualitative models are developed to realize this purpose. The result is a highly structured subject matter model that enables the evaluation of trainee behavior by means of an adapted version of the evaluation algorithm.

More specifically, the ERS training system has to diagnose and evaluate the trainee's problem solving behavior [10]. Trainees should acquire problem-solving skills such as predicting or 'postdating' the behavior of systems using qualitative terms. Hence, the trainee's problem solving behavior consists of a set of inferences about the behavior of these systems. The way the trainee interacts with the learning environment reflects this problem solving behavior. The ERS training system therefore has to monitor this interaction and diagnose deviations, with respect to some standard, in terms of problem solving errors made by the trainee.

In this paper, the model-based evaluation method [11, 12] is applied to diagnose and evaluate the trainee behavior.

4.1 The model-based evaluation method

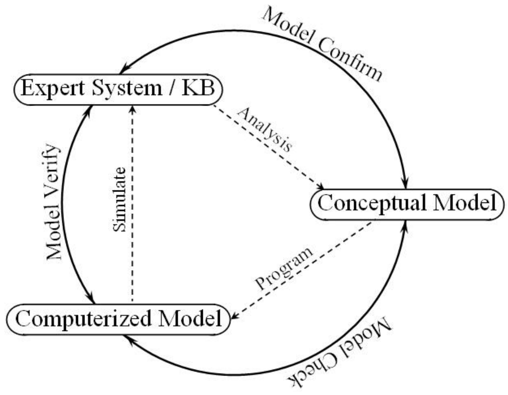

Figure 1: the conceptual framework of ITS

It is now becoming common in many countries to use the simulator as a testing tool for granting certificates. For the first time, government officials responsible for certifying maritime officers may now require officers to demonstrate on-the-job skills required for licensing officers using simulator testing instead of the traditional oral examination part for a particular certification. The question is "how much do we know about the effectiveness of training and evaluation on the simulator?" In this paper, the Intelligent Tutoring System (ITS) based on the model-based evaluation method and expert system is described as the supervision and evaluation system. The Conceptual Framework of ITS is shown in Fig. 1.

ITS can monitor and control trainees' terminals on line. According to the status and items selected by Instructor workstation, one of experiment items will be produced by ITS. After that, trainee can begin operating on software and/or hardware. ITS will record the operation step by step. The records include trainee's name, commenced time, completed time, running mode, condition and contents of operating. Based on the correctness of operation, a score is given by ITS system. Result of operation can be printed through ITS station computer.

4.1.1 Operating data acquisition

In order to realize the functions of ITS, the operation signals from both hardware and software should be sent and collected. The Figure 2 shows the mining

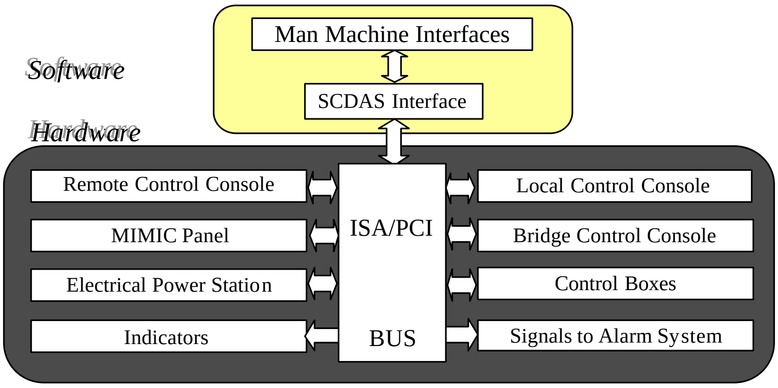

Figure 2: data acquisition and control system

method of data from hardware. All the data are then translated to the database (shown in Fig. 3). It can be divided into several bases according to their different functions in ITS system (shown in Fig. 4).

4.1.2 Some working definitions

For benefit to describing and to comprehend the evaluation methods, some working definitions are sketched out.

Definition 1: *Operation Object* is a Man-Machine Interface (MMI) or a functional area on a hardware panel/console. Operation object can be described as an aggregation $O\{W_i, S_j\}$ based on a special sequence.

Where, W_i is workstation. $(i=1, 2, \dots, 8)$

S_j is subsystem of workstation. $(j=1, 2, \dots, n)$

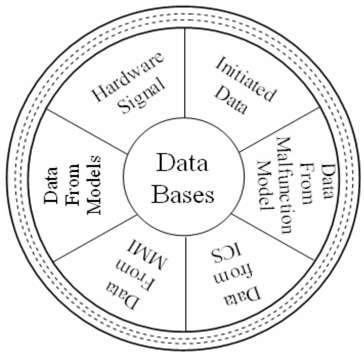

Figure 3: the data control system

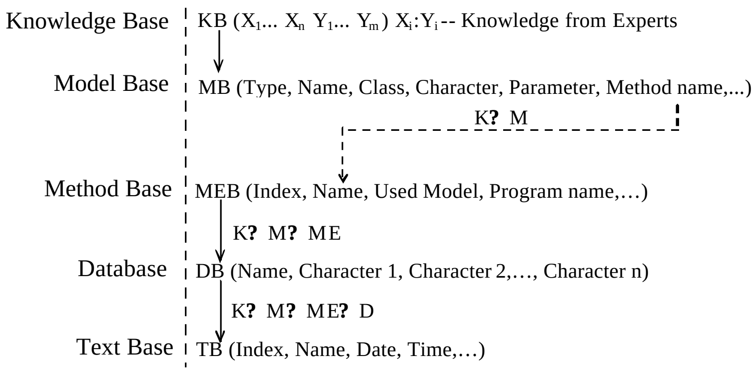

Figure 4: the relationships among databases

Definition 2: *Evaluation Node* is an operational switch, push-button, pump, heater, cooler, valve or isolated equipment etc. in an operation object O_i. Evaluation Node can be described as $N\{(O_i, (H/S)_i, (A/D)_i, V_i, F_i) | i=1, 2, \dots, n\}$. Where, *H/S* is to describe the characteristic of an evaluation node. *(H=Hardware, S=Software); A/D* is to describe the value characteristic of an evaluation node. *(A= analog signal, D=digital signal); V* is the value of an evaluation node; *F* is the flag of an evaluation node. *(F=True* means the value has been changed; *F=False* means the value has not been changed*).*

Definition 3: *Node Series* is a series of interacted evaluation node N_i, which are connected together to realize some special functions according to a functional relationship. Node Series can be marked as $S[N_1, N_n]$, $(N_i \in S[N_1, N_n])$.

4.1.3 Description of evaluation methods

According to the different relationships and illation & search method among Evaluation Nodes N_i in a Node Series S_i, the evaluation methods can be divided into 3 types: Type A, Type B and Type C.

Type A is to describe the linear relationship among Evaluation Node in a Node Series S_i (shown in Fig. 5). N_i is only influenced by N_{i-1}. The final score of a Node Series is described as:

$$Y = \sum_{i=1}^{n} C_i \cdot f_i \cdot w_i \tag{1}$$

Where, w_i is the weighting factor of N_i.

A matrix M_A can describe the whole relationship of the Node Series S_i.

$$M_A = \begin{array}{c} \begin{array}{cccc} X & N_{i-1} & N_i & C_i \end{array} \\ \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & a \end{bmatrix} \end{array} \tag{2}$$

Where, $a = [0\ ,\ 1]$ (3)

Type B is to describe the non-linear relationship among Evaluation Node in a Node Series S_i (shown in Fig. 6).

$$Y = F(X) \tag{4}$$

$$f(\bullet) = A \cdot B \cdot C \cdot D \tag{5}$$

$$B = \sum_{i=1}^{n}(b_i \cdot f_{bi} \cdot w_{bi}) / \sum_{i=1}^{n}(b_i \cdot w_{bi}) \tag{6}$$

$$C = (c_1 c_2 \ldots c_n) \cdot w_c \tag{7}$$

$w: Weighting\ \ Factor$

$$M_B = \begin{array}{c} \begin{array}{cccccc} X & A & B & C & D & Y \end{array} \\ \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} \end{array} \tag{8}$$

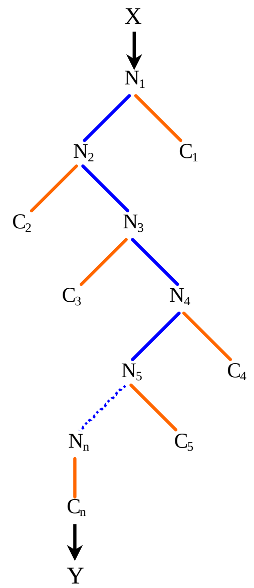

Figure 5: illation & search tree A

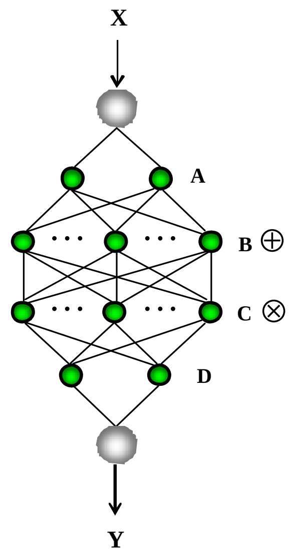

Figure 6: illation & search tree B

Type C is only used for malfunction simulation (shown in Fig. 7). Each malfunction is provided with up to eight choices for trainee to select. Each choice has an operation description and a preset score according to the expert system. If selected operation is correct to the simulated malfunction, the preset score will be counted in; otherwise the preset score will be discounted. Some incorrect operation choices can even result in other consequent malfunctions. It means if these incorrect operations are selected, other critical malfunctions will occur afterwards and the assessing score will be very low. The following equations (9)~(13) are used for the descriptions of Type C in detail.

$$C=\{C_1 C_2 \cdots C_n\} \quad (9)$$

$$d_i = \sum_{k=1}^{8} s_{ik} \cdot f_i \quad (10)$$

$$f_i = \begin{cases} 0 & not \;\; selected \\ 1 & seleted \end{cases} \quad (11)$$

$$Y = \sum_{i=1}^{m} \overline{d_i} \cdot w_{di} \quad (12)$$

w_{di} : *Weighting Factor*

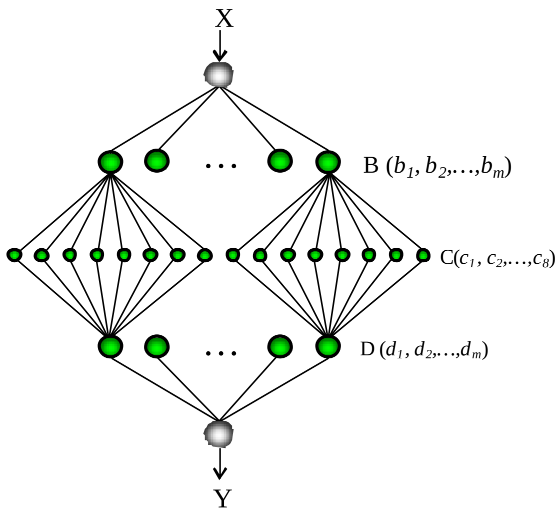

Figure 7: illation & search tree C

$$M_C = \begin{bmatrix} d_1 \\ d_2 \\ . \\ . \\ . \\ d_m \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & . & . & . & c_{1n} \\ c_{21} & c_{22} & . & . & . & c_{2n} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ c_{m1} & c_{m1} & . & . & . & c_{mn} \end{bmatrix} \quad (13)$$

Based on three kinds of aforementioned evaluation methods, the final score of training operation can be given according to the flowchart of Fig. 8. A fuzzy assessment combined with an expert system, refinement and explanation strategies is affiliated to evaluation module in order to get a convincing result.

4.1.4 The applications of evaluation method in MET

In this DIS-based real-time ERS at the Faculty of Maritime Sciences of Kobe University, there are too many simulated machinery models and MMI. Here, only an example of the application in MET training is described. In this exampled MMI (shown in Fig. 9), there are 3 Node Series: $S_1[N_1 \;,\; N_{16}]$ for HTFW system, S_2 $[N_1 \;,\; N_{12}]$ for LTFW system and $S_3[N_1 \;,\; N_{13}]$ for seawater cooling system. The main information of this exampled MMI is listed in Table 1.

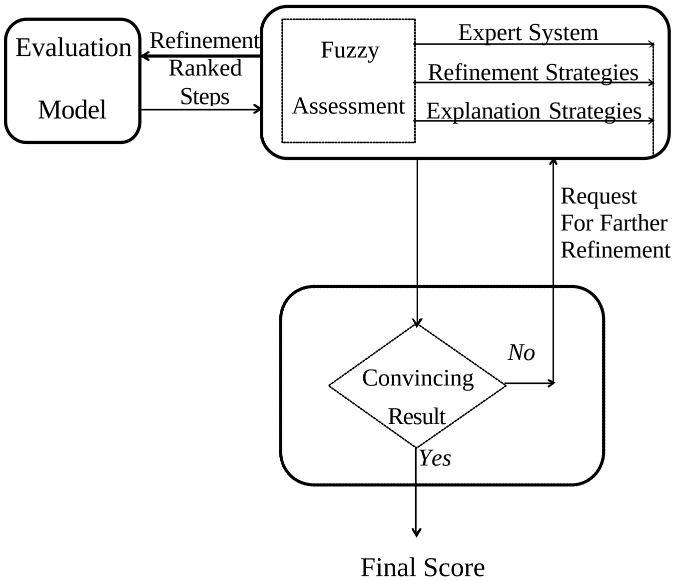

Figure 8: final score analysis flowchart

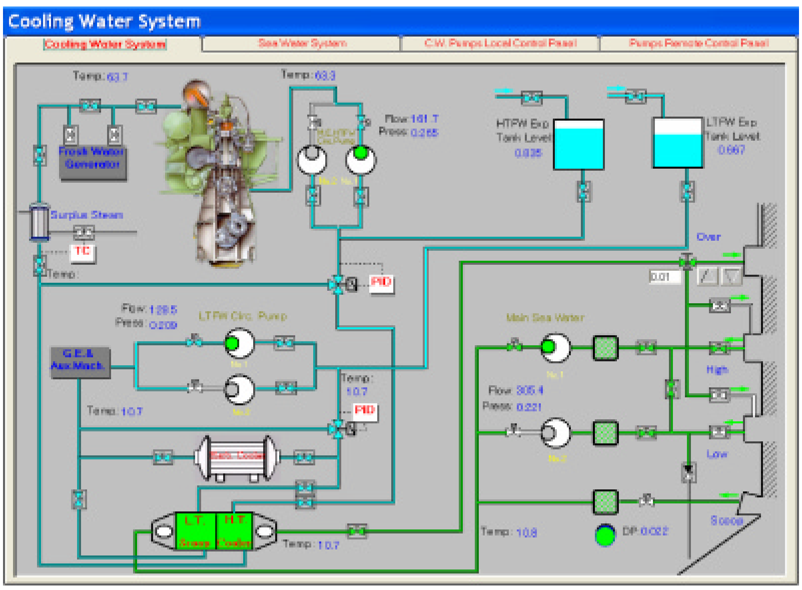

Figure 9: a MMI of cooling water system

Table 1: main information of the exampled MMI

<table>
<tr><th>Workstation</th><th>Subsystem</th><th>Node Series</th><th>Node Number</th><th colspan="2">Evaluation Method</th></tr>
<tr><td rowspan="4">AM01</td><td rowspan="4">AM01002</td><td>1</td><td>16</td><td>A</td><td rowspan="2">B</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">13</td><td rowspan="2">A</td></tr>
<tr><td rowspan="2">B</td></tr>
<tr><td>2</td><td>12</td><td>A</td></tr>
</table>

In each Node Series, Type A is used for evaluation. On the other hand, Type B is used for the interaction influences between S_1 and S_3, S_2 and S_3. In the fact, S_1 is also influenced by Main Engine system (in ME workstation), AM01004 subsystem (Fresh Water Generator subsystem), AM02003 subsystem (Preheating System in AM02 workstation) and AM01015 subsystem (HTFW PID controller system). Consequently, the different Node Series can be collected according to the logical relationships with Type A, Type B or Type C.

5 Conclusions

Along with the development tendency of intelligent ships, the requirements to marine engineers are also rising. Consequently, a DIS-based real-time ERS is developed to suit for those development tendencies at the Faculty of Maritime Sciences of Kobe University. It can realize the opening structures and compatibility, and provide a realistic environment for trainees in catching the engine room technology.

On the other hand, the evaluation methods of the DIS-based real-time ERS are also described in detail. The evaluation methods are divided into 3 types: Type A, Type B and Type C according to the different interaction relationships among evaluated objects. The application of evaluation methods in DIS-based real-time ERS is exemplified. It can avoid the human effect in evaluation, and can give a satisfactory score to realize automatic evaluation and self-training.

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