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論 文

On the Visual Scene Validity of the Microcomputer Aided Port Design Simulator

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마이크로 컴퓨터를 이용한 항만설계 시뮬레이터의 영상정보 신뢰성에 관한 연구

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Abstract

One of the main uses for ship simulators is in the field of port design, and an increasing number of simulators, of varying degrees of fidelity, are being used for this purpose. An essential feature of all

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such simulators is their visual scene, which must be of sufficent fidelity to convey the key visual cues adequately.

This paper examines the ability of a number of experienced mariners to perceive speeds and distances correctly using Computer Generated Imagery visual scenes of different fidelity, compared with their performance at sea.

From the results, it was found that the microcomputer based simulator might be considered, as far as its visual scene representation is concerned, to be as valid as the full mission ship simulator for the port design task.

1. INTRODUCTION

Recent rapid developments in computer hardware, particularly in microcomputer technology, have enabled complex marine simulators to be controlled by networks of microcomputers, [1]. The main advantage of a microcomputer based ship simulator lies in its cost effectiveness, compared with a large scale full mission ship simulator, with a realistic mock-up of the ship's bridge and a visual system which produces a realistic outside view.

The small, park task simulator has to date been seen as complementing, rather than substituting for a large full mission simulator, in that its relative cheapness tends to be balanced by a perceived lack of fidelity and range of application, [2]. It has yet to be proved however whether a microcomputer based ship simulator produces results which are similar to those obtainable from a real ship in the real world. When used for their most common role, that of port design, the overall fidelity of the simulator becomes of paramount importance.

The representation of the visual scene is an essential feature of all ship simulators, as when conning a vessel in the real world the mariner or pilot uses his visual sense in preference to other sensors, particularly in a port approach situation. Change of a ship's position, speed and heading, and those of target ships are all initially detected through visual means. It is therefore essential for a simulator to provide an adequate level of visual representation, regardless of how the scene is generated, and whether it is a nocturnal or daylight presentation. To date most opinion on the validity of a visual scene has been subjective in nature, and has been concerned more with the first impression of reality, as opposed to the success of the simulator in presenting adequate and sufficient information in an effective and economical manner.

This paper seeks to examine the validity of a microcomputer based ship simulator which was specially designed for the port design role. The simulator chosen was the MARDYN ship simulator, made by Maritime Dynamics, which was one of the earlier examples of this type of facility. The visual scene of the simulator is an elementary form of Computer Generated Imagery, (CGI), based on a single 6502 processor per channel. The CGI system is capable of representing a number of key visual cues, such as jetties, mountains, bridges and navigation aids, and up to seven target ships. The visual update rate is low, usually at typically 1 Hz, and the resolution is also low. Lights and buoys are represented, with their apparent distance being controlled by reducing their size to just one pixel and then eliminating them from the visual scene altogether, [3]. This simulator was chosen for investigation both because of its availability and also because the differences between the presentation of this simulator and others of greater fidelity will be large, giving a greater possibility of making significant validity measurements.

The visual scene validity of the microcomputer aided port design simulator is examined by comparing the results, in a typical port design scenario, with those from a full mission bridge simulator and with those from the real world in a seagoing test, (Fig. 1).

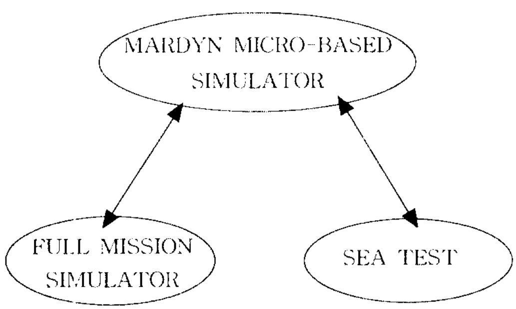

Fig. 1 Comparison Methodology-simulators and sea test

The test between the two simulators was divided into two parts; the first was an individual perception test, in which mariners' perceptions on distance, speed, bearing, rate of turn and the relative position from a leading line are measured and compared, and the second a dynamic test in which the track of a simulated ship is compared between the two simulators.

2. EXPERIMENTAL METHODOLOGY

2.1. ASPECTS OF VALIDITY OF CGI VISUAL DISPLAYS

Although the display of dynamic computer images can, through the manipulation of colour, appear to be three dimensional, the projection is to a flat screen and so has only two dimensions. This can be seen when the projected image is observed from different positions on the bridge of the ship. The position of perceived objects relative to other objects does not change with viewing position, and although this is not seen as a serious deficiency so far as detection and recognition are concerned, [2], the effect is always noticeable. In addition, a CGI scene has a limited capacity for data processing. The visual cues which are important for perception therefore should be ascertained before the modelling begins and incorporated so that correct perception can be induced with a display of only limited visual detail. A scene can, accordingly, be generated by the appropriate management of graphic elements, which, although not a true representation of the real world, is sufficient to satisfy the viewer that what is perceived coincides with reality.

In determining the validity of marine simulation imagery, it is likely that an understanding of the way in which mariners perceive their environment visually is required, as the information from instruments such as radar, compass and log, and noise, vibration and other factors in addition to the visual scene, all make a contribution to the mariner's perception of his ship's condition.

Few simulation facilities have so far devoted much attention to the validity of various aspects of simulation. Previous work has been carried out by the Computer Aided Operations Resarch Facility, CAORF, [4],[6], and the Marine Research Institute Netherlands, MARIN, [1]. In the present study, comparison of the validity of the visual scene of the MARDYN micro based simulator is assessed partly by comparing its performance with that of a full mission simulator established at the Korea Marine Training and Research Institute. For the purpose of this exercise, the visual scene of this simulator is assumed to be valid, as it uses a system of similar complexity and fidelity to that of CAORF, the validity of whose visual scene has been assessed as having a degree of realism sufficient for valid simulation, [5],[6].

2.2. PERCEPTUAL INFORMATION AVAILABLE FROM VISUAL SCENE

To validate the visual scene of a simulator, it is a prerequisite to examine the type of information mariners can obtain from a visual scene. Ringrose, [2], divided the information into three categories; distance, speed and rate of turn. In this paper, however, the visual information obtainable is considered to be in five categories; distance, speed, bearing, rate of turn and relative position from a leading line. Each of these five types of information is considerd to be relevant to the task of visually conning a vessel. The primary information which the human eye can detect are distance and bearing, while speed and rate of turn are evaluated by the mariner from these primary quantities.

Distance is perceived directly, and judged by experience and feeling based on previous knowledge, whereas speed judgement involves psychological interpretations which are more complex than direct distance perception. The means by which mariners perceive their own ship's speed visually are from the movement of the ship against a background of static objects, and from the movement with respect to the adjacent sea surface. The open sea situation, where there are no conspicuous visual cues, therefore provides less accurate perception information than does a port area. Similarly, the perception of both bearing rate of turn is more difficult in the open sea, where there are fewer vertical lines against which the relative bearing and rate of change can be assessed.

2.3. EXPERIMENTAL PROCEDURE

The experiment is divided into two parts, an individual perception test and a dynamic test. In the individual perception test, the level of accuracy of perception of distance, speed, bearing and rate of turn in a simulated port approach is scored separately and an analysis is made statistically of the results from the visual scene of each simulator, to ascertain what information mariners obtain from the visual scene, and how much difference in accuracy exists between the two visual systems. The dynamic test is aimed at comparing the fidelity of the two visual presentation systems in an overall manner, by comparing the swept paths of two simulated ships, each undergoing an identical task in each simulator. The cost function used in the dynamic test is the total area of the path deviation from the ideal track, or $\int_0^t y(t)dt$, where y(t) is the deviation from the ideal track with respect to time.

Only visual information was provided for either test, all other sensory cues being blanked out in the simulators, in an attempt to compare the information obtained from visual cues alone.

It will be appreciated that in the dynamic test, the track will be affected by the dynamics of the simulated vessel and the ability of the individual mariners as well as the information from the visual scene. Since the way of making a ship model is different between the two simulators, it was not possible to use a model from the full mission simulator in the port design simulator. The ship mathematical model for the port design simulator was, therefore, developed from the performance data of the chosen model of the full mission simulator, and considerable efforts were made to make the performance of the ship models in each simulator identical. Table 1 shows a comparison between the key performance parameters between the two simulated ships, from which it may be deduced

Table 1. Differences of Performance Parameters Between Two Ship Models

Ship Type: Bulk Carrier Size: 60,000 dwt Length pp: 247m			
Performance:	Bridge Sim	Micro Sim	Diff %
Circle			
Transfer, m	445	470	5.6
Advance, m	767	820	6.9
Tactical Dia, m	777	850	9.4
Acceleration time, to 2/3 speed, s	390	385	1.2
Inertia time, to 1/3 speed, s	960	930	3.1

that the performance differences are likely to be small. The ship's reaction to the rudder angle is thought to affect the cost function a lot in the dynamic test. To minimise this effect, the rudder response time were checked for both models, and coefficients of the model for the port design simulator were adjusted so that a variation in its reaction of less than 5% was observed. Three different mariners were asked to con each simulator in an attempt to eliminate the variability between pilots.

2.4. EXPERIMENTAL SCENARIO

(1) Simulated Waterway

The same port area was used for each simulator, Busan harbour, Korea. for the purpose of the tests, an artificial waterway was designed in the outer harbour, consisting of two breakwaters and a channel with two pairs of leading marks, (Fig. 2). Since it was not possible for the author to put new breakwaters and buoys in the database of the full mission simulator, the existing Nos. 3 and 4 buoys were assumed to be the ends of the inner breakwaters. For the same reason the ends of the outer breakwaters were made up of two stationary ships, 252m long. Leading marks for the second leading line were made up of a sailing boat and a pilot boat.

For the microcomputer based simulator, buoys were used as the leading marks and actual breakwaters were used, consisting of visual curtains of the same size as the ships making up the breakwaters of the full mission simulator.

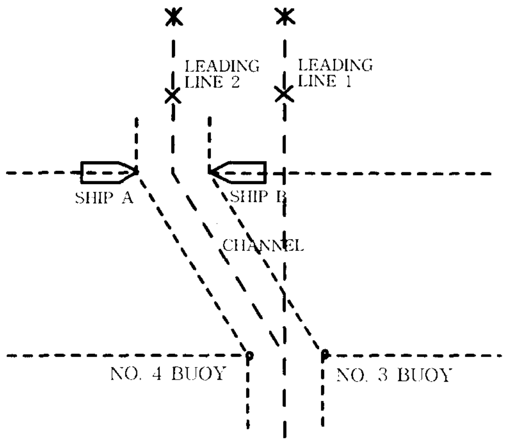

Fig. 2 Layout of Artificial Harbour

(2) Individual Perception Test

In the Individual Perception Test, 20 mariners, each qualified to at least Second Mate standard, were asked to answer a number of questions relating to their perception of the visual scene while the model ship was being conned along the designed channel. Before the test run started, test subjects were informed of the ship's length, capacity and height of eye, which were 247m, 60,000 dwt and 21m respectively. Information on the distance between the two buoys, 385m, the length of the moored ship, 250m, and the total length of the channel, 2,570m, was also given. A short briefing was given to enable the subjects to understand the objectives of the experiment and the scenario through which the ship was to be conned. The method of questioning, whereby questions were asked during the vessel's manoeuvres, was explained. Subjects were asked to answer each question as accurately as possible, leaving the answer blank if they were unable to provide an answer.

The questionnaire, designed to obtain quantitative data on the perceptions of distance, speed, bearing, rate of turn and distance from a leading line, is reproduced at Annex A.

(3) Dynamic Test

Each of three experienced mariners, with sea experience of between 5 and 10 years, was asked to con the simulated ship along the artificial waterway so that the vessel passed along the two leading lines, and along the channel line between the two sets of breakwaters. The engine speed was kept constant and no additional information was available from instrumentation. Each subject was allowed two familiarisation runs before any experimental runs were attempted. A total of 9 runs was carried out by all mariners, except two, who were able to complete only 6 runs.

(4) Sea Test

Poor perception of distances and speeds in either simulator could be due either to the poor performance of the simulators or to the difficulty of mariners perceiving these quantities at sea. An important part of the experiment was therefore to test the ability of mariners at sea, carrying out similar tasks to those of the Individual Perception Test. The training vessel Margherita was made available for this task, with the support of the on-board staff. Margherita is a converted minesweeper of 32m length and an eye height of only 6m, operating from Cardiff. The sea test was carried out at calm sea with no wind, as was the case of the simulator. While ideally a ship of similar size, operating in the same sea area would be more suitable, this ship nevertheless provided a sea environment in which to test the perception of mariners in similar circumstances. As the size and, type of the real ship was different from those of the simulated ship, the dynamic test was not carried out for the real ship. A series of questions was asked which were as near as possible to those asked in the simulators, modified only by the necessarily changed environment.

3. ANALYSIS AND RESULTS

3.1. ANALYSIS METHODOLOGY

(1) Individual Perception Tests

To perform a statistical analysis for the perception of distance, bearing, speed and rate of turn, six null hypotheses are made. To test the hypotheses, the results of the experiments are analysed by a T-Test, since the variations of the populations are unknown and the size of the samples is 20, [8],[9]. The analysis was carried out using the SPSS-X package. A two-tailed test was performed, and the significance level, which is the probability of rejecting a null hypothesis Ho when it is true, was chosen as 0.05. A null hypothesis Ho is rejected if a two-tailed probability for it is less than the significance level 0.05, [10],[11].

In addition to the T-Test, mean and standard deviation results are compared with real values to provide an indication of the accuracy of perception of the sample groups in each case. Similar analyses were made for both the simulator tests and the sea test. For the sea test, some minor corrections had to be made to the assessments in order to match them to the simulator results. In these case, general statistics were compared rather indirectly, the T-Test not being performed.

(2) Dynamic Test

The analysis of the dynamic test consisted of measuring the area of the swept path's divergence from the ideal track in each case and plotting the resulting Cost Function. To minimise the effects of mariner variability, the results of all three mariners on each case were averaged.

3.2. RESULTS

(1) Individual Perception Tests

1) Distance Perception

The difference between the distance perceptions for the two simulators was not regarded as significant at the 0.05 level(refer to Annex B, Table B.1). Overall distance perception was poor. The sea test confirmed that mariners' distance perception at sea is also poor, and it may be deduced that the distance perception obtained from the microcomputer based simulator is not significantly different from that in the real world. It appears also that difficulties experienced by mariners in assessing distance from a simulator's visual presentation is due not to the simulator's shortcomings, but to the human's low capability of distance perception.

2) Speed Perception

Three tests were made for the assessment of the mariners' perception of ship speed, two relating to the own ship and one relating to a crossing ship. Standard deviations of speed assessment in each simulator were large, but it is concluded that there is not a significant difference in the perception of speeds between the two simulators(see Table B.2). In the sea test, estimates of a crossing ships going at 7 knots varied from 3 to 9 knots. The statistical analysis concluded that the accuracy of measurement at sea was greater than in either of the simulators. This is thought to be due in part to the lack of cues such as bow wave and wake in the simulator visual systems. In a port design scenario, there are few occasions when a crossing ship's speed is important, and the speed of one's own ship is directly obtainable from the log information.

3) Bearing Perception

Bearing assessment was limited to objects close on the bow, and the accuracy of assessment was in all cases much higher than for either distance of speed assessment. There was no significant difference between the two simulators(see Table B.3). Bearing assessment in the simulators was, however, more accurate than at sea. This is thought to be caused more by the difficulty of providing a suitable object at sea, where the object used tended to be too close, and changing in bearing rather rapidly.

4) Rate of Turn Perception

Although the null hypothesis, of there being no significant difference between the two simulators, was again not rejected for rate of turn perception, the variance was large compared with the mean in each case(see Table B.4). This suggests that mariners find assessment of rate of turn difficult, which was confirmed by the sea test.

5) Relative Position from a Leading Line

Again there was no significant difference between the two simulators in the ability of mariners to perceive the distance from a leading line. Again also, the variance was large, and the sea test confirmed that mariners, while able to tell with near certainty which side of a line they are on, are not able to assess the distance from the line with any accuracy.

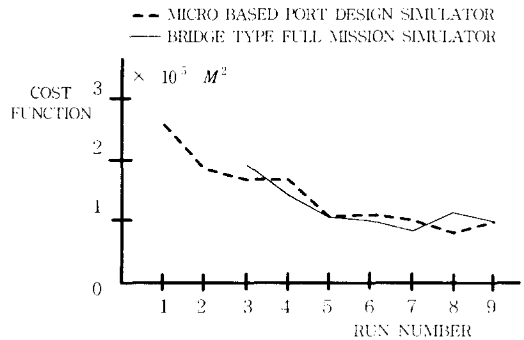

Fig. 3 Comparison of Cost Function Values between Two Simulatore

(2) Dynamic Test

The Cost Functions for successive averaged runs for each type of simulator are shown in Fig. 3. The effects of the learning process are clearly shown for the first four runs. Because of this learning phase, the analysis was carried out on runs 5-9 only. Both simulators exhibit the same tendency, of converging towards a Cost Function value of 1.0. with a difference between the two mean values of less than 0.1%.

It is concluded therefore that there is no significant difference between the quality and quantity of the information mariners receive from either simulator.

4. GENERAL CONCLUSIONS

The overall conclusions from the research are that:

① there is no significant difference between the two simulators tested regarding the ability of mariners to perceive visual cues relating to speeds and positions of ships in a visual scene.

② mariners in general perform poorly in assessing distances and speeds at sea, but can estimate a bearing close to the bow with reasonable accuracy, both in the simulator and at sea.

③ simulator visual systems without bow wave and wake representation do not appear to give sufficient cues for mariners to assess a target vessel's speed accurately.

④ rate of turn assessment is uniformly poor in both simulators and at sea.

⑤ the microcomputer based simulator may be considered, as far as its visual scene representation is concerned, to be as valid as the full mission ship simulator for the port design task.

The overall results of the tests show sufficient correlation between the micro based simulator, the full mission simulator and reality for port design tasks to be undertaken using a simulator's visual imagery. It should be noted that for performing actual port design tasks, additional information will be availavle to the mariner.

As all mariners taking part in this experiment were experienced to at least Second Mate level, no conclusions can be drawn on the suitability of visual systems for training inexperienced mariners.

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ANNEX A : List of Individual Perception Questions.

1. What is our distance from the buoy on the starboard side?
2. What is the speed of our ship?
3. What is the bearing of the biggest island in front? (Own ship's heading is given).
4. What is the speed of our ship now? (Speed is changed without informing subjects).
5. What is the speed of the crossing vessel? (Own ship's speed is known to the subjects).
6. What is our distance from the crossing vessel?
7. What is our distance from the bow of the ship on our starboard side?
8. Is our ship turning to starboard or to port?
9. The maximum rate of turn of this ship is --- degrees per minute. What is our present rate of turn?
10. Is our ship to port or to starboard of the leading line ahead?
11. By how many meters is our ship away from the leading line?

ANNEX B : Tables of the T-Test Results

Table B.1 Results of T-Test on Distance Perception

T-TEST

GROUP 1 _ SIM EQ 1: BRIDGE TYPE
GROUP 2 _ SIM EQ 2: PORT DESIGN

Variable	Number of Cases	Mean	Standard Deviation	t Value	Degrees of Freedom	2-tail Prob.
Q1 "Distance Perception of Near Object"						
GROUP 1	20	252.00	115.92			
			Pooled Var. :	.41	38	.684
			Separate Var. :	.41	37.77	.684
GROUP 2	20	237.50	107.29			
(Real Value; 260)				(F Value; 1.17	2-tail Prob.; .739)	
Q6 "Distance Perception of Far Object"						
GROUP 1	20	885.00	354.70			
			Pooled Var. :	.36	38	.721
			Separate Var. :	.36	36.91	.721
GROUP 2	20	840.65	422.02			
(Real Value; 800)				(F Value; 1.42	2-tail Prob.; .456)	

Variable	Number of Cases	Mean	Standard Deviation		t Value	Degrees of Freedom	2-tail Prob.
Q7 "Distance Perception of Medium Distance Object"							
GROUP 1	20	384.50	187.54				
				Pooled Var. :	-.59	38	.558
				Separate Var. :	-.59	32.42	.558
GROUP 2	20	414.00	120.63				
(Real Value; 350)					(F Value; 2.42	2-tail Prob.; .062)	

Table B.2 Results of T-Test on Speed Perception

T-TEST

GROUP 1 _ SIM EQ 1: BRIDGE TYPE

GROUP 2 _ SIM EQ 2: PORT DESIGN

Variable	Number of Cases	Mean	Standard Deviation		t Value	Degrees of Freedom	2-tail Prob.
Q2 "Speed Perception of Own Ship"							
GROUP 1	20	7.4250	2.662				
				Pooled Var. :	-1.91	38	.064
				Separate Var. :	-1.91	35.91	.065
GROUP 2	20	8.8650	2.082				
(Real Value; 10.0)					(F Value; 1.64	2-tail Prob.; .229)	
Q4 "Speed Perception of Own Ship"							
GROUP 1	20	8.1350	2.890				
				Pooled Var. :	1.99	38	.054
				Separate Var. :	1.99	30.82	.055
GROUP 2	20	6.6400	1.707				
(Real Value; 8.4)					(F Value; 2.87	2-tail Prob.; .027)	
Q5 "Speed Perception of Target Ship"							
GROUP 1	20	8.6500	3.341				
				Pooled Var. :	-.68	38	.499
				Separate Var. :	-.68	38	.499
GROUP 2	20	9.3750	3.371				
(Real Value; 5.0)					(F Value; 1.02	2-tail Prob.; .969)	

Table B.3 Results of T-Test on Bearing Perception

T-TEST

GROUP 1 _ SIM EQ 1: BRIDGE TYPE
GROUP 2 _ SIM EQ 2: PORT DESIGN

Variable	Number of Cases	Mean	Standard Deviation		t Value	Degrees of Freedom	2-tail Prob.
Q3 "Bearing Perception of an Object"							
GROUP 1	20	084.95	1.905				
				Pooled Var. :	-1.96	38	.057
				Separate Var. :	-1.96	33.24	.058
GROUP 2	20	086.45	2.837				
(Real Value; 085)					(F Value; 2.22	2-tail Prob.; .091)	

Table B.4 Results of T-Test on Rate of Turn Perception

T-TEST

GROUP 1 _ SIM EQ 1: BRIDGE TYPE
GROUP 2 _ SIM EQ 2: PORT DESIGN

Variable	Number of Cases	Mean	Standard Deviation		t Value	Degrees of Freedom	2-tail Prob.
Q9 "Perception of Rate of Turn"							
GROUP 1	20	15.90	7.174				
				Pooled Var. :	-1.44	38	.158
				Separate Var. :	-1.44	37.52	.158
GROUP 2	20	19.00	6.407				
(Real Value; 15)					(F Value; 1.25	2-tail Prob.; .627)	