1. Introduction

Engine Room Simulator (ERS) has been used quite extensively on Maritime Education and Training (MET) for over a couple of decades in order to improve seafarers’ practical skills of watchkeeping and UMS (Unmanned Machinery Spaces) services [1].

Generally, there are two main kinds of ERS: Full-mission ERS and PC-based ERS.

Regarding the Full-mission ERS, reality is absolutely needed in acclimating trainees to an actual engine room environment. The operations of the machinery can be simulated as close as possible to their actual conditions on ships in service due to the fact that both physical and spiritual conditions are included as “Reality of the environment”. Furthermore, “Repeatability of a training subject” is very much expected in the training for some certain subjects covered thoroughly [2].

Oppositely, PC-based ERS is only the simulated software as a lower-priced alternative for the engineers/operators to be familiar with the engine room systems. Especially, in the computerized ship, the operations of engine room systems are realized on the screen by mouse-click or screen-touch. The development of computerizing is not to deemphasize the skills of the operators, but enhance the almightiness and familiarity to skills. Engineers make the most decisions with information interpreted “through the window”, which is becoming a trend in real modern ocean ships. Therefore, PC-based ERS is not the simple attachment, but an important supplement in Simulator Aided Education and Training (SAET).

According to the factors of development tendencies on intelligent ship, a multi-mode ERS is developed basing on the merits of those two types ERS. This paper describes its brief features, facilities and functions on SAET training and retraining. On the other hand, the evaluation methods of multi-mode ERS are also described in detail.

2. The Multi-mode ERS

Considering the operational environment, physical reality, action reality, normal simulation, abnormal simulation and interaction, the emphases of this multi-mode ERS are changed from simple technology to how to benefit training and evaluation as a tool of SAET. It includes the simulated engine room, the integrated control room, the bridge control room, the instructor control room, the chief engineer room, the extending training room, etc.
2.1 The Simulated Engine Room

A multi-purposed large mimic panel, a local manual operation console and a lot of simulated control boxes are located as controlled objects in this room. On the mimic panel, the main engine (ME), auxiliary machinery (AM) plants and all pipe systems in the engine room of service ship can be displayed vividly (shown in Fig.1). Statuses of machinery plants, valves and important parameters are displayed by twin-color LED, switches and real meters, respectively. Working media in pipes can be shown by LED and flow interactively according to the simulated liquid flow rate. Liquid levels in tanks can be shown on individual CRTs with the wavy surfaces.

The main function of mimic panel is not only designed for display, but also for operation and real-time control. The following subsystems can be displayed, monitored and controlled:

- Fuel oil system
- Lubricating oil system
- Starting and controlling air system
- Sea water system
- Low temperature fresh water (LTFW) system
- High temperature fresh water (HTFW) system
- Boiler system
- Bilge water system
- Sewage disposal system

2.2 The Integrated Control Room

The integrated control console and the electric power station are located in this room.

2.2.1 The Simulated integrated control console

The integrated control console is complicated due to the fact that multi-mode ERS takes modern ships as simulated object. Most of typical engine room equipments and systems can be controlled and supervised in integrated control console (shown in Fig.2), which can be divided into 7 functional areas:

- Main engine controlling and supervising area
- Auxiliary machinery controlling and supervising area
- Pumps remote control and supervising area
- Liquid level of tanks measuring and supervising area
- Main engine remote control and protection area
- Important parameters’ displaying area
- Integrated alarm and monitoring area

2.2.2 The Simulated electric power station

The Simulated electric power station consists of main switchboard (generator control panels, parallel operation panel and load control panels) and emergency switch board (shown in Fig.3). The simulated operation and the communication with the instructor console and other workstation are realized by a control station. The Man-Machine Interface (MMI) on the CRT of control station is synchronized with the operation of main switchboard and emergency switchboard; therefore, it can operate the electric power station in real-time condition.

2.3 The Bridge Control Room

Fig.1 The Mimic Panel

Fig.2 The Simulated Integrated Control Console

Fig.3 The Simulated Electric Power Station

Fig.4 The Bridge Control Console
A complete bridge control console is equipped with telegraph, telegraph recorder, rudder angle indicator and some important measuring meters (shown in Fig.4). It can realize to control remotely and supervise the main engine and other important equipments in the engine room.

2.4 The Instructor Room (The Instructor Workstation)
The instructor can initialize the whole ERS conditions, set special parameters, preset the simulated malfunctions for training, record and control the trainees’ operations, monitor the whole simulator situation and training process. The simulated sound system of engine room is also located with the loudspeaker boxes in the simulated engine room.

The instructor workstation can monitor and control the whole ERS workstation and hardware on line. It can realize:
- System initialization
- Running mode setting and resetting
- Self-detection of the whole ERS workstations
- Time proportion selection
- Running condition setting and resetting
- Parameter setting and adjustment
- Operating control
- Alarm and supervising
- Training process recording
- Malfunction setting and resetting
- Sound simulation and noise simulation
- Evaluation

2.5 The Chief Engineer Room (The C/E Workstation)
The chief engineer workstation is linked to the alarm workstation as on ship in service. Necessary alarm information is shown in this workstation, stand-by pumps and devices can be controlled as well as on the integrated control console.

2.6 The Extending Training Room
Considering the fact that the aforementioned workstations of multi-mode ERS are very limited for large number trainees at the same time, the extending training workstations (PC-based) are required to simulate the modern ships effectively. If the aforementioned workstations are in the mode of off-line, the trainee could study on the individual subsystems by themselves. It is benefited to trainees in appropriate knowledge before effective application of the whole multi-mode ERS.

Extending workstations utilize modern and effective learning methods in a flexible environment, independent of local and temporal limitation. It can support both instructor-guided training and self-instruction by using different resources. Therefore, it is well-suited for self-training, as well as group training, with the evaluation of participants by means of evaluation system or an instructor. On the other hand, a large scale screen for data projector is equipped and linked with main LAN, so that more trainees can watch the demonstrated operation of the whole multi-mode ERS as well as on CRTs. A real-time control and monitoring station is equipped to control and monitor all the trainee workstations. Trainees can analyze their own performance and mistake which may have occurred during the training process.

The basic role of the extending workstation is to familiarize with the individual equipments and associated systems. Comparing with traditional training methods, it can realize tri-dimensional graphical visualization of machinery elements for better understanding of the functional principles and complex auxiliary machinery operation, which are difficult to be realized in laboratories due to the size or technical requirements of the installations [3].

3. Evaluation Methods
It is now becoming common in many countries to use the simulator as a testing tool in 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 [4]. 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 expert system is described as the supervision and evaluation system. The Conceptual Framework of ITS is shown in Fig.5.

![Fig.5 The Conceptual Framework of ITS](image-url)
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. According to the rate of correct of operation, the score is given by ITS system. Result of operating can be printed through ITS station computer.

3.1 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 Fig.6 shows the mining method of data from hardware. And then all the data are translated to the database (shown in Fig.7). It can be divided into several bases according to their different function in ITS system (shown in Fig. 8).

3.2 Some Working Definitions

In order to benefit to describe and 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. ($i=1, 2, ..., 8$)

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

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 $N((H/S)_i(±0), (A/D)_i, V_i, F_i)|i=1, 2, ..., n|.$

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 $S(N_1, N_2, ..., N_n).$

3.3 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.9). $N_i$ is only influenced by $N_{i-1}$. The final score of a Node Series is described as:

$$Y = \sum_{j=1}^{n} C_j \cdot f_j \cdot w_j$$

Where,

$w_j$ is the weighting factor of $N_j$.

A matrix $M_r$ can describe the whole relationship of the Node Series $S_c$.

$$M_r = \begin{bmatrix}
0 & 1 & 0 & 1 \\
1 & 0 & 0 & 1 \\
1 & 1 & 1 & \sigma
\end{bmatrix}$$

Fig.6 The Data Mining System

Fig.7 The Data Control System

Fig.8 The Relationships among Bases
Type C is only used for malfunction simulation (shown in Fig. 11). 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.

\[ C = \{C_1, C_2, \ldots, C_n\} \quad \ldots \quad (9) \]

\[ d_i = \sum_{i=1}^{n} s_i \cdot f_i \quad \ldots \quad (10) \]

\[ f_i = \begin{cases} 0 & \text{not selected} \\ 1 & \text{selected} \end{cases} \quad \ldots \quad (11) \]

\[ Y = \sum_{i=1}^{n} d_i \cdot w_{di} \quad \ldots \quad (12) \]

\[ w_{di} : \text{Weighting Factor} \]

Based on three kinds of aforementioned evaluation methods, the final score of training operation can be given according to the flowchart of Fig. 12. A fuzzy assessment combined
with an expert system, refinement and explanation strategies is affiliated to evaluation module in order to get a convincing result.

3.4 An Example for the Application

Here, an example of the application in SAET training is described. In this exampled MMI (shown in Fig.13), 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 sea water cooling system. The main information of this exampled MMI is listed in Table 1.

**Table 1 Main Information of the Examped MMI**

<table>
<thead>
<tr>
<th>Workstation</th>
<th>Subsystem</th>
<th>Node Series</th>
<th>Node Number</th>
<th>Evaluation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM01</td>
<td>AM01002</td>
<td>1</td>
<td>16</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>13</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>12</td>
<td>B</td>
</tr>
</tbody>
</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 \( S_2 \), \( S_2 \) 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.

4. Conclusion

Along with the development tendency of intelligent ships, the requirements to marine engineers are also rising. Consequently, a multi-mode ERS is developed to suit for those development tendencies. It can realize the opening structures and compatibility, provide a realistic environment for trainees in catching the engine room technology, and be upgraded easily in order to simulate different ships.

On the other hand, the evaluation methods of the Multi-mode 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 Multi-mode ERS is exemplified. It can avoid the human effect in evaluation, and can give a satisfied score to realize automatic evaluation and self-training.

**REFERENCES**


