# Perception of Ship's Movement in Docking Maneuvering using Ship-Handling Simulator

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**Abstract**

Recently it is coming to be high reality on visual system in ship-handling simulator depending on the technical development of 3D computer graphics. Even with high reality, it is possible that visual information presented seafarers through screen or display is not equivalent to the real world. In docking maneuvering, visual targets or obstructs are sighted close to ship's operator or within few hundred meters, so it might be possible to affect visual information such as the difference between both eyes' and single eye's visual sight. Because it is not possible to perceive of very slow ship's movement by visual in case of very large vessels, so the Doppler Docking SONAR and/or Docking Speed and Distance Measurement Equipment were developed and applied for safety docking maneuvering. By the way, the simulator training includes the ship's maneuvering training in docking, but in Ship-handling Simulator and also onboard, there are some limitations of perception of ship's movement with visual information. In this paper, perception of ship's movement with visual system in Ship-handling Simulator and competition of performances of visual systems that are conventional screen type with Fixed Eye-point system and Stereo Visual System will be discussed after experiences with visual systems to goals the performances of Full Mission Simulator. We got some conclusions not only on the effectiveness for visual system but also on the human behavior in docking maneuver.

**Keyword;** Ship-handling Simulator, Stereo Graphics, Movable Eye Point, Docking Maneuvering

## 1. Introduction

In recent years, it is coming to be high reality on visual system in ship-handling simulator depending on the technical development of 3D computer graphics [(5)]. However, even if the reality has been developed, there is a very strong possibility that the visual information presented seafarers through screen or display is not equivalent to the real world [(5), (1) (2)]. In docking maneuvering, visual targets or obstructs are sighted close to ship's operator within few hundred meters, so the visual information might be affected by the difference between both eyes' and single eye's visual sight. In case of very large vessel such as VLCC (Very Large Crude Oil Carrier), it is not possible to perceive very slow ship's movement from visual sight, so the Doppler Docking SONAR and/or Docking Speed and Distance Measurement Equipment have been developed and applied for safety

docking maneuvering. The training on ship-handling simulator produces the docking maneuvering on various vessels including these large vessels. There are some limitations to perceive ship's movement from visual sight on such as docking maneuvering. However the perception of ship's movement has not evaluated on ship-handling simulator's function up to now. In this paper, stereo visual system are proposed to bring ship's operator with realistic visual sight, and effect of stereo visual system is compared with effect of general fixed eye-point system, and it is investigated how to be affected perception of ship's movement in docking maneuvering by difference between both visual systems.

## 2. Effects on Both Eyes' visual Sight

On general visual system in ship-handling simulator, high quality 3D computer graphics provide ship's operator with virtual reality. But it is described on a plane surface such as screen or display, so ship's operator should perceive the perspective of visual targets and obstructions through the 3D image on plane visual information. In addition, the image on the screen is described according not to both eyes' visual sight but to single eye's one. It is possible that some results of various maneuvering on simulator training are affected by different reality of the visual information describe above.

### 2.1 Perspective concerned with both eyes' parallax

Perspective is often one of important information to perceive distance or movement of object exactly. Ship's operator perceives the object through right and left eyes each, and the difference between right eye's sight and left one provides the operator with perspective on the sight. So the perspective is strongly affected by parallax of both eyes, and the effect is increased to get closer to objects. In docking maneuvering, ship's operator usually perceives ship's movement through the sight of close visual objects. Therefore the simulator training, which includes docking maneuvering, might bring a different result from the real maneuvering.

### 2.2 Distance to image into focus concerned with both eyes' parallax

Fig.1 shows relationship between distance to image into focus and both eyes' parallax in wide of both eyes. It is indicated that an object in the image on close screen brings ship's operator larger parallax than the object on real sight.

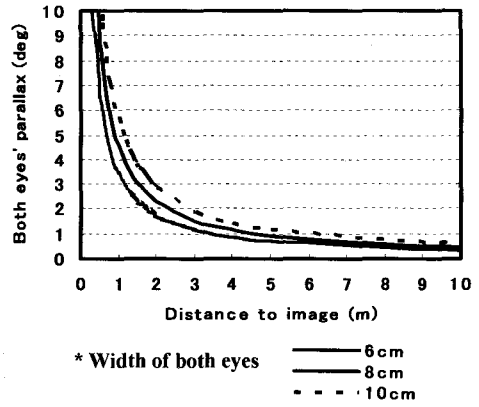



**Fig.1** Relationship between distance to image and both eyes' parallax

In ship-handling simulator, in order to remove the effect mentioned-above as possible, there is a choice to set up the longer screen distance[3]. Long screen distance moves the image away to the position affected a little by the parallax and offset perspective by live and realistic impression according to large size visual projected on enclosed large screen. But long screen distance, or long projection might bring not so bright image on the screen, and require large construction and high cost.

In case of short screen distance, ship's operator is able to get clear image and details at close range. But the operator is affected strongly by both eyes' parallax when he or she fix own eyes into objects on the image. And the operator should perceive perspective of visual targets and obstructions through the cubic effect on plane visual information.
Up to now, in ship-handling simulator, the visual system, which is able to remove unreal effect mentioned above, has not developed.

## 3. Effect on Stereo Visual System

If the training or assessment in docking maneuvering is executed using simulator with general fixed eye-point system, the result of the maneuvering might be different from reality because of wrong perception of ship's movement. Stereo visual system is expected to be effective in realistic perception of ship's movement in docking maneuvering. In order to evaluate the effect of the system, the following evaluation experiment was executed.

### 3.1 Evaluation Experiment

To grasp basic characteristic on the operator's perception of ship's movement, the perception under simple movement was investigated. The examinees as ship's operator are 5 captains and 6 mates, so total 11 examinees. Fig.2 shows the example image in docking maneuvering of experiment.
Status of the experiment is as follows.

Own ship: Container carrier. (65,000 GT, breadth 35 m, eye-height 25 m and 200 m from eye-point to her bow)
Situation: Own ship is in docking with port side along side, 35 m parallel to the berth (same as own ship breadth).
Refresh rate: 65 HZ (both fixed eye-point and stereo visual systems)
Screen: Plasma display, 65 inches. size 1,434 mm X 806 mm

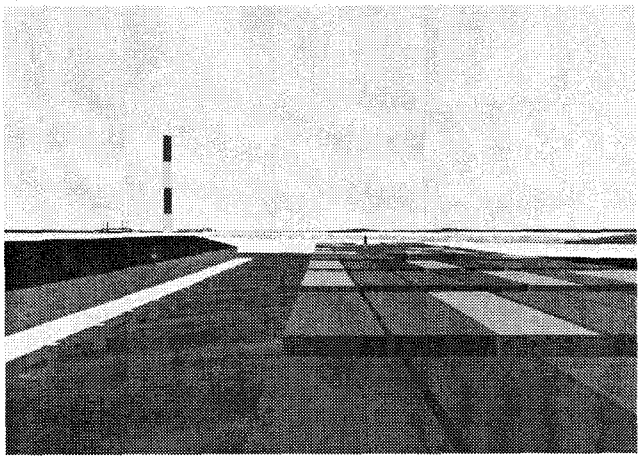


**Fig.2** Example of Image in Docking Maneuvering

The examinees should be able to behave under conditions as follows.

Position: Standing at 1 m from display as same as eye-point of image simulated on the display, horizontal angle of image 67.5 deg.
Attachment: First experiment is executed with fixed eye-point visual system, and second one is executed with stereo visual system.
Perception: Examinee answers at the time when he or she just perceive moving direction and rate each in oral.

At initial time, own ship is in 35 m (Breadth of own ship) parallel to the berth, after start own ship is "moving parallel toward the berth with 3 rate (very slow: 5 cm/s, slow: 15 cm/s or fast: 30 cm/s)", "moving parallel away from the berth with 3 rate (same as mentioned above)" or "stationary". Examinees answer the moving direction

and impression of rate (3 rate; very slow, slow or fast) as soon as he or she perceives each, at seven cases executed at random with fixed eye-point system, secondly repeated at random with stereo visual system.

### 3.2 Results of Experiment

On perception of ship's movement, the ship's operator is required to perceive direction and rate of the movement correctly. So the correctness of examinee's answer and the time for the correct perception were evaluated on the direction and the rate. In addition, it is expected that some differences will be induced on result of docking maneuvering between captain with the experience of docking maneuvering and mate without the experience. So the results of experiment divided into captains' and mates' were evaluated and discussed.

#### 3.2.1 Perception on Direction of Ship's Movement

On this experiment, the results of examinee's answer on the direction are divided into only 4 patterns as follows.

(1) Both answers on fixed eye-point system and stereo system are correct.
(2) Answer is incorrect on fixed eye-point system and correct on stereo system.
(3) Answer is correct on fixed-eye-point system and incorrect on stereo system.
(4) Both answers are incorrect on fixed eye-point system and stereo system.

It is clear that examinee on the result (1) or (4) is not affected by difference of the visual system. On the other side, it is considered that examinee on the result (2) or (3) is more or less affected by difference of the visual system. Fig.3 shows the comparison of results between captains and mates. Each pattern in the bar graph indicates ratio of the results mentioned above.

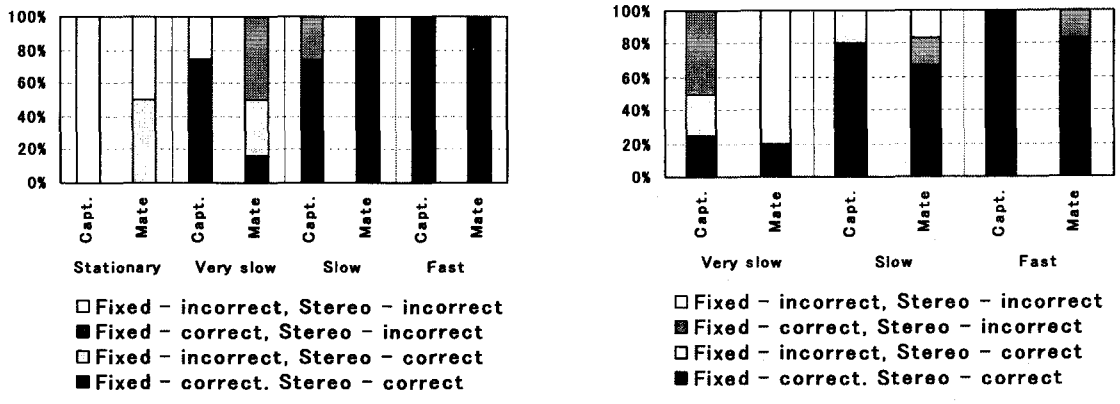



**Fig.3** Ratio on results of examinee's answer to perceive moving direction

Remarkable points in these results are as follows.

(1) On very slow movement, the effect depended on the type of visual system is observed remarkably except the result of captains under moving toward the berth.
(2) On very slow movement, there is a clear difference between captains' and mates' result under moving toward the berth, and mates are strongly affected by the type of visual system.
(3) On slow or fast movement, the effect depended on the type of visual system is not observed remarkably in both results of captains and mates.

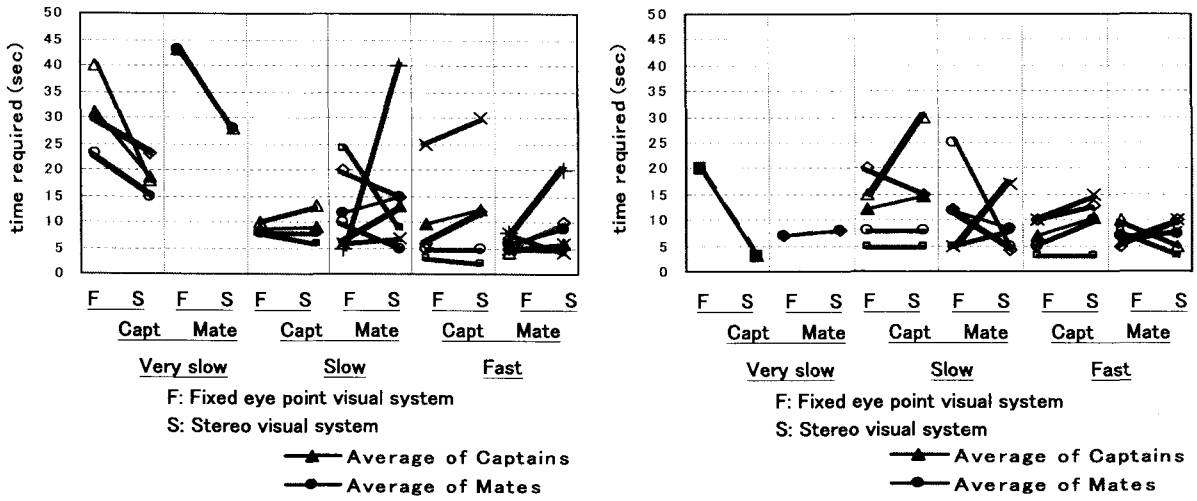
On fast or slow movement, it is easy to grasp the movement because the rate makes the image motion large and it is estimated clearly that reality of the visual sight does not affect strongly to perception of the movement.
In docking maneuvering, ship's operator should be sensitive to very slow movement especially toward the berth.

So, experience of docking improves the operator's ability to perceive the movement. Therefore, it is estimated that captains can perceive ship's movement from some fixed indexes unaffected by realistic visual sight or unrealistic sight. But mates don't have any experiences of docking maneuvering and have no fixed index to grasp movement especially under very slow rate.

There is a possibility that mates perceive the movement through motion of unrealistic image on display mentioned in section 2. So it is estimated that stereo visual system is available to provide mates with realistic perception of movement on realistic visual sight.

**3.2.2 Time required perceiving direction of ship's movement**

The result of time required to perceive direction of ship's movement is shown in Fig.4. Time variation and tendency between fixed eye-point and stereo visual systems on perception of direction is represented to these figures.




(a) Under moving toward berth

(b) Under moving away from berth

**Fig.4** Time required to perceive correct moving direction

Remarkable points in these results are as follows.

On very slow rate, time required with stereo visual system is shorter than the time with fixed eye-point visual system.

(1) In the result of captains except very slow rate, time required on stereo visual system tends to be longer than on fixed eye-point visual system, and the tendency is remarkable on the faster rate.

(2) Time required and tendency of each captain are not varied widely.

(3) Individual difference of tendency in the result of mates is larger than captains.

On slow rate of ship's movement, paradoxically speaking, there is a possibility that unrealistic image provided by fixed eye-point system delays time required to perceive ship's movement, stereo visual system is able to bring the realistic image that affect to docking maneuvering on ship-handling simulator.

In case of mates, time to perceive ship's movement is depended on index chosen, for example, relationship foremast and landmarks, relative motion of berth fenders, etc. It is possible that distance to the index chosen by mate's own is affected by both eyes' parallax and produce on the individual difference.

On the real docking maneuvering, captains know landmark on long distance is not appropriate to perceive ship's movement in slow rate, and captains perceive the movement from various fixed indexes on close sight, for example, relative motion of close object, angle variation of the object, and variation of space to the berth.

### 3.2.3 Perception on Rate of Ship's Movement

In docking maneuvering, it is important to grasp not only direction but also rate of the ship's movement exactly. So it is required to evaluate examinee's impression of the rate affected by visual system.

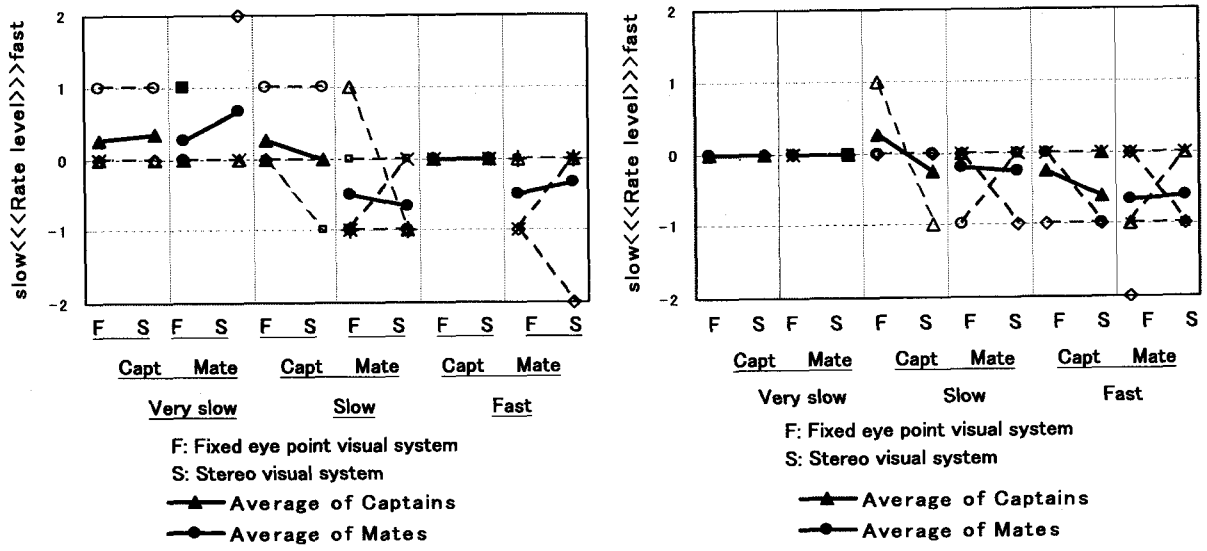
The result of the impression under each situation is shown in Fig.5. Numerals on vertical line show gap between the impression and correct rate, for example, "2" means that the impression is two levels faster than correct rate, and "–2" means opposite to it.

Remarkable points in these results are as follows.

(1) Individual difference of tendency in the result of mates is larger than captains especially on the faster rate under moving toward the berth.

(2) On very slow rate under moving toward the berth, result of captains is not affected strongly by the difference of visual system.

(3) Under moving away from the berth, tendency of captains' result is almost as same as tendency of mates' result.




(a) Under moving toward berth

(b) Under moving away from berth

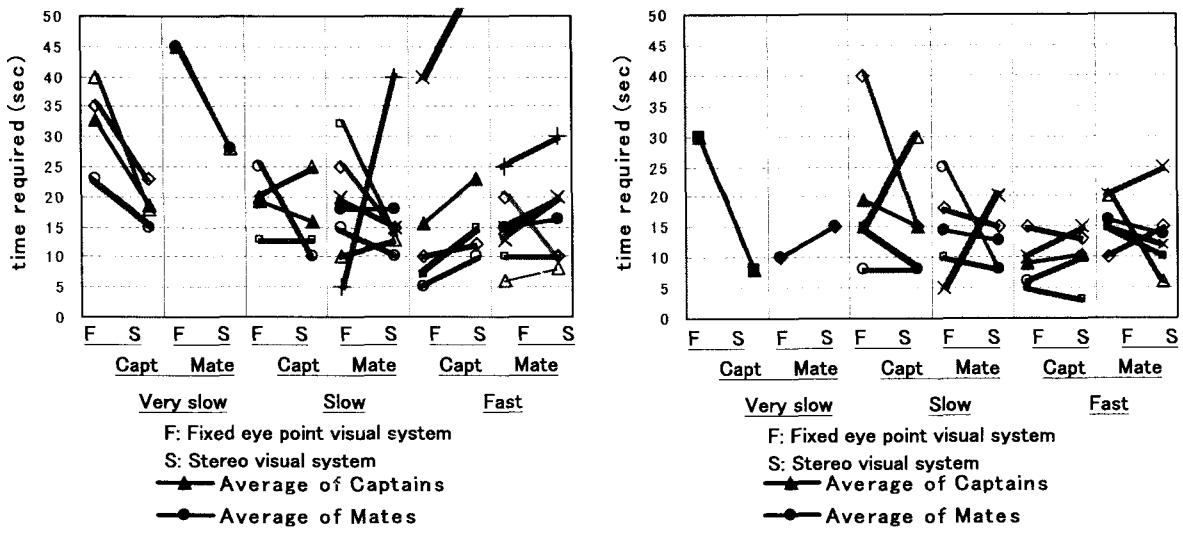
**Fig.5** Impression of moving rate perceived under moving toward the berth

On fast or slow rate under moving away, there is not any tendency and difference of the results. But under moving toward the berth, there is a clear difference between captains and mates. It is estimated that the difference is caused by the experience as mentioned in section 3.2.1.

On very slow rate, the impression of mates with stereo system tends to be faster than the impression with fixed eye-point system, so the result is affected a little by visual system. This is also caused by above reason.

### 3.2.4 Time required perceiving rate of ship's movement

The result of time required to perceive rate of ship's movement is shown in Fig.6. Time variation and tendency between fixed eye-point and stereo visual systems on perception of rate is represented to these figures.




(a) Under moving toward berth

(b) Under moving away from berth

**Fig.6** Time required to perceive moving rate

Remarkable points in these results are as follows.

(1) Individual difference of tendency in the results of both captains and mates are large especially on faster rate.

(2) In the result of captains on very slow rate under moving toward the berth, time required with stereo visual system is shorter than the time with fixed eye-point visual system.

On perception for rate of ship's movement, ship's operator has index to percept the rate developed through own experience. So it is possible that the result is affected strongly by individual experience, and individual difference might be induced larger. But time to grasp the rate is larger than time to grasp the direction, so the tendency on perception of the rate is not clearer than the tendency on the direction.

## 4. Further Problem

As discussing above, in docking maneuvering on the simulator training, some differences on effects of fixed eye-point visual system or stereo visual system on perception for ship's movement are evaluated.
Remarkable tendency depending on visual system are as follows.

(1) Ship's operator who has experience of docking maneuvering tends to perceive ship's movement correctly and it is not strongly affected by visual system.

(2) Ship's operator who has no experience of docking maneuvering tends to be varied individually on correct perception of ship's movement and it is strongly affected by visual system.

(3) Under moving toward the berth, especially on very slow rate, stereo visual system provides ship's operator who has experience of docking maneuvering with the perception of ship's movement in a shorter time than fixed eye-point visual system.

On perception of ship's movement, ship's operator is affected by image described through single-eye sight on fixed eye-point system and it is possible that perception of ship's movement is delayed. In addition, it is possible that effects induced by fixed eye-point visual system provide ship's operator non- experienced docking maneuvering with different maneuvering in real docking.
To grasp basic characteristic on the operator's perception of ship's movement, the perception under very simple

movement such as abeam and parallel movement was investigated. However, real ship's movement is very complex with different speed between bow and stern, in other words ROT (Rate of Turn) is generated. Therefore, on the training of docking maneuvering in ship-handling simulator, it is estimated that the tendency under fixed eye-point visual system describe above is appeared larger.

In the ship-handling simulator with close screen or display, stereo visual system is more available for the training docking maneuvering than fixed eye-point visual system. But close screen or display has various problems such as motion and position of eye-point, so it is required to combine stereo system with Movable Eye-point System [3], [4] in order to remove the effect of maneuvering caused by unrealistic visual information, and systematic validation on combined visual system should be evaluated. In addition, visual image on not only closed screen or display but also others will be applied stereo visual system for realistic perception of ship's movement in docking maneuvering on ship-handling simulator such as wing-mode type.

## 5. Conclusion

It is concluded that the stereo visual system is available to simulator training including docking maneuvering in small-sized ship-handling simulator that has close screen or display. And it is not required to supply large construction in order to provide ship's operator realistic visual information that affects to result of maneuvering.

## Reference


(1) Yasuo Arai, Hiroaki Kobayashi, Makoto Endo, Masanori Endo, Hiroyuki Mizuno, Shiro Arai, Masanori Tsugane, Shoichi Senda, Shin Murata and Tomoki Oku, "A Study on the Systematic Validation of Ship-handling Simulator's Function Corresponding Nautical Missions", Conference Proceedings MARSIM2000, pp.97-112, 2000

(2) Y. Arail, H. Kobayashi, M. Endo, M. Endo, S. Arai, M. Takeuchi, M. Tsugane, S. Senda, S. Murata & T. Minamiya, "Systematic validation on ship-handling simulator's function for its utilities", MARINE TECHNOLOGY IV, pp. 21-30, 2001

(3) Yasuo ARAI, Taro MINAMIYA, Shigeyuki OKUDA "Basic Study on the 3D Visual System for Multiple Eye-points", The Journal of Japan Institute of Navigation, Vol.107, ISSN 0388-7405, pp.55-60, 2002

(4) Yasuo ARAI, Taro MINAMIYA and Shigeyuki OKUDA "Ship-handling Simulator Using Multi-Movable Eye points Visual System", Conference Proceedings of MARSIM'03, Vol.1, pp. RA-29-1-7, 2003

(5) Masatoshi Endo, "Survey of New Technology and its Application on Ship Maneuvering Simulators", NAVIGATION, Vol.150, ISSN 0919-9985, pp.33-38, 2001

(6) Hiroaki Kobayashi and Akiko Uchino, "On the Human Characteristics Concerning Visual Information", The Journal of Japan Institute of Navigation, Vol.91, ISSN 0388-7405, pp.255-261, 1994