자동화선박의 선교 레이아웃의 최적 설계

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Optimum Design of Ship's Bridge Layout for the Automated Ocean Going Vessels

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Abstract

A study on the ergonomic design of the automated ship's bridge and console layout was carried out through this paper. The goal of this study is to find out the effective and ergonomic optimal design solutions of bridge layout hence to reduce the duty officer's workload and increase the safety of navigation. The conventional bridge layouts and modernized Integrated bridge layouts were compared using several factors. To use human factors, an ergonomic control panel layout system based on constraint satisfaction algorithm was quoted. And the integrated ergonomic bridge layout was converged and applied to the redesign of the navigational console layout.

1. Introduction

In conjunction with the fast developments of computer systems, the trends of ship's automation nowadays have made automatic route tracking and automatic sailing really practicable applications by executing Integrated Navigation System(INS) or Total Navigation System as it may. The advent of INS is very desirable in the view of safe and economic operation of ships and protecting marine environments. But in spite of all the benefits of modern navigation system, unverified

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system configuration and the strange arrangement of equipments at the ship's bridge could be rather dangerous and perilous to the mariners who unfamiliar with such a new system. The design of ship's efficient bridge layout is very important for this matter and must consider ergonomics and workloads of duty officers as basic factors of the consideration to design the ship's bridge and integrated navigational console layout.

In this study, the international trends on the ship's bridge layout was reviewed and a wide questionnaire for the survey of opinions and demands about the bridge design was done against the mariners who are working on board more than 90 ocean going vessels as Masters or mates. And the result of analysis was used as one of the important basic factors concerning the ergonomic design of the bridge layout.

The conventional bridge layouts and modernized Integrated bridge layouts were compared using several factors such as the distances of duty officer's working line, the time consumed at performing the sequence of tasks at different navigational modes in bridge. For this comparison, 3 types of navigational modes were introduced and modeled as standard tasks of marine officers on duty. As a result, the integrated bridge was found as superior than conventional bridge.

To use several human factors in designing of the automated ship's bridge layout, an ergonomic control panel layout system based on constraint satisfaction algorithm was quoted. And, according to the importance principle, frequency-of-use principle, functional principle and sequence-of-use principle, the integrated ergonomic bridge layout was converged and applied to the redesign of the present navigational console layout.

2. The role of ship's bridge

Ship's bridge is the most important place where all the maneuvering characteristics of the ship are specified, ordered and monitored by navigator who is in charge of the whole control of that ship. Ship's bridge is normally defined as "an erection generally amid-ships or aft over the main deck to accomodate the chart and navigation room, generally as living quarters for the officers on duty during the navigation" or "superstructure, on upper deck, having a clear view forward and on either side, and from which a ship is conned and navigated". But these definitions are rather structural explanations about the bridge without any considerations on the man-machine interface, human behavior on the control of ship and working environments which may effect safety navigation.

Ship's bridge was developed rapidly after the advent of steel ships and at present days, the role of ship's bridge is very comprehensive. All kinds of navigational information is gathered into the bridge and processed according to certain predefined way and monitored or controlled by human or automated devices.

The principal roles and functions of modern ship's bridge can be summarized as follows;

- Navigation maneuvering and traffic surveillance
- Route planning and route tracking
- Extended monitoring on the marine safety (GMDSS)
- Alarm and monitoring of propulsion machineries
- General communication and information exchange
- Cargo handling or monitoring, ballast control
- Operating of integrated ship management system

3. Navigational modes of the ship

The kinds of information which navigator needs to control the whole ship are various. It can be classified as quantitative/qualitative

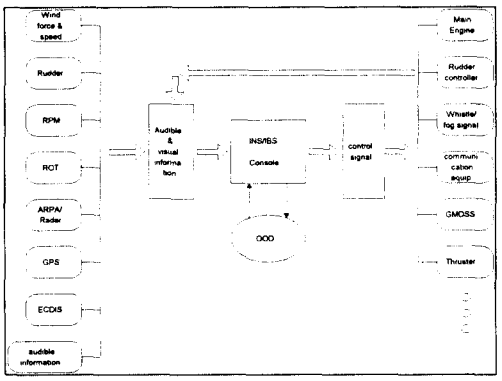


Fig. 1. Flow diagram of navigational information in ship's bridge

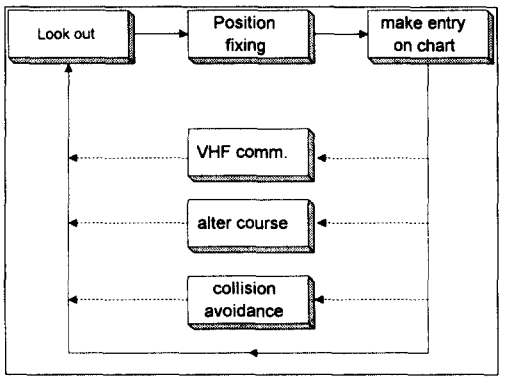


Fig. 2. Model of the bridge work sequence in coast pilot

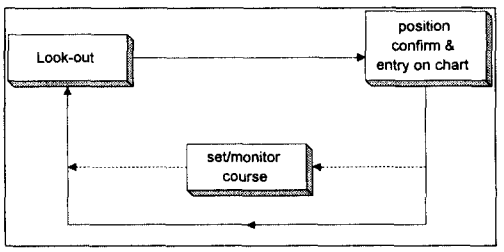


Fig. 3. Model of the bridge work sequence in ocean sailing

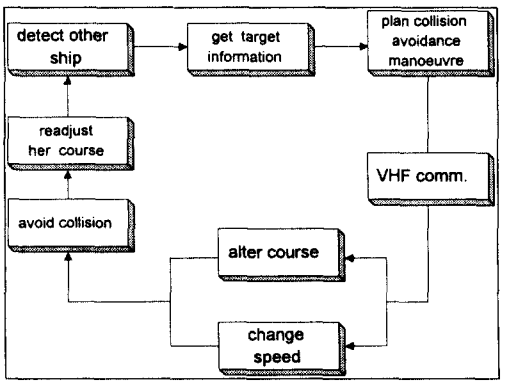


Fig. 4. Model of the bridge work sequence in collision avoidance

information, status, warning and signal information, representation, identification information, alphanumeric and symbolic information, and so on. Typical information flow diagram in modern ship's bridge is shown on Fig. 1. All these informations are provided to the officers on duty(OOD) at nearly same time and OOD should analyze, evaluate and make decisions accordingly to manoeuvre the ship and control the related equipments at once.

The content of duty officer's task is differ in navigational situations where the ship is navigating with different environmental conditions. And to design the efficient bridge layout, it is very important to analyze the duty officer's behavior and characteristics of works at different navigation modes.

The navigational modes of the ship can be classified in many ways on the basis of several related factors. In this paper, the navigational modes were classified into three parts as coast pilot mode, ocean sailing mode and collision avoidance mode. The identical ship may sail through all of these three navigational modes during her single voyage, but the kind of OOD's work, workload or stress level and the length of activity of the OOD are different. Fig. 2, Fig. 3 and Fig.4 illustrate the model of the duty officer's work sequences on the bridge with each navigational mode. Table 1 shows the contents of bridge work and related navigational equipments at each modes.

〈Table 1〉 The contents of bridge work and related navigational equipments

Navigation Mode	Contents of OOD's work	related equipments
Coasting pilot	- continuous position fixing using valid shore objects - check the bearing and distance of light house or buoy - continuous watch on the target ship's movement - safety communication with passing vessels or doubtful approaching vessels - report own ship's position to related traffic control center - look out	- Radar, ARPA - ECDIS - Gyro repeater - VHF - Manual steering system - Whistle
Ocean sailing	- look out - position fixing at regular interval - confirm her course	- GPS - ECDIS or paper chart - Auto-pilot system
Collision avoidance	- detect target vessels - monitor the bearing change between target and own ship - make communication with target ship - use whistle - position confirm and secure marginal water area - alter own ship's course - alter own ship's speed	- Radar, ARPA - Gyro repeater - ECDIS - VHF - Manual steering system - Whistle - Engine control

4. Analysis of the navigational equipments in bridge

Many kinds of navigational equipments are installed legally or spontaneously in the ship's bridge. Most of them display some kinds of visual information with or without any audible alarm signals in certain formats. But all equipments could not have the same importance or equal frequency of use by navigators. 〈Table 2〉 indicates the kinds of navigational equipments typically installed on the bridge of any modern merchant vessels.

To analyze the priority, importance and the order of frequency-of-use of the navigational equipments in bridge, wide questionnaire was done against the mariners consisted of expert marine captains and mates who were working on board. 〈Table 3〉 shows the frequence-of-use and importance level of navigational equipments at each navigational modes. Grade 5 is the highest level of use and importance which means that the equipment is very important and used frequently and continuously. Grade 4 means that the equipment is important and used frequently but intermittently and grade 3 is for the equipments somewhat important but used as occasion demands. The result of questionnaire can be used as important factors to design the ergonomic navigational console because they can present a kind of complex standard for equipment layout. The digital speed and distant indicator and NID are the most frequent-of-use equipments throughout all the navigational modes. The

〈Table 2〉 Navigational equipments installed on the ship's bridge

#	Navigation equipments	#	Navigation equipments
1	ARPA (X-band) Keyboard, track-ball	24	Navigation light control panel
2	Auto Telephone	25	Signal light control panel
3	Bow thruster control panel	26	Air temp. air pressure indicator
4	Dimmer sw. for alarm/ind. lamps	27	ARPA (X-band) Display unit
5	Dimmer sw. for ceiling lights	28	Basic alarm panel
6	Dimmer sw. for nav. Equipments	29	Digital speed and distance ind.
7	ECDIS input keyboard, track-ball	30	ECDIS Screen
8	Em'cy fire pump	31	Fuel pump mark indicator
9	Em'cy stop for accom. fan	32	GPS/DGPS navigator
10	Eng. remote control(Autochief-4)	33	Gyro repeater
11	Engine Telegraph	34	Hospital alarm
12	Fog signal controller	35	M/E order printer
13	Interphone, direct calling phone	36	Navigation Information Display(NID)
14	Radar (S-band) Keyboard, track-ball	37	Passage way water tight door ind.
15	Sound power telephone	38	Radar (S-band) Display unit
16	Steering wheel (Manual steering)	39	P.A comm. Unit
17	Test buttons(Bz, Lamp, Flicker)	40	ROT(Rate of turn) indicator
18	VHF radio telephone w/DSC, 2ndary	41	RPM indicator
19	VHF radio telephone w/DSC, primary	42	Rudder Angle ind
20	Whistle push button	43	Steering gear alarm panel (#1, #2)
21	Window wiper sw. box	44	Watch alarm lamp
22	Auto pilot control unit	45	Water depth indicator
23	Flood light control panel	46	Wind speed/direction indicator

〈Table 3〉 Frequence-of-use and importance level of navigational equipments

Grade	Frequence-of-use			Importance		
	Ocean sailing	Coasting	Collision avoidance	Ocean sailing	Coasting	Collision avoidance
5	22, 29, 32, 36	1, 7, 14, 16, 27, 29, 30, 36, 38, 42	1, 14, 16, 27, 29, 36, 38, 42	22, 32	1, 14, 20, 30, 32, 33, 45	1, 11, 12, 14, 16, 18, 19, 20, 27, 33, 38
4	7, 41, 46	10, 11, 22, 32, 33, 40, 41, 46	7, 18, 19, 30	4, 6, 24, 29, 33, 36	4, 6, 7, 11, 16, 18, 19, 22, 24, 25, 29, 35, 36, 38, 41, 42, 46	13, 24, 25, 29, 30, 35, 36, 42
3	1, 12, 14, 16, 21, 27, 38	12, 18, 19, 20, 21, 45	10, 11, 12, 13, 20, 21, 35, 40, 41	1, 7, 8, 10, 12, 13, 14,16, 18, 19, 20, 21, 25, 26, 27, 28, 37, 38, 43, 44, 46	2, 8, 10, 12, 13, 21, 26, 28, 40, 43, 44	8, 10, 15, 21, 28, 32, 37, 40, 41, 43, 46

equipments such as NID, ECDIS, ARPA, radar, steering wheel and fog signal controller are important at both of the frequence-of-use and importance.

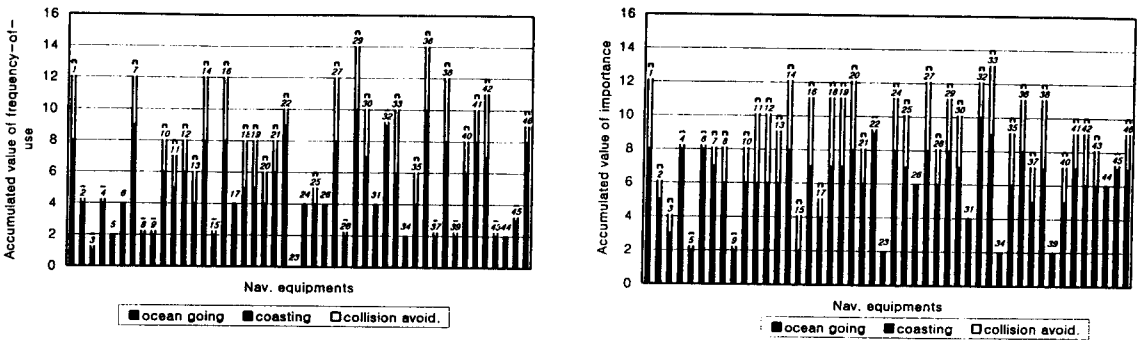
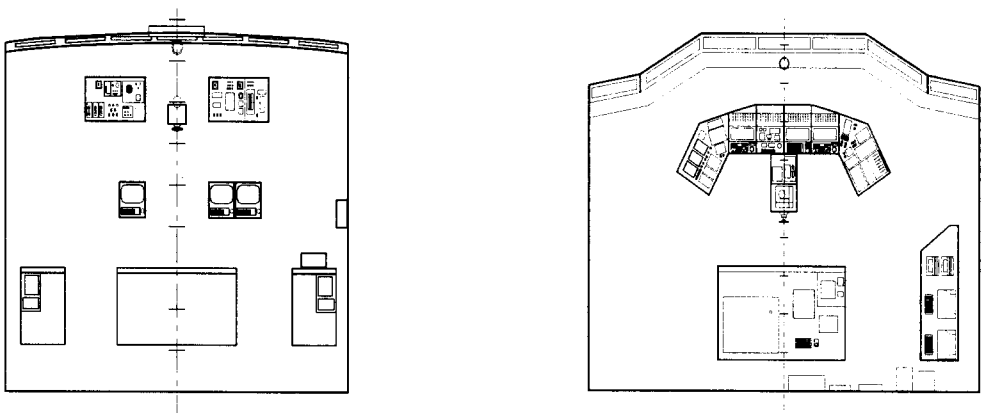


Fig. 5. Accumulated weight value of the equipments

Fig. 5 shows the result of questionnaire survey represented by the accumulated weight value of the equipments on the basis of frequence-of-use and importance at each navigational modes.

5. Comparison between Conventional and Integrated bridge layouts

Most of the ship's bridge layout can be distinguished as one of the two types, that is the conventional type and integrated type. The conventional type is the bridge which all of the navigational equipments located scattered, dispersed or as standalone consoles(Fig. 6-a). On the contrary, modern automated ships' bridge layouts tend to be integrated which has single integrated navigational console for the one man bridge operating concept(Fig. 6-b). In 1990, The comparison between two types of bridge layout was carried out with several standards such as the amount of OOD's mental workloads and/or accuracy of route tracking navigation. In this paper, the comparison was done by the length of OOD's working pass which is the accumulated activity tracks of the operator by working sequences at each navigational mode. And also



(a) conventional type

(b) integrated type

Fig. 6. Types of ship's bridge layout

〈Table 4〉 The variables for constraints

Variable	Purpose	Ergonomic basis
S_{ij}	relative location status between equipments(i, j)	functional grouping sequence-of-use
I_{ij}	finite set of equipments which can be located between two equipments	functional grouping sequence-of-use
D_{ij}	maximum distance between equipments	functional grouping sequence-of-use
PV	equipments be installed on preferred view area	frequency-of-use importance
CW	equipments be installed on comfortable control area	frequency-of-use importance

the spending time on each working sequences were considered as a comparison criterion.

In the case of activity tracks, integrated bridge was only 24%, 8% and 31% of conventional one at coasting, ocean going and collision avoidance mode accordingly. And the spending times in integrated bridge were also shorter than conventional one with the rate of 63%, 60% and 64% at each mode.

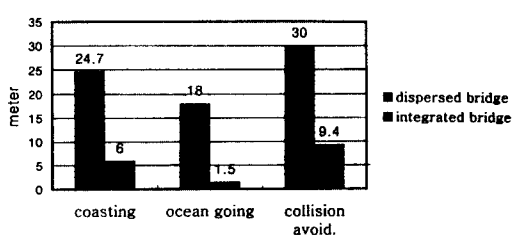
The results of comparison between conventional and integrated bridge layouts on the basis of activity track length of OOD and the comparison of spending times at each mode are shown in Fig.7.

6. Ergonomic Design of the Bridge layout

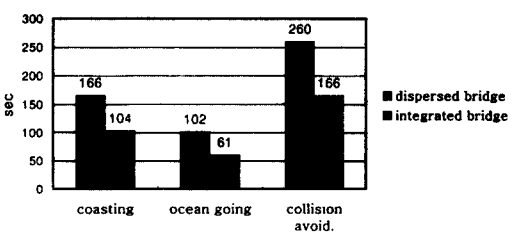
Control panel layout(CPL) is defined as a medium which is constituted during the designing process of man-machine system. Control panel designing is to design the arrangement of several control and information display devices on control panel in most effective ways to produce better work performance and an output which meets the purpose of man-machine system. There are several kinds of CPL methods like as sequential order comparison method, grouping method, user's habit analysis method and etc.

In this paper, the bridge layout design was carried out with interactive control panel layout method using importance principle, frequency-of-use principle, functional principle and sequence-of-use principle as multiple criteria.

The interactive control panel layout method is the constraints satisfaction problem method and the procedure is shown in Fig. 8. This method used several constraints like as the relative locations of equipments, finite set of equipments which can be located between two equipments, maximum distance between equipments, etc. The constraints are expressed by 5 variables which are shown on 〈Table 4〉.



(a) Comparison of the length of activity tracks at each modes



(b) Comparison of the spending times at each modes

Fig.7. The length of activity tracks of operator and the spending time

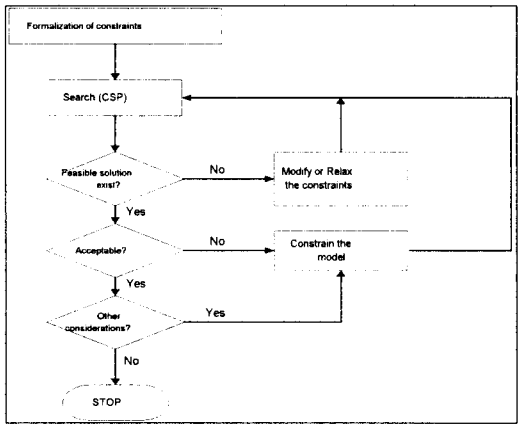


Fig. 8. An interactive and iterative layout procedure

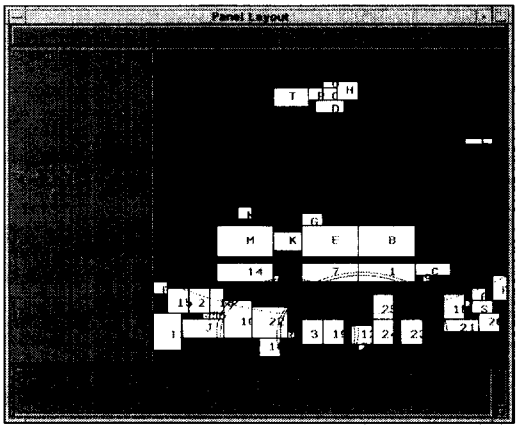


Fig. 9. layout solution after applying the constraints

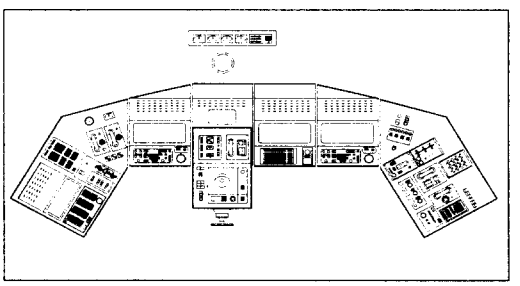


Fig.10. applying layout on cockpit type navigational console

The result of applying control panel layout method with several constraints is shown at Fig. 9 and Fig. 10 is the reflected layout of cockpit type navigational console.

7. Conclusion

A part of the ergonomic design of the ship's bridge and navigational console layout was carried out in this paper. To design more efficient ergonomic ship's bridge layout, several human factors and the experiences and opinions from the end users like pilots, masters and mates from various type of ship should be taken into the basic consideration. In this paper, to use several human factors in designing of the ship's bridge layout, an ergonomic control panel layout system based on constraint satisfaction algorithm was quoted. And, according to the importance principle, frequency-of-use principle, functional principle and sequence-of-use principle, the integrated ergonomic bridge layout was converged and applied to the redesign of the navigational console layout.

The results of study can present some guidelines on the ergonomic design of the ship's bridge layouts from the point of mariner's view.

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