Study on the Development of IMIMS to Improve Maritime Education and Training

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ABSTRACT

This paper deals with the development of the Integrated Marine Information and Management System (IMIMS) based on maritime Information and Communication Technology (ICT), database technology, Artificial Intelligence, fault diagnosis and prediction technology. IMIMS consists of the ship-based system and the shore-based system by sharing the information and databases. The structures and functions of each section are introduced respectively.

IMIMS can provide powerful tools and supports for interactive Maritime Education and Training (MET) by sharing databases and data processing functions. In this paper, how to benefit MET from IMIMS is also described in detail, which includes by sharing the resourceful database, the strong function of fault analysis and evaluation, and by combining with Engine Room Simulator (ERS). Especially, ERS has been used quite extensively on seafarer training for over a couple of decades in order to improve seafarers' practical skills of watchkeeping and UMS services. This kind of connection can improve MET training effect based on the real data from ships. It also can help to improve the physical models and mathematical models of engine room simulator, to make the simulator having tremendous training and research potential, and to perfect the engine room simulator as a MET tool for training and examination on each level of certificates.

1. Introduction

The extreme rapid development of Information and Communication Technology (ICT) brings great opportunities for the maritime society to develop customized application systems, and integrate the systems on board ship as well as between the ship and the land organizations. The data communication between ship and shore services can be easily transmitted by satellite, e-mail, mobile storage equipment or documents (Refer to Fig.1). With import and export functions for operational data, a shipboard system can be connected with data log so as to translate the field data of navigation and power plant system, receive instructional data for on-line performance analysis system and shore-based requirements. Moreover, ICT can make it possible to employ real-time operation monitoring systems to realize shore-based remote diagnosis and trouble-shooting, and even can realize "ship operations on shore" (Hara, 2000).

A survey showed that the vessels spent 12-24 hours in port and 10-20days at sea on average (Bennett, Dec. 2001/Jan. 2002). In other words, the ships are mostly not under the direct control by shipping companies. The shipping companies do not know exactly what the ships are doing, and how the ship conditions are in time. In order to supervise the vessels effectively and safely at any moment, and meet the requirement of modern maritime transports; ship owners, shipping companies, classification societies and the equipment suppliers should also be fully integrated with ship navigation and safety management at sea.

This paper describes the development and applications of IMIMS based on ICT, database technology, Artificial Intelligence, fault diagnosis and prediction technology. IMIMS consists of the ship-based system and the shore-based system by sharing the information and databases. The structures and functions of each section, as well as the ICT technology, database technology, Artificial Intelligence, trend prediction and fault diagnosis technology, are introduced respectively.

IMIMS can provide powerful aided tools and supports for interactive MET by sharing databases and data processing functions. In this paper, how to benefit MET from IMIMS is also described in detail. Especially, ERS has been used quite extensively on seafarer training for over a couple of decades in order to improve seafarers' practical skills of watchkeeping and UMS services. This paper deals with the connection between IMIMS and ERS by describing the PC-based ERS and full mission ERS, respectively.

2. Information and Communication Technology

In recent years, many maritime R&D institutes have focused on utilizing the benefits of Information and Communication Technology in ship operation and management (Telle, 2000). In order to exchange the ideas and experiences to assist ICT development and problem solving, the Association of Maritime Managers in IT and Communications, a not-for-profit organization, was established in November 2002 to promote the current use of ICT in shipping and enhance its status and importance (Ocean Voice, Dec. 2002/Jan. 2003). Based on ICT, the ship owners, equipment supplying industries, software producers and classification societies have been involved in navigation and safety management at sea. Especially, availability of standard PC, Internet/Intranet/Extranet and satellite communication technology has provided the opportunity to integrate the systems on board and on shore.

The new INMARSAT technology serviced for maritime satellite communication terminals can offer high-speed and cost-effective voice, image and video and plain text data communication based on either the MPDS(Mobile Packet Data Service) protocol with constant 24×7 online access or 64kbps ISDN (Integrated Services Digital Network) (Ocean Voice, Dec.2001/Jan.2002; Huang and Lin, 2002). With it, information can flow all the way from shore-based Intranet/Extranet to the captains and crews of any registered ships on the high sea, offering significant advantages to ship owners wishing to increase efficiency in the safety and management of maritime business. MPDS provides constant ship/shore online access to applications such as remote surveillance and diagnosis of onboard mechanical systems, cargo monitoring and control and purchase and logistics handling. Position reporting, electronic charts, weather reports, maintenance schedules and automatic equipment and machinery surveillance reports can now be transmitted and received as soon as possible.

3. IMIMS

Maritime safety analysis, evaluation and management are a very complicated subject where safety is determined by numerous factors including human error and remote information communication. Many safety assessment techniques currently used in the maritime industries are comparatively mature tools (Tran *et al*, 2003). However, in many circumstances, the application of these tools may not be suitable or give unsatisfactory results due to the lack of applicable safety related data or the high level of uncertainty involved in the safety data available (How *et al*, 2002). Integrated safety analysis method and sharing information are therefore required to identify major hazards and assess the associated risks in a more rational way in various environments where mature tools cannot be effectively or efficiently applied. Integrated Marine Information and Management System (IMIMS) is therefore one attempt to cope with this situation.

IMIMS consists of the ship-based system and the shore-based system by sharing the information and databases. The data communication between shipboard and ashore can be transmitted by e-mail, mobile storage equipment or documents (Shimura, 2000). Especially, large volume data and/or long periodical data can be sent to shore by mobile storage equipment in order to reduce cost (shown in Fig.1). The former aggregates several information acquired from the engine and navigation division of ship, transmits them outward and receives signals from outside. The latter communicates much information between the registered ships and the shipping company, analyzes the data and information, provides the electronic recording and reporting charts, supports for officers/engineers decision, services for ship maneuvering, engine operation and maintenance and surveillance, fault diagnosis and prediction, etc.

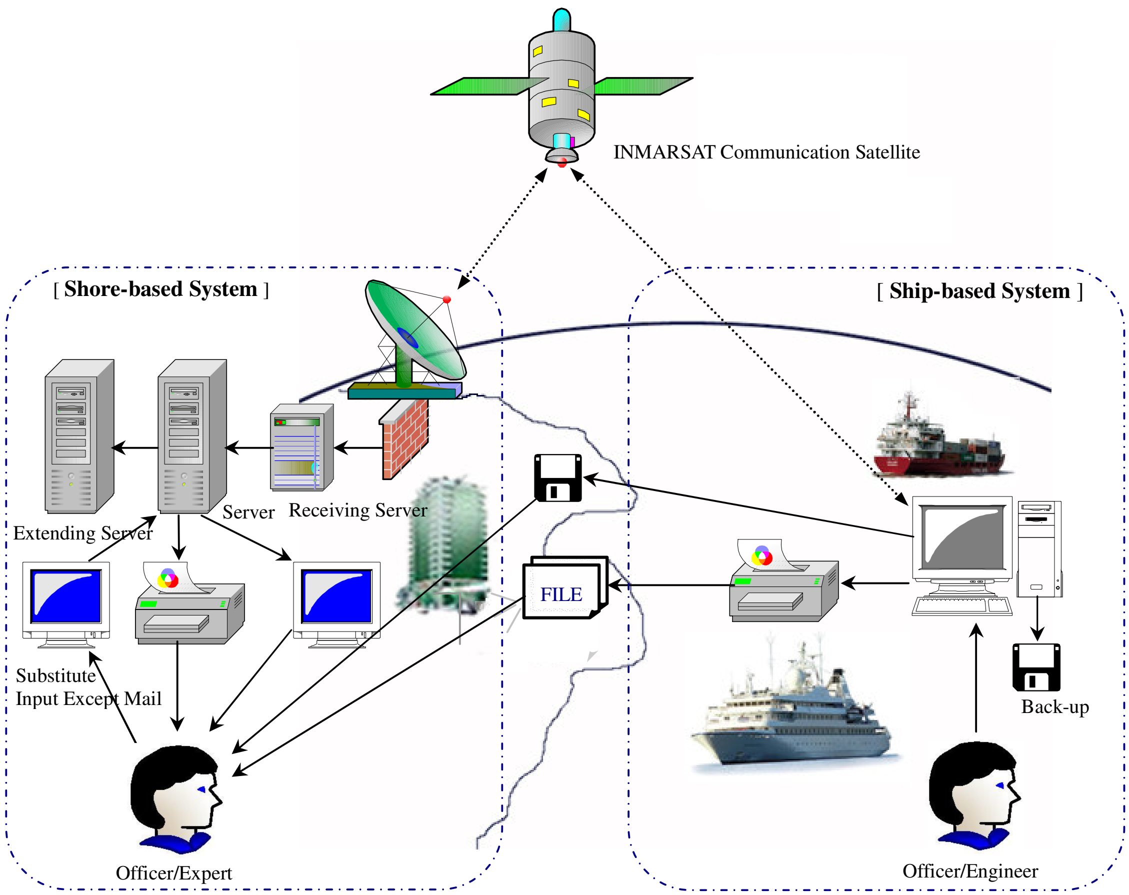

Figure 1: System Schematic Diagram

3.1 Database and Data Dictionary

In this system, one of the basic and important things is to build databases. The volume and management models of databases will affect directly the normal operation and functions of this system. In the fact, databases are very often designed and optimized at the level of the DBMS(Databases Management System) engine rather than taking into consideration the applications that run on top of them (Stolte and Alonso, 2003). Therefore, in order to be convenient for data management and effective analysis, a data dictionary should also be built. It is a list of all the variables and constants, along with their attributes that could be exchanged. For private exchange of data between two workstations, a dictionary can be defined and transmitted separately or with the data. This is similar to the process used when two workstations exchange encrypted messages. It is difficult or impossible to understand the data without the data dictionary (Miler *et al*, 2002). Therefore, a drift data dictionary, which is intended to be used to exchange shipboard data for large-scale transmission and communication, has been developed in this system.

3.2 Ship-based System

To achieve safe and economical services of the ship, the optimized operation and appropriate maintenance for the machinery on board ship are indispensable. However, maintenance and repair works of self-completion type, in which all of the necessary works are executed by engineers or crew on board, becomes more and more difficult in modernized automated ship because of increase of aged crew, shortage of skilled engineers and reduction of crew numbers due to cutting down transportation cost (Ono and Nagaya, 2000; Togawa and Tagami, 2001; Annual Report, 2003). It has become clear that the average failure rate of the whole of ship equipment was 7.2[case/1000hr.], and the work for the repair was 5.0[man·hr.] through statistical analysis by the SRIC of Japan (Ship Reliability Investigation Committee). It is noticed that the failure ratio of miscellaneous equipment is about 43% (Kiriya, 2001). In order to improve this circumstance, it is necessary to build up the supporting system by which the ships are supported by expert on shore. Therefore, many transportation industries have tried to solve these problems continuously and to apply the highly automated onboard system for labor-saved and realization of safety navigation. And they also made efforts to establish the standardized maneuvering procedures and some effective navigation support systems.

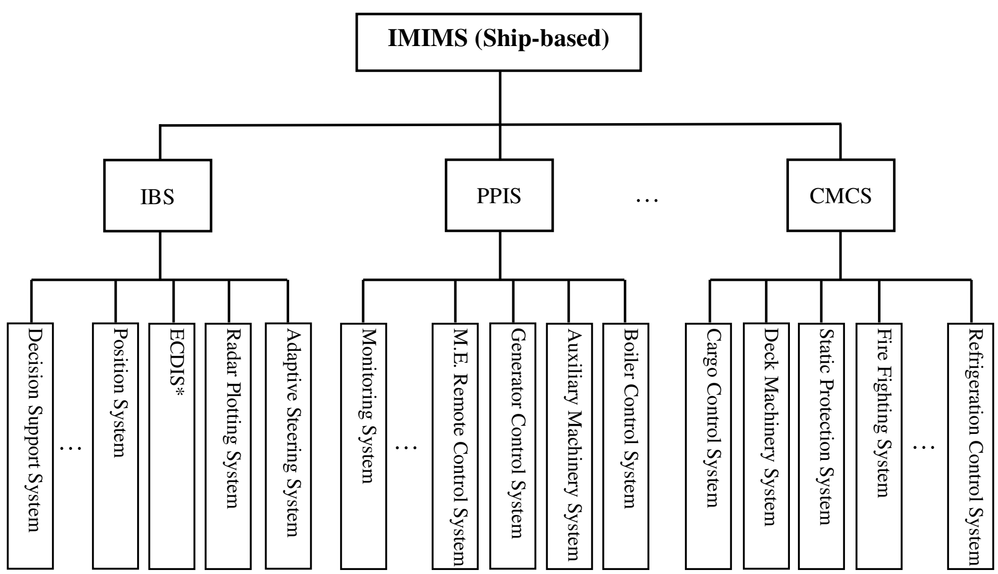

Figure 2: IMIMS (Ship-based system)

**** ECDIS: Electronic Chart Displaying and Information System***

As an important composing section, ship-based system of IMIMS services mainly for the management of single ship. Its main functions are to integrate and manage the necessary information collected from Integrated Bridge System (IBS), Power Plant Information System (PPIS), Cargo Monitoring and Control System (CMCS) etc., besides routine operation and management (shown in Fig.2). It can transmit the collected data to shipping company and receives instruction information from outside.

3.3 Shore-based System

Shore-based system of IMIMS services mainly for the shipping company and the fleet as a whole. It includes Navigational Fairs Management System (NFMS), Machinery Management System (MMS), Multiple through Transport System (MTTS), Safety Supervision Information System (SSIS), and Decision Support System (DSS) etc. (shown in Fig.3).

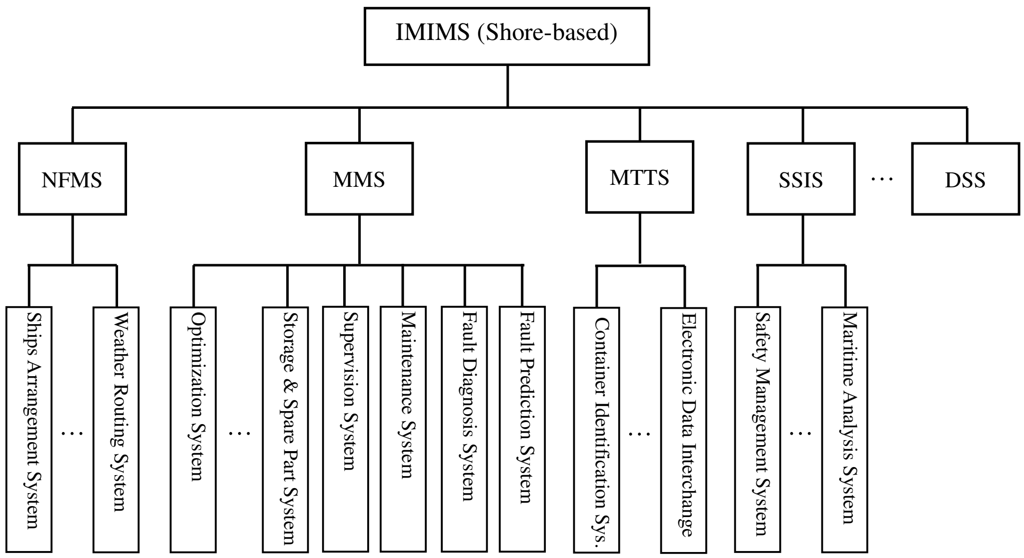

Figure 3: IMIMS (Shore-based system)

As all of the data in shore-based system is accumulated from the service ship and is stored as a general database in the servers of shipping company, it can be transferred easily to other ships in order to avoid the same fault happened in other ships. The stored data can be put to use practically in the prescribed manner to be referred by operators and instructors. So the operation in a ship is labor-saved possibly (Shimada, 2001). This system is able to storage and to keep the data of dock to deck. These data can be stored and managed for several decades in the Servers of the shipping company. Using this system, we can survey the trend graphs of the setting parameters of the registered ships, the position data of the ship, the abstraction logbook data of the weather conditions and the engine data etc. We can analyze the specification data of the engine; manage the maintenance and the spare parts of the machines. Thus management officers can not only know the conditions of the ship on the sea in real-time, but also manage the ship's services safely and efficiently.

According to the former description, It can be concluded that the users on the Intranet/Extranet of shipping company can pick up required data from the logging processes, and at the same time new logging processes can be configured from the office in addition to the predefined users running continuously, and the raw data from such processes can be transferred to the office. Namely, IMIMS specializes in collection, storing, classification, transmission, processing, statistic analysis, and inquiring of ship information. It can offer the services for ship's real-time surveillance, electronic charts recording and reporting and dynamic inquiring of ship information, cargo monitoring and control, shore-based decision support, weather routing, maintenance management, shore-based performance and condition monitoring of power plants, remote fault diagnosis and prediction of shipboard mechanical systems etc.

4. How to Benefit MET from IMIMS?

Reports indicate that approximately 80% of marine accidents involve some type of human error even in an era where there are major developments in the communication of information and marine equipment (Yonemoto *et al*, 2001). It is considered that the main reasons for the wrong actions are inadequacy and insufficiency of professional knowledge and skills (Vladimir, 2003). It is also reported that improving the quality of the display available to the operator could reduce human errors (Hindmarch, 2001). Moreover, most of malfunctions are only the expected value of impact; the variance of malfunction might also affect the decision made by both the trainee and the processor (Fu *et al*, 2002). By improving the quality of information available to the operator, then he is more able to fully utilize his mental resources, and reduce the cognitive effort required to reach a considered and informed decision. When all the main information is presented to the operator in a more visible form, then the time taken to respond in the correct manner should also be reduced. Therefore, safe navigation cannot be achieved without improving the operator's safety management skills and methods. Some shipping companies have developed their modern IMIMSs. But the abundant databases, which are servicing for maritime safety management of ship's transportation and shipping companies, have nothing to do with MET until now. It is the time that MET ought to benefit from these resourceful real data.

4.1 By Sharing the Database

IMIMS can provide some powerful aided tools and supports for interactive MET by sharing databases and data processing functions. It is well known that the human process of learning appears to be based on multiple sensory inputs, reinforcement, and a period of time for assimilation and assessment. The process clearly is complex, but it appears that the use of multiple sensory inputs to the learner is an important feature (Ni *et al*, 2002). Consequently, it is worthwhile combining service ships, shipping companies and maritime training in one common subject to highlight accidents and human error analysis, trouble-shooting and safe operation algorithms, functions and models of training tools, resource management and safety assessment in MET. Based on contact continuously with those multiple knowledge and experience, the trainees have such a good opportunity to learn broader living technologies about human errors and maritime safety management from MET courses.

But how are the data mined and processed? This paper focuses particularly on the processing method of data collecting and sorting in power plant information system as an example.

At present, digital control schemes of modern marine power plant system are replacing traditional manual control and operation (Keyhani *et al*, 2002). Some modernized ships are using Distributed Interactive Control System (DICS) in engine room. In generally, DICS includes several control stations or remote I/O processors, operation stations and control stations (shown in fig.4). They are linked together and can fulfill the missions of data mining, processing, logic control and parameter adjustment etc.

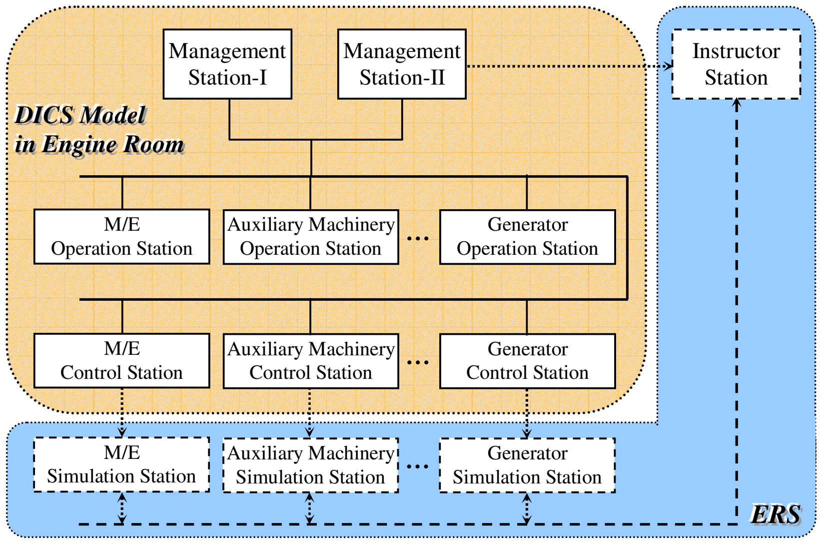

Figure 4: The structure of DICS in Engine Room

The new method of data analysis in IMINS is to integrate data from several sources, and use then in composite calculations and analyses (shown in fig. 5). In isolated model, each system can "play with its own voice", without too much concern about what the others are doing. But, when data from several systems are used in integrated analysis, the sources must have mutual consistency, the "whole orchestra" must be tuned, so that it plays in harmony. Consequently, IMIMS can present more effectively the collected and classified information to the officers/engineers. All the useful information can be highlighted and emphasized so as to arrest the users' attention. It is benefit to find the potential malfunctions early and remedy them as soon as possible.

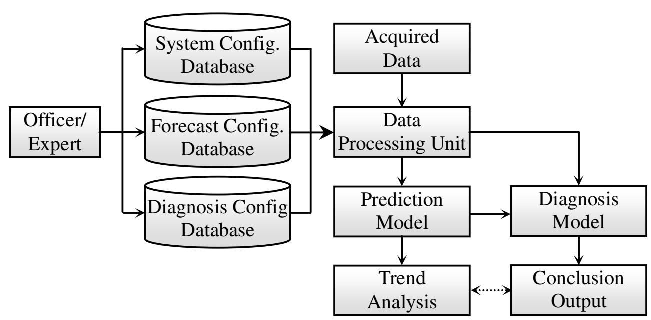

Figure 5:
***The functional structure of information* processing**

Of cause, it is also helpful in reducing human errors due to misunderstanding or ignoring the information. The strong processing function of data in IMIMS can be transplanted to MET. It is helpful for trainee to learn the real reason of faults and accidents by comparing the analysis results between trainee and system. It also can benefit the trainee in the training of processing ability of integrated information and management ability, especially.

4.2 By Sharing the Function of Fault Analysis

It is well known that the safety of a system is very difficult to measure precisely and quantitatively (How *et al*, 2002). This is primarily due to the fact that the safety performance of a system depends largely on the behavior of the human involvement. It is extremely difficult for MET instructors to generate a mathematical model or words to represent and describe the safety behavior/discipline of a maritime system, as safety is a multiple-level and multiple-variable problem. Fortunately, the fuzzy multiple-objective technique has been well established by mathematicians. System safety analysis and evaluation is typically a fuzzy process and most of the objective functions reflect human factors, which are qualitative variables. In an actual safety analysis and evaluation system, most problems consist of a combination of qualitative or linguistic variables and quantitative objective functions. Therefore, Artificial Intelligence (AI) is applied in the fault analysis and evaluation in IMIMS.

Artificial Intelligence is a vast, loosely defined area encompassing various aspects of pattern recognition and image processing, natural language and speech processing, automated reasoning and a host of other disciplines (Loebis *et al*, 2002). Fuzzy logic, expert system and Artificial Neural Network (ANN) are three of the most widely used approaches in Artificial Intelligence methods for safety analysis and decision support.

In this system, the Nonlinear Autoregressive Moving Average (NARMA) identification algorithm based on Diagonal Recurrent Neural Network (DRNN) is developed for modeling time series data in fault prediction model (shown in Fig.6) (Lu *et al*, 2001). Its output is defined as (Dou and Tang, 2001):

$$\hat{x}_{t+k} = \sum_{j=1}^{h} wo_{jk} f(s_j(t)) \quad (1)$$

Where, $s_j(t)$ is the input of each node of hidden layers. It can be defined as:

$$s_j(t) = wi_{1j} \cdot \hat{x}_{t-1} + wi_{2j} \cdot x_{t-1} + wh_j \cdot f(s_j(t-1)) \quad (2)$$

$f(\bullet)$ is *Sigmoid* function， namely, $f(x) = 1/(1+e^{-x})$.

The Fuzzy Neural Network (FNN) is applied in fault diagnosis model (shown in Fig.7).

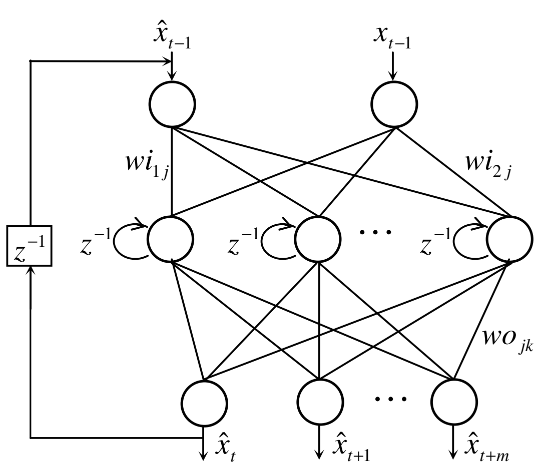

Figure 6:
DRNN-based NARMA Fault Prediction Model

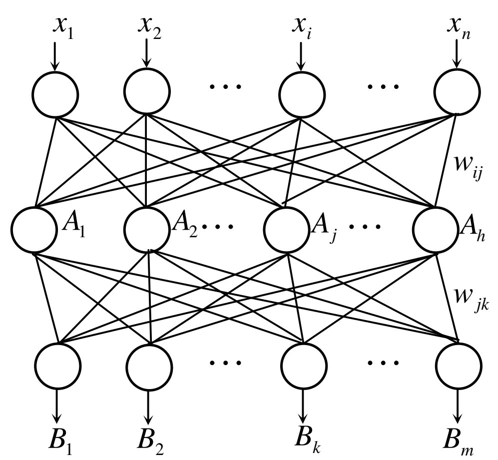

Figure 7:
FNN-based Fault Diagnosis Model

Where,

$$A_j = (\prod_{i=1}^{n} x_i^{w_{ij}})^{\alpha_j} \quad , \quad \alpha_j \in [0,+\infty) \tag{3}$$

$$w_{ij} = \frac{d1_{ij}^2}{\sum_{i=1}^{n} d1_{ij}^2} , \qquad d1_{ij} \in (-\infty,+\infty) \tag{4}$$

$$B_k = 1 - [\prod_{j=1}^{h} (1 - A_j)^{w_{jk}})^{\beta_k} \quad , \quad \beta_k \in [0,+\infty) \tag{5}$$

$$w_{jk} = \frac{d2_{jk}^2}{\sum_{j=1}^{h} d2_{jk}^2} , \qquad d2_{jk} \in (-\infty,+\infty) \tag{6}$$

According to the fault analysis and prediction in IMIMS, some potential fault or accident can be found and avoided in advance. Therefore, it is a potential assistant tool for MET to select and specify the marine safety and management system. If the function of fault analysis is used in MET, the advantages of analysis ability of large quantities of data can benefit the trainee to find the relationship between data/phenomena and fault/result. Owing to recognizing and learning abilities, the trainee can get some assistant in predicating and decision-making problems. Consequently, it is helpful for trainee to improve their abilities in dealing with fault analysis and remedying.

4.3 By Combining with ERS

Engine room simulator has been used quite extensively on seafarer training for over a couple of decades in order to improve seafarers' practical skills of watchkeeping and UMS services (Russell, 2001). It is widely accepted in maritime academies and training center as a testing tool in granting certificates. Unfortunately, most of engine room simulators only emphasize on the operational level as their objective of MET training. However, in order to comply entirely with the International requirements and regulations of STCW95 (the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers) and ISM (International Safety Management) code, the importance of the management level should be highlighted during simulator training. This kind of connection can improve the training effect based on the field data from ships. It also can help to improve the physical models and mathematical models of engine room simulator, to make the simulator having tremendous training and research potential, and to perfect the engine room simulator as one of MET tool for training and examination on each level of certificates.

4.3.1 Combining with PC-based ERS

Here, what is called PC-based ERS is only those simulator software used on board ship as a lower-priced alternative for the engineers/operators to be familiar with the power plant. Under this situation, The characteristic parameters, e.g. speed, output, temperatures, pressures and all the boundary conditions etc., of main engine and auxiliary machinery can be drawn out from databases automatically according to the shared data dictionary and imported into the interactive initializing Man-Machine Interfaces of simulator. It can "create" a special PC-based ERS serviced only for this ship (shown in Fig.8), benefit for the new seafarers and graduated students in being familiar with these power plants as soon as possible based on the same system with service ship or direct connect the ERS with control stations on board ship, respectively or synthetically (Refer to fig.4).

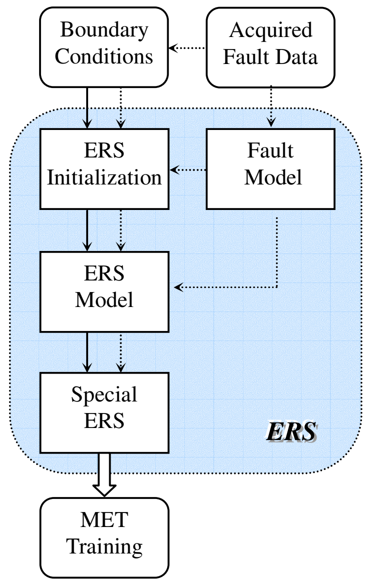

Figure 8: Special PC-based ERS

On the other hand, under the fault simulation model, some related data also can be imported into the ERS to update the existing fault models and to improve the simulating effects of fault training. Even it can realize the fault prediction and avoid the same fault happened again by summing up the experience and training again and again.

4.3.2 Combining with Full Mission ERS

Full mission ERS has been used quite extensively on MET training for over a couple of decades, which includes both hardware and software. In order to perfect the functions and training effect, updating of full mission ERS should to be done continuously. A method is to recur to shore-based databases of IMIMS. It can realize:

- to analyses of fault and accidents correctly;
- to modify and improve the physical and mathematical models by software developers;
- to optimize the existing fault models;
- to update and add the occurred faults and accidents;
- to predict the faults on service ship;
- to provide monitoring systems in shore-based remote diagnosis and trouble-shooting;
- to highlight the R&D function of simulators.

Moreover, besides the traditional technique-based training, it also can realize management-based training by sharing the management information to remedy the lack in management.

5. Conclusion

The development of information and communication technology, and especially the expansion of satellite communication, network technology, remote surveillance and control systems, has created the possibilities of significant both reducing of the crew numbers and enhancing safety management at sea (Listewnik and Wiewióra, 2001). In consequence, it also leads to increase skill requirements and technology support from broader fields, for example the equipment developers, classification societies, experts, MET instructors etc. Modern ICT provides a wide range of opportunities for further developments in ship management. All parties including ship officers, ship owners, classification societies and the equipment suppliers should be fully integrated in ship management (Telle, 2000). IMIMS is therefore an attempt to meet the requirement of modern maritime technology.

IMIMS consists of the ship-based system and the shore-based system by sharing the information and databases. The former services mainly for the management of single ship with collection information from integrated bridge system, power plant system, cargo monitoring and control system etc., transmits them outward and receives signals from outside. The latter services mainly for the shipping company and the fleet, communicates information between the registered ships and the shipping companies, deals with the data and information, supports for officers/engineers decision, benefits for ship maneuvering, engine operation and maintenance and surveillance, fault diagnosis and prediction, etc.

On the other hand, IMIMS can also provide some powerful tools and supports for interactive MET by sharing the resourceful database, the strong function of fault analysis and evaluation, and combining with ERS. This kind of connection can improve the training effect based on the real data from ships. It also can help to improve the physical models and mathematical models of engine room simulator, to make the simulator having tremendous training and research potential, and to perfect the engine room simulator as one of MET tool for training and examination on each level of certificates. It is also helpful in reducing human errors due to misunderstanding or ignoring the information, can benefit for trainee to learn the real reason of faults and accidents by comparing the analysis results between by trainee and by system, and can improve the MET training effect and management abilities of processing the integrated information.

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