Systematic validation on ship-handling simulator’s function for its utilities

Y. Arai¹, H. Kobayashi², M. Endo³, M. Endo², S. Arai⁴, M. Takeuchi⁴, M. Tsugane⁵, S. Senda⁶, S. Murata⁷ & T. Minamiya¹

¹Marine Technical College, Japan.
²Tokyo University of Mercantile Marine, Japan.
³Toyama National College of Maritime Technology, Japan.
⁴M.O.Marine Consultant Co., Japan.
⁵Japan Marine Science, Japan.
⁶M.O.L, Japan.
⁷Institute for Sea Training, Japan.

Abstract

Ship-handling simulator is often used to train seamen for maneuvering and/or to research marine environments and so on. Lacking the validation for the simulator's function, it is so often that the construction of very expensively large ship-handling simulator is adopted in order to pursue the reality of simulation too. In this reason, authors studied the validation of ship-handling simulator’s function by clarifying the role that the simulator’s function contributes for using simulators in which typical nautical missions are executed under maneuvering situations such as “Collision avoidance”, “Passing fairway”, “Approaching anchorage” and “Berthing”. The result of this study showed the relationship between the ship-handling simulator's functions and ship-operator's performance corresponding nautical missions were discussed with the results of experience using the Full Mission Simulators in Japan to validate the simulator’s function. In this paper, the relationship between simulator’s function and human performance are presented after complements of study and
proposed the simulator's function depending on visual system for its utilities. The conclusion of complements of study is such as follows: The performance of visual system, HFOV (Horizontal Field Of View) is very important not only in the stage of collision avoidance but also in the stage of berthing. So, Full Mission simulator needs wide FOV. Another performance such as AOI (Adjust Of Image-size) and texture effect not only to be realistic but also to the accuracy of observed distance. Binoculars' function is also important because of gathering information of target ship's movement and so on.

1 Introduction

Ship-handling simulator is often used to train seamen for maneuvering and/or to research marine environments and so on. However, the validation for the simulator's function is still lacking, because of over request for reality of simulation, too expensive and large construction of ship-handling simulator is often adopted. In this reason, authors studied the validation of ship-handling simulator's function by clarifying the role that the simulator's function contributes for using simulators in typical nautical missions. In this paper, the effects of simulator functions are discussed, then, for the effect of the validation, the functions of full mission simulator for its utilities are proposed.

2 Relationship between maneuvering situation and visual information

The typical and nautical missions are executed under ship-handling situations such as "Collision avoidance", "Passing fairway", "Approaching anchorage" and "Berthing". While the visual information is greatly influenced to maneuvering, it is proven that the visual information accelerates the scale-up simulator. The effect of ship operator to judgment and behavior by the visual information seems to be different by the maneuvering situation. Then, the great influences of the visual information in the each maneuvering situation are estimated shown as table 1.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Function of Visual Information</th>
<th>Bridge Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collision Avoidance</td>
<td>Horizontal FOV</td>
<td>RADAR, ARPA</td>
</tr>
<tr>
<td>Passing Fairway</td>
<td>Shading, Texture, AOI</td>
<td>RADAR</td>
</tr>
<tr>
<td>Approaching to Anchorage</td>
<td>Disturbance, Texture of sea-surface</td>
<td>RADAR, Doppler Sonar</td>
</tr>
<tr>
<td>Berthing</td>
<td>Horizontal FOV, Complexity of harbor</td>
<td>RADAR</td>
</tr>
<tr>
<td></td>
<td>Fineness of Object Image</td>
<td></td>
</tr>
</tbody>
</table>
The authors studied the effects of visual system performances [1] [2], and so advanced this study in each situation; we discussed the relationship between ship-handling simulator’s function and ship operator’s performance corresponding nautical missions as follows.

2.1 Collision avoidance

What kind of effect will HFOV and binoculars function cause in the maneuvering for collision avoidance? In the case of narrow FOV, the information on target ship beyond the limit of the FOV must be depended on RADAR and ARPA, and the accuracy of target information and time delay seems to affect the maneuvering for collision avoidance. On the binoculars function, it is an important function to grasp the vector of target ship in the long distance. Ship operator should depend on ARPA for target information without binoculars, so it is considered that the detection of course change of target ship is delayed as the result. The verification experiment of HFOV and the binoculars function in maneuvering for collision avoidance was carried out from the above viewpoint.

2.1.1 Effect of horizontal FOV

The comparisons indexes between FOV 225deg (basis) and 135deg are shown in the left side of Figure 1, according to the results of experiments carried out under the situations that the two crossing vessels closed without changing course are set, and in the initial stage one of them cannot be confirmed on the case of FOV 135 deg.

![Figure 1: Comparison of HFOV (basis 225deg), and of binocular (basis using).](image-url)
On FOV 135deg, maximum rudder angle for collision avoidance is showing a tendency to be larger than FOV 225deg. The others are shown the same tendency, that is, the case in small HFOV and in which it cannot recognize target at the start of action for the collision avoidance, it becomes an large operation in ample time, which is similar to restricted visibility. The tendency continues, after the target ship enters the visual field range, and it appears to the end of action.

On collision avoidance, especially, in the risk of collision for crossing vessel, the first found position of the target is important, and so 225deg is necessary for HFOV.

2.1.2 Effect of binoculars

As setting on the binocular function, one of the several vessels will change the course and the fear of the collision should occur. The comparison investigation by the existence of binoculars was carried out. The comparisons indexes between using (basis) and no-using binocular are shown in the right side of Figure 1, according to the results of investigation by the effect of binocular.

The indexes such as the time of using RADAR, the start time of action for collision avoidance, the frequency of steering and DCPA are evidently distinguished between “using” and “no-using”. The results are proven that to grasp the movement of target ship has been retarded in “no-using binocular” because of depending on RADAR and ARPA information calculated according to the data in a past. In the reasons, binocular function is one of the important simulator’s functions to grasp the movement of target ship on collision avoidance.

2.2 Passing fairway

In addition to lookout and collision avoidance, adjustment of the apparent course by positioning, estimation of leeway and etc. becomes an important task in the passing narrow channel and so on. The object for maneuvering contains not only artificial small objects such as lighthouse and buoy but also comparatively large objects such as island and summit of mountain. In positioning by the cross bearing and grasp of the deviation according to the object for heading mark, the visibility of the object greatly influences. The case in which the simulator is compared with the real world, the small object becomes difficult to be seen, as it becomes a long distance for the diffusion of limit and projection light of the resolution. In case of which island and summit are used as object for maneuvering, it may become difficult that the boundary in background and object for maneuvering is distinguished. In the real world, it is possible to sense the perspective, if there is an enough distance between backgrounds and object for maneuvering, by differences of the
permeability of the visible ray and so on.

In simulator, the technique of AOI that gradually increases the object size by the application of the LOD in proportion to the distance of the object is used. The shading function expresses shade and shadow by one light source (such as sun). When this function is used, it is effective to clarify the distance relation, even if the same colored object overlaps, because the contour of the object is conspicuous. In addition, it is effective that texture brings about the perspective sense by the size of the pattern. What kind of effect AOI, shading function and texture function concretely causes the maneuvering, and simulation experiment of narrow channel navigation was carried out, and the effect of the function was verified. The indexes in figures show having the simulator function for the alphabet shown in the following.

T: Texture function (texture on mountain surface)
S: Shading function (shading on the surface of objects)
A: AOI function (lighthouse, light beacon, buoy)

2.2.1 Effect of texture function
On passing fairway, detecting and utilizing of island and summit is indispensable to heading mark and positioning object. In the result of verification, the visibility and utilization are raised by putting texture such as shown in Figure 3 and 4. However, only putting texture doesn’t take effect well, but to put shading together takes remarkable effect.

2.2.2 Effect of shading function
To put texture on island and summit, not only increase attendance, but also effect for ship-handling information of visibility and positioning, it is mentioned, but the most effective function for detecting island and summit is the shading function such as shown in Figure 2 and 3. In short, for the visibility, to put the shading function is the most suitable but to put texture together does not have the intended effect. In the discussion from the

![Figure 2: Visibility of object.](image1)

![Figure 3: Utilization of object.](image2)
view point of visibility, only shading function is the most effective, in the case of reality, island and summit are sometimes in front of other mountain and it is difficult to distinguish them. In the case of requirement for reality, it is necessary to have both texture and shading function.

2.2.3 Effect of AOI function

The visibility and utilization of small object such as lighthouse and buoy is shown in Figure 2 and 3. The effect of lighthouse is appeared remarkably. And, in the case of without AOI function, the effect of shading function is appeared. On the buoy and light beacon, showing the figure, the effect of AOI is appeared but it is not as well as lighthouse. It is reason that the image size adjustment dependent on distance is set the same situation, 3,000m and 6,000m as lighthouse. In the case of smaller object than the lighthouse, the distance for adjustment should be set dependent on the original size.

2.3 Approaching to anchorage

The texture is the function, which perceives inclination sensation, namely the depth feel, of the sea surface by the pattern for the ship operator. It is said that the relative movement brings about the speed sense. It is necessary to carry out the investigation of whether the effect affects the ship handling how much. The experiment was carried out on the assumption of anchoring in outside of the harbor that a grasp of exact speed and distance is necessary, and again, that visual information of shore and object is scarce.

2.3.1 Effect of wave texture

The comparisons indexes between “with wave texture” and “without wave texture” are shown in Figure 4.

![Figure 4: Comparison of effect with or without texture.](image-url)
On without "wave texture", there is more frequency of information demand than with "texture". The difference of speed sensation and depth feel with the wave texture seemed to appear on this. On the deviation (absolute value) between positions of diminishing speed plan and maneuvering result, the comparisons indexes are appeared little. So, more data of the experiment results is necessary to find some tendencies. On deviation between scheduled and result anchor position, there are not any comparisons between "with" and "without" under calm, and almost result are concentrated about 200m. From this fact, it is to obtain speed and range information by the instrument except for visual information properly. So, in the condition without external force, ship maneuvering is not influenced by existence of wave texture. Under external force, the deviation on "without" is approximately two times larger than on "with". The appropriate steering seemed to be possible by wave texture in spite of the frequency of an information demand.

The delicate movement of the ship in the stage of very low speed is detected by the wave texture, and the appropriate maneuvering becomes possible.

2.4 Berthing

In maneuvering for berthing, it becomes a situation, which extremely approaches the shore in comparison with maneuvering phase in order experiment. The proportion, which the shore image occupies in the display screen naturally, increases, and it is clearly distinguished to the shape of structure of one piece. What kind of effect is will cause the ship-handling by degree of details of the shore image and by the size of level angle of visibility? As an influential factor for the ship-handling, HFOV, complexity of the harbor and quality of the image of maneuvering object were taken up, and the experiment was carried out.

2.4.1 Effect of object shape in harbor

4 types of harbors were set in combination of harbor shape and image quality, and several patterns of berthing experiments in combination of 6 indexes were carried out, and the result of the experiments were compared, then the effects of indexes were considered.

The indexes are shown in the following.

- L: Large HFOV (200-225deg), S: Small HFOV (100-165deg)
- C: Complex shape of harbor (complicated harbor surrounded by wharves, BW, etc.)
- S: Simple shape of harbor (the harbor only of the dolphin pier in opened sea area)
- 3D: 3D object image (building and enormous tank are simulated 3D)
- P: Pole object image (building is simulated in the column)
The comparison of simple and complex harbor on ship-handling are shown in Figure 5.

![Graph comparing deviation, rudder angle, and distance for simple and complex harbor](image)

**Figure 5:** Comparison of effect in simple and complex harbor.

On deviation from planned course line, on average of rudder angle and on remaining distance in first thruster using, all results of simple harbor is larger than complex harbor. It is proven that the ship-handling on simple harbor takes large action because of ample sea room for ship-handling. In addition, it is limited that the information of ship position and delicate movement is taken by simple shape of harbor, so judgment and behavior of ship operator is often delayed. The result of ship-handling is dependent on harbor shape even if the same course and heading mark is set.

The comparison of 3D and pole object on ship-handling are shown in Figure 6.

![Graph comparing 3D and pole object](image)

**Figure 6:** Comparison of effect with 3D object or pole object.

In complex harbor, the deviation in remaining 0.5miles to berth and also the average of rudder angle on pole object are larger than on 3D object. Then, remaining distance in first
thruster using on pole object is smaller than on 3D object. Namely, the ship-handling on pole object tends to be delayed because of the difficulty to grasp ship position and delicate movement from pole object. So, it is necessary on berthing that the objects in harbor are simulated 3D. In simple harbor, dispersion of the ship-handling result is large due to ample sea room for ship-handling, so tendency of 3D object and pole object is not appeared remarkably. And, the degree of clearness and accuracy on the 3D object is not verified yet, so the verification on detail of the 3D object is a subject in future.

2.4.2 Effect of HFOV

The comparison of remaining distance at the point of using eng. is shown in Figure 7. Remaining distance at stop’d eng. on 225deg. is larger than on 135deg. It is proven that the large HFOV provide the information so much more for FOV, but the information from small HFOV is insufficient, so the ship-handling in this case is delayed. It is the better that HFOV is as large as possible. But in future, the degree of HFOV should be verified.

![Figure 7: Comparison of remaining distance at the point of using eng.](image)

3. Proposal of simulator’s function depending on visual system

In the field of ship-handling simulators, many types and levels of performance exit. The Levels of simulator that can be distinguished are suggested in the design draft and are as follows; (category1) Full Mission, (category2) Multi Task, (category3) Limited Task and (category4) Single Task. Full Mission Simulator in (category1) is said that “Capable of simulating a total environment, including capability for advanced maneuvering and pilotage training in restricted waterways”[3] So, we discussed the effect of simulator’s performance to the behavior and the maneuvering results in 4 cases such as “Collision Avoidance”,

---

"Passing Fairway", "approaching anchorage" and "berthing". Then, for the effects of visual information mentioned above, the functions of full mission simulator depending on visual system for it's utilities can be proposed. The proposal is shown as follows.

- **Horizontal FOV**: 225deg or more to detect target in ample time on collision avoidance and berthing.
- **Binocular function**: to grasp movement of target ship in long distance on collision avoidance.
- **Shading function**: to raise visibility of the object for distinguishing on positioning.
- **Texture function**: to raise the presence (putting shading function together for prevention of protective coloring).
- **AOI function**: to raise visibility of small object in long distance on positioning.
- **Wave texture function**: to grasp delicate movement of ship in the stage of very low speed.
- **Complex shape of harbor**: to make no difference from real ship-handling on berthing.
- **3D object in harbor**: to grasp delicate movement of ship on berthing.

4. Conclusion

In this paper, the relationship between simulator’s function and human performance are presented after complements of study and proposed the simulator’s function depending on visual system for its utilities. However, in a future, it is necessary to verify the effects of clearness and accuracy on visual information. And on the visual system dependent on moving of eye point, for example, wing mode maneuvering on simulator, it must be verified and validated what influence the behavior of ship operator is.

References

