The windscreen used as a display for navigation information

An introductory study

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Abstract

Grounding and collision are, next to fire, threats to a safe journey. The navigator needs to know exactly where the ship is and that the ship is on the expected route, which means that there is no risk for grounding, and finally that interference with surrounding traffic is avoided.

Navigators may suffer from loss of important information, for instance in situations where visibility is reduced and in darkness. In addition to watching the surroundings, the navigator needs to monitor the radar screen and, more frequently, an electronic chart display (ECDIS). These displays provide information but the monitoring and managing of the displays may reduce the navigator's attention on the surrounding world. A recent accident report (Investigation report C4/1998) pointed out that adjustment of sea clutter required the navigator to go through five separate steps on the radar equipment. Accidents have also happened where the navigator in the course of events have been preoccupied with e.g. adjustment of radar screen clutter (MS Sleipner, 2000).

The solution suggested here integrates information from a number of sources and presents safety-critical navigational information on the windscreen in front of the navigator. Such information can consist of markings for navigable channel, contours and waypoints of a pre-defined route, contours of shorelines and rocks, wrecks etc., and possibly heading and speed of surrounding vessels as well as information regarding the potential threat from an oncoming vessel. It is important that the projected objects are subtle and do not interfere with the navigator's focus on the real world.

The different pieces of information presented in the navigator's visual field will be picked up from DGPS/GPS, transponders, radar, ARPA and electronic chart systems (ECDIS).

In the experiment reported here a Plexiglas display covered with holographic film was used as the windscreen that safety critical information was projected on. Tracking equipment was used to let the navigator move freely and continuously have the enhanced information in the correct position, as an overlay on the real world.

Introduction

Traffic with high-speed craft (HSC) is increasing. The initial focus of the P2005-project funded by Teknikbrostiftelsen was to find out (i) how navigational information could be provided mariners in better ways and (ii) how joystick manoeuvring of high-speed craft could be improved and become less error prone.

Manoeuvring with joysticks

The manoeuvring system is highly dependent of the ship and its construction, e.g. type of hull, number of water jets, bow and stern thrusters. On the route the steering methods exercised mostly involve autopilot and course control. A haptic joystick should consequently only be useful at berthing. In such situations it could provide impressions of wind, current/tide, distance to the dock and other obstacles. The immediate risk at this moment is primarily damages to the hull, which of course can be expensive, both in terms of repair charges and non-payment of tickets depending on cancelled tours while the ship is in the shipyard. The risk for serious damage to passengers is estimated to be less likely in this situation.

The initial field studies, including interviews with masters and observations of crews in action on high-speed craft ferries (Olsson, 2001), showed that development of a new joystick with haptic feedback seemed less significant than to improve the information currently presented to the crew. This point of view is immediately related to increasing the passengers' safety rather than avoiding less significant damage to the hull at berthing. In some cases it has been possible to defer such incidents to joystick errors, for instance where modes have been mixed up or misunderstood. In general systems with a number of different manoeuvring modes should be avoided, since the risk of making mistakes increases. An optimal manoeuvring system must be efficient and effective; it shall not require different kinds of control executed to make sure that the mode is the intended.

Information presentation on the bridge

On the route, high-speed craft often travel with maximal speed, which means that the distance covered in a few seconds will be considerable and that slower traffic ahead is easily caught up with. The number of high-speed craft operators is rapidly growing as well. Our increased knowledge of the conditions on the bridge and experiences thus far support the assumption that the primary issue that needs attention urgently is to make sure that navigators know the position of their own ship, where they are heading and the positions of surrounding traffic. This information is obviously available, but not in the best possible manner. There are difficulties both in collecting and interpreting information. PCs, displays and mice/trackballs are fully introduced on the bridge, but the systems and their usability have not been adapted to the marine environment. For instance it is not feasible to have hierarchical display systems where a navigator must go through a number of screens to reach the one that has the sought after information, or to select items in menus with a mouse. Furthermore, the present situation with a number of screens connected to different pieces of equipment, basically a new screen for each manufacturer, where the navigator has to integrate and interpret valuable information to a basis for decision-making, is not viable in the long run. These conditions will most likely result in an unnecessarily growing cognitive load and deteriorated decision-making that takes longer time. The navigator has to divide his or her attention between different displays and the reality.

The marine environment requires systems to be robust, effective, displaying critical information on top, not demanding sophisticated handling that just might be accepted in an office environment. These perspectives have increased our determination to work more with the layout, integration and presentation of information on the bridge, the ergonomics of the information.

During our field studies and interviews, masters have often enough confirmed that the information environment on the bridge can be cumbersome and disturbing to decision making and depending on its layout and function hinder the crew from being in full view of the surroundings at all times. A typical example of such a situation is when the visibility is reduced by for instance fog or rough weather. At this moment there might emanate a need for scrutinising a radar echo in detail. If the navigator in this situation has to go through several steps, that involves both using roller ball, selecting menus and pressing different keys, to adjust the screen, valuable time will be lost and a completely new situation regarding position and surrounding traffic might have developed. As a consequence the risk of a grounding or collision might have increased.

The radar set must be extremely effective, efficient and easy to handle, this is the navigator's most important instrument. In demanding situations when the need is at its largest there is no time to wonder about how to perform adjustments and reduce clutter.

Besides providing information that is easier to pick up, we wanted to place safety critical information in the navigator's field of view, which would make it easily integrated with the environment. Here we have investigated the possibility of providing augmented reality projected on the windscreen.

Method

Subjects

Three male subjects with between 20 – 30 years of maritime experience (Masters) participated in the evaluation. Their current occupation varies, one of the subjects is a Master, one is a Teacher at Kalmar Maritime Academy upholding his certificates (one year sailing in five years), and one is a Chief ship inspector from the Swedish Maritime Administration.

The subjects were all familiar with the fairway chosen for the second study although one of them had not travelled there recently.

Study one

The integrated display that was to be evaluated consists of two parts, a conning display and an electronic chart combined with radar information and information on surrounding vessels.

A number of enhanced information elements (Barcheus, 2002) were presented to the subject while questions were asked about use, accuracy and visualisation. The subjects were also asked to prioritise nautical information present on a bridge. The single elements were then combined to a whole that was discussed and the subjects were given time to discuss pros and cons of the present display and possible improvements.

The subjects were interviewed one at the time. The information elements were presented in the same order to all of them and the procedure lasted in between one and one and a half hour. Each session was tape-recorded and transcribed.

Study two

Navigation information is presented on a simulated windscreen. The intended task is to evaluate subjective parameters, possible benefits and drawbacks of the suggested presentation and to judge its overall usability. The evaluation should also examine if the system is immediately comprehensible and in what direction potential enhancements should be made.

Apparatus

3D-landscape

Digital chart information issued by the Swedish Maritime Administration in mid/mif-format has been transformed into a 3D-landscape covering an area of the archipelago north of Stockholm. This is a typical part of the Swedish archipelago that embraces thousands of islands. An important fairway used by frequent ferry traffic between Stockholm – Mariehamn – Åbo/Helsinki stretches through this area. Islands have been given a height matching their size and rendered a fairly rough surface in typical colours. The rendering of the archipelago is rough but the overall impression is fairly good for the purpose of evaluating the augmented reality described below. Fairway markings as buoys and light buoys have been included and visualised in the 3D-world. Only minor adjustments of heading are required to go through the implemented fairway that stretches from southwest to northeast. The distance is about 10 kilometres. The 3D-world is projected on a silver screen size 1.73 m tall and 2.31 m wide, 3 m in front of the navigator. The projector (640 x 420 dpi) is attached to the roof 4 m above the navigator.

Shoreline information from the digital chart has been used to generate radar information. In front of the navigators place there is a flat 18" (1280 x 1024 dpi) screen envisioning a conventional radar overview. The radar has three ranges, 0.75 nm, 1 nm, and 1.5 nm. In this evaluation the radar is set to 1.5 nm, but the navigator can adjust the setting.

Behind that display there is a Plexiglas board size 0.91 m tall and 1.05 m wide, covered with a holographic film. This film admits back projection of the so-called augmented reality, showing information navigation information. The projector (1024 x 768 dpi) showing this information is attached to the floor just in front of the silver screen (pointing towards the navigator). A filter is added to diminish the light otherwise emitted from the projector.

The fairway markings included in the augmented reality are shoreline contour (blue), buoys (red and green), light buoys (red and green), fairway channel (red on one side, green on the other) and heading (white) for current ship and other ships. See

Appendix III for exact colour data. The buoys are cylinder shaped, 5 m tall, and have a radius of 1 m. The light buoys are conical, 6 m tall and have a radius of 3 m. The heading indicator is 50 m long. The symbol of the surrounding vessels was 20 m x 10 m x 1m, which means that they are four times longer in the 3D-world.

Four vessels reside in the world; they are 90 meters long, 30 meters tall and 15 meters wide. The bridge is placed 20 meters above the surface. The ship model is crude; no specific characteristics have been included. It is possible to alter speed and heading of each vessel in addition to viewing the world from each bridge. The viewing angle can be adjusted to the left or the right, ± 90°. The ship can only be manoeuvred with arrow keys at the moment; no joystick is implemented. In this experiment three boats are used, no 3 is navigated by the subject from A to D, it have a maximum speed of 30 knots, no 2 travels from B to D with a speed of 10 knots, no 4 travels from C to A with a speed of 30 knots.

A head tracking equipment is used in order to allow the navigator to move comfortably in his chair and still have the augmented reality in match of the real world (the 3D-world here). A box in front of the navigator emits red light, that is reflected on A small reflecting dot is placed between the navigator's eyes. The tracking equipment is calibrated with the subject's initial position once before each evaluation session.

Four computers in sync are required to run the 3D-world, the radar information, the augmented reality and the tracking equipment.

Scenarios

The potential augmented reality was judged to be efficient when weather conditions decrease normal visibility. Subsequently the following weather conditions were considered to be examined:

1. Dark/Augmented reality high brightness.
2. Fog/Augmented reality low brightness.
3. Dark/Augmented low brightness.
4. Fog/Augmented high brightness.
5. Dark/No augmented reality.
6. Fog/No augmented reality.
7. Clear/Augmented reality high brightness.

The subjects went through the seven scenarios below while they navigated along a fairway from a fixed starting point to where they ended up 5 minutes later. The scenarios were distributed to the subjects in a predefined order. All subjects started with scenario

7, and run through the rest as follows S1 {1, 2, 3, 4, 5, 6}, S2 {3, 4, 5, 6, 1, 2}, S3 {5, 6, 1, 2, 3, 4}. The scenarios included exposure to surrounding traffic in the fairway, overtaking a slower vessel of the same size and meeting another vessel of the same size and the same speed.

Table 1. Weather conditions, with or without augmented reality display.

Augmented reality/ Weather conditions	Without augmented reality	Visible - low brightness	Visible - high brightness
Dark	X	X	X
Fog	X	X	X
Clear weather			X

Experimental variables

Constant variables: Subject's nautical experience, size of symbols on the augmented display, colour of symbols, radar presentation mode, and calm sea conditions.

Independent variables: Weather conditions (clear, foggy, dark), augmented reality (high or low brightness).

Dependent variables: Questionnaire, interview, comments from subject's while running scenarios.

Procedure

The subjects were introduced to the 3D-world, the augmented reality and the radar according to a written instruction. They were told to take their ship along the fairway. They were told to immediately speed up to 30 knots and keep that speed. They started running a scenario where the weather is clear and the symbols on the augmented reality displayed in high brightness, and then they run through the other six scenarios in the order described above. The subjects were told to ask question and reveal their thoughts and immediate impressions while they were running the scenarios. They were also probed a couple of times to check to what degree they concentrated on the augmented reality or the 3D-landscape. The subjects were given five minutes on each scenario. In between the scenarios (except for number 5 and 6), the subjects were asked 15 questions about their impression of the navigable channel, the shoreline and situation awareness. These questions were posed on a 5-degree scale from e.g. much too bright (1), too bright (2), neither bright nor dark (3), too dark (4), much too dark (5).

In the conditions without augmented reality the scenario was stopped once and the subject was asked to estimate if the ship was within the navigable channel.

Concluding interviews with the subjects were performed according to a fixed framework, see Appendix II. The total time spent on scenarios and interview was less than two hours for each subject. The sessions were tape-recorded and transcribed.

Results, study 1

The results presented here is a summary of the comments made by the subjects. They are documented in the same order as the issues were presented to the subjects.

All subjects agreed on the potential merits of integrating information critical to navigating and manoeuvring the ship in one display.

Prioritisation of information

The most important information is heading, speed over ground (SOG), and course over ground (COG), route, deviation from route, position/heading of other vessels, and closest point of approach. Someone remarked that this information often is provided through curved vectors in present systems. It is important to know whether the vector presents information related to true or relative movement, two states that the master may switch between.

Deviation is related to the size and the shape of the superstructure, on a big ship it is very important to know, but on a small ship it becomes less important.

Two of the subjects argued that requirements differ depending on the waters. In coastal waters or harbour, deviation and rate of turn (ROT) become more important.

The strength of the DGPS/GPS-signal is required. Although there wasn't complete consensus in the group, three levels might be sufficient, DGSP, GPS or no signal.

Curved predictor

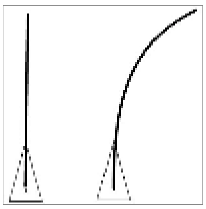

Figure 1. Curved predictor (SOG, COG, ROT), shows predicted position in one, two or three minutes.

All agreed that it must be possible to adjust the time-scale, e.g. to be able to control closest point of approach. It's not enough to see what will happen in one, two or three minutes. Preferably the adjustable scale should be continuous.

A curved predictor works well on a larger ship that holds a steady course, the continuous swerving of a smaller ship could make the prediction less useful, a behaviour that one of the subjects had experienced previously.

Principles for the electronic chart

Nobody was satisfied with the fixed chart range. The range is something you work with

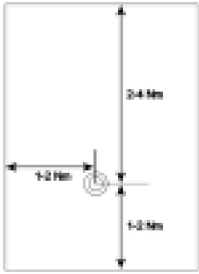

Figure 2. Electronic chart. Head-up is fixed as well as own vessel position.

continuously to watch close waters and find out what you will face further on. Depending on weather, speed and current situation, any range from 0.5 to 18 nautical miles seems to be used. One of the subjects also wished to be able to enlarge the chart to be able to use it at berthing. The position of the symbol for your own ship is acceptable, but it must be correctly scaled at berthing.

Head-up could be accepted as the sole mode according to one subject. The others argued that head-up is superior for coastal or harbour mode, while north-up is better at sea. All agreed that course-up is preferred to head-up.

Complete electronic chart

Figure 3. Complete electronic chart with radar overlay.

All agreed that the electronic chart must be as “clean” as possible; information that is irrelevant for the current vessel should not be displayed. Seven depth levels is not necessary, you only need to see if the water is deep enough for your own ship, i.e. if you have keel clearance. This also makes the figure depth superfluous as was stated by the subjects.

The position of your own ship must be the symbol you detect first, impossible to mix up with other information. The colour chosen in this presentation was not working. The most salient symbol was the light blue ARPA-generated ship symbol. One subject commented on the number of different symbols: there are three in this simple chart and that is the largest number you can handle if you want the image to be easy to scan. One subject commented that the ARPA/GPS-generated ship symbols were difficult to interpret.

The route was not included here; all agreed that it must be visible in the chart along with buoyage.

Trails of surrounding traffic were also mentioned as information that would improve monitoring.

A question was raised whether the chart would be accepted when e.g. the ship turns at high speed and the chart and the radar are mismatched for a while.

SOG

Figure 4. Speed over ground, presented in digits with an accuracy of one decimal.

All agreed that a digital presentation of speed works, the decimal might be superfluous but as one subject added it might act as an indicator of tendency to accelerate or slow down.

ROT

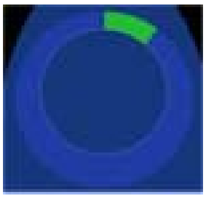

Figure 4. Rate of turn, displayed as an analogue symbol.

ROT is most important on large ships and in harbour mode. Large ships require more time before they start to turn, and even more time before the turn can be terminated. It was suggested by one subject that this symbol would be sufficient on small high-speed ferries, where you only need an indication of the direction of the turn. Two of the subjects required a symbol accompanied by the ROT in figures; some ships turns with a constant ROT. One subject suggested that a logarithmic scale would be more useful, the exact ROT is more important to see initially in a turn.

Water jet forces

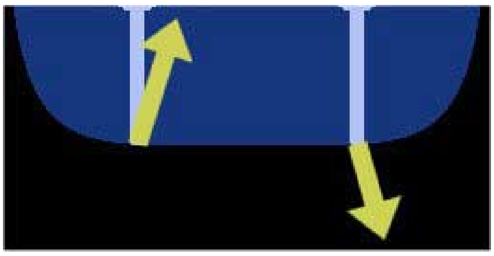

Figure 5. Indication of the direction of water jet power.

One subject thought that the presentation was reasonably correct, the others thought that it was difficult to interpret, at least initially until you become used to it. One subject commented that pilots, that are unfamiliar with the water jets, flows and buckets, might have difficulties in understanding this representation. The size of the arrows was discussed; you need to know at least the maximum size to be able to estimate the current steam, and you probably need an indication halfway between as well.

One subject commented that this information only becomes vital at manoeuvres in low speed.

It was suggested that a third arrow, placed for instance between the two propulsion symbols (see Fig 8, below green dot in the middle), could indicate in what direction the ship is moving. This might be difficult to estimate when the speed is slow.

Propulsion

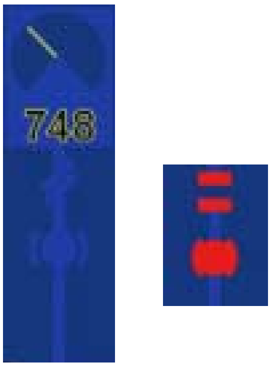

Figure 6. Propulsion and gear/brake-system, to the right the gear is not connected while the brake is engaged.

The analogue meter is sufficient, all subjects regarded the numeric value redundant. If the information is required, it was suggested that the analogue meter could have markings at the critical revolutions.

Wind indicator

Wind direction is indicated with a yellow arrow on the compass card (see Fig 8). All subjects commented that the wind in itself is not interesting; the master wants to know how it affects the ship and the deviation. The question is: What will happen when I turn 90 degrees starboard? Flags are often used as a guide rather than an instrument indicating wind speed as 7 m/s and direction as 313 degrees. Although, it was recommended that the effect of the wind might be displayed in figures as well.

One subject suggested that the arrow should point to the ship rather than the compass card.

The complete integrate

Two of the subjects sh d integrated display, while
the third remarked tha conning, complemented
with an electronic cha integrated display would
work better in coastal robably work on a smaller
vessel suggested one a larger ship you would
probably need to be b ject asked for separate
deviation indicators be

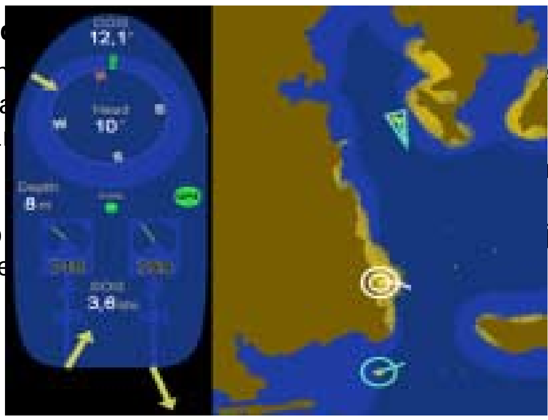

Figure 7. The complete display with conning information to the left and electronic chart to the right.

Both heading and COG should be displayed with three numerals to avoid misreading. Someone remarked that the size of the heading and the compass card in the integrated display is somewhat exaggerated.

One subject suggested that information concerning speed log and whether it is in operation would be useful in addition to the DGPS/GPS strength indicator. SOG might be calculated from the log or from GPS information.

The route information was missing in this display. In addition to route, one of the subjects wanted to see course to waypoint, distance to waypoint and cross track.

One of the subjects remarked that an indication of communication channel was missing. The master handles the communication and it is probably a good idea to show current channel.

One subject suggested that the best would be if integrated displays were standardised, but, on the other hand, it would be nice if you could customise the contents according to your own needs, since the preferences differ between individuals.

One of the subjects suggested after the evaluation that the potential benefit of the integrated display was less than that of the augmented reality (see Study 2), enhanced with conning information.

Results, study 2

Table 1 gives an overview of means and standard deviations for the 15 questions that were repeated after all scenarios with augmented reality (N=3). These results are only an indication of opinions. See Appendix IV for the complete phrasing of the questions.

Question	Mean	Std. Deviation
1. Fairway – brightness	2,67	,976
2. Fairway – colour	2,87	,834
3. Fairway – importance	4,07	1,163
4. Fairway – use in darkness	1,93	1,100
5. Fairway – use in fog	2,73	1,486
6. Fairway – situation awareness	3,20	1,373
8. Fairway – perception of future	4,07	,704
9. Shoreline – thickness	3,20	,775
10. Shoreline – colour	2,27	,704
11. Shoreline – brightness	3,20	1,082
12. Shoreline – use in darkness	3,33	1,175
13. Shoreline – use in fog	3,67	,900
14. Shoreline – perception of future	2,60	1,183
15. Shoreline – importance	3,27	1,100

Table 1. Questions asked after each scenario, descriptive statistics.

Below, the comments and subjective answers from questionnaire and interviews have been analysed and summarised for the main information elements displayed.

Radar

The simple radar only showing shorelines and ones own ship contributed to an unnatural situation. All of the subjects stated that they normally survey the radar 90 – 95 % of the time, while they frequently take a quick look over the other displays and the surroundings, varying from once to several times per minute. Weather conditions may reduce the monitoring of the surroundings to zero; the radar becomes the only means to get information on surrounding traffic. All of the subjects complained about the missing radar information regarding surrounding traffic and buoys, which normally is present. One subject said that with the augmented reality he was tricked into looking out more than he else would have done under such conditions. One of the subjects said that he would never have been driving at this speed (30 knots) under such conditions. Although, the same subject admitted later on, somewhat surprised, that he depended and trusted more and more on the augmented reality, checking the radar less and less frequently.

Shoreline

All subjects were disturbed by the blue shoreline, mostly at the start, but it kept irritating them throughout the session. It was said to be standing out too much and thereby being disturbing, it was furthermore flickering, messy, and too bright and lacked proper contrast. It was also covering the real world in the background in the clear weather condition, making it difficult to look through the augmented reality. In the condition where it was dark and the augmented reality was displayed with medium brightness, it was said to be better, even if it still was too bright, too luminous. Even if the comments on the appearance of the shoreline were negative, two of the subjects maintained the view that it is important to see the shoreline. One of the subjects suspected that he would not use the shoreline; he considered it a matter of curiosity that he could live without.

Fairway

All of the subjects were initially attracted to the fairway on the augmented reality; they agreed that the fairway gives a good perception of what will happen in the near future. Two of them maintained this positive attitude throughout the scenarios. At some point during the scenarios all of the subjects considered safe water as a competitor to the constructed fairway, safe water is a concept that a master uses in his planning of a route. One subject came to the conclusion that he would prefer to see safe water on the augmented reality, at least if the fairway was available in the conventional radar display. The subject who had not travelled these waters for some years remained most positive to the fairway through all of the scenarios.

Buoys

The subjects were positive to the buoys on the augmented reality. The dimension of buoys was matching real conditions and all subjects were satisfied with their size. Green buoys can be difficult to spot against land. Here the buoys on the augmented reality acted as a director or guidance for where to look for the real objects according to two of the subjects.

Ship symbol

One of the subjects expressed strong objections to the size of the ship symbol on the augmented reality since the size of the real ship emerging in the fog was a real surprise. The ship symbol had a heading indicator, but the ship symbol was detected before it was possible to determine in which direction the vessel was moving. Two subjects commented that this hindered their planning; they would have liked to manoeuvre their ship in a position appropriate for either overtake or meet the other vessel earlier on.

Head movements and augmented reality matching

The subjects complained that the augmented reality matched the 3D-world less perfect at the edges of the display. Otherwise they commented that is probably would be possible to calibrate a system better in a real setting with other equipment.

Discussion

Here we have tried to display the route in a kind of safe "corridor" directly on the windscreen of the bridge and in addition show the heading of the ship and headings of surrounding ships that may constitute a potential danger further on.

All of the subjects commented on fairways that they don't “exist” in reality. Fairways mainly exist in coastal waters and in harbours, and most of the time ships travel in these fairways, but not all of the time. Sometimes it might be necessary to leave the fairway to avoid a collision or some other danger. As an alternative to displaying a fairway on the augmented reality, it might be satisfactory to display navigable water and the vessels predetermined route.

The complete shoreline surrounding and island was presented in this experiment. It might be a better idea to only present the shoreline that traditional radar presents, and in addition shorten the range that is covered.

When the visibility is good there is little need for this supplementary information. The shoreline presented here may have been too crude and intrusive; otherwise it may be a good idea to let the system be active at all times to avoid problems with surprises and not being used to the information presentation. At least a warning system can always remain active.

Future work

This report describes an initial setting; our goal is not to develop a final technical solution. We want to shed light over the possibilities that new technique and novel applications of this technique offer in increasing safety at sea. In a real setting a number of technical solutions in addition to projecting information directly on the windscreen are viable, e.g., projection on special glasses worn by the navigator or laser projection directly on the navigator's retina. Whether the final solution includes glasses or visors for the crew on the bridge or other equipment is not the scope for this report.

The information presented on the augmented reality was kept down to a minimum in this setting. The possibility of including more information without compromising safety should be investigated, as was also suggested by one of the subjects, who wanted to see heading, COG, SOG etc. in the augmented reality.

When a baseline for augmented reality and its content has been established it is time for a more realistic test. In the next phase we intend to measure a number of performance shaping factors during a simulated tour, and register objective measures as well as subject opinions, in order to be able to answer questions on the effectiveness of the system and it's capability of improving safety.

Finally the improved setting should optimally be evaluated on a real bridge. No such plans are completed at this moment.

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Appendix I.

Instruction to subjects in Swedish

Instruktion till fp

Idag kommer vi att presentera ett nytt sätt att förmedla information angående strandlinjer och farledsmarkeringar till navigatörer.

Vi har byggt upp en navigatörsarbetsplats med en radardisplay och bakom den en halvgenomskinlig plexiglasskärm där information om farledsmarkeringar som tidigare har presenterats i elektroniska sjökort kommer att visas. Plexiglasskivan är tänkt att motsvara vindrutan på en konventionell fartygsbrygga. Farledsmarkeringar på plexiglasskivan har också förbundits med linjer som avgränsar farleden och har kompletterats med strandlinjer som visar omgivande öar och skär. Vi kallar informationen och dess presentationsform för **förstärkt verklighet** då tanken är att man även ska kunna se rakt igenom skivan för att inte missa annan viktig information i omvärlden.

För att kunna utvärdera om den nya informationen skulle kunna visas på vindrutan på en fartygsbrygga krävs en något så när realistisk skärgårdsmiljö som bakgrundsinformation. Därför har vi skapat en konstgjord 3D-värld utifrån sjökort 612. Den världen visas på en filmduk på väggen bakom vår navigatörsarbetsplats. Öar och landmassor har endast en kontur som har en pålagd yta, de ser alltså ut som en äppelmunk, med ett hål i mitten. Farledsmarkeringen är inte heller komplett, vi har en lagt in en liten del av farleden som sträcker sig i syd-västlig – nord-östlig riktning. Här finns endast ett antal prickar och lysbojar som gör det möjligt att navigera en kort sträcka. Prickar är 5 meter höga och har en radie på 1 meter, lysbojar har en höjd av 6 meter och en radie på 3 meter, utseendemässigt har de endast enklast möjliga symboliska former.

På plexiglasskivan visas motsvarande strandlinjer, dvs. omkretsen på öar plus farledsmarkeringar.

Radardisplayen visar radarekon efter landmassor och efter de båtar som finns i 3D-världen. Räckvidden kan ställas in i några fasta lägen, 0.75 Nm och 1.5 Nm. I radardisplayen visas också hastigheten hos den farkost som du kör i meter per sekund, där 15 m/s motsvara ca 30 knop, vilket också är maxhastigheten hos farkosten.

För att den förstärkta verkligheten ska matcha 3D-världen på filmduken när den som navigerar rör sig använder vi oss av en s.k. tracker. Du som navigatör får en liten reflekterande prick att fästa över det öga som du använder t.ex. när du siktar mot något och blundar med ena ögat. Trackerutrustningen håller reda på exakt position för den lilla pricken och anpassar projicering av förstärkt verklighet och 3D-värld till denna.

I vår värld kan man köra omkring med några färjor under olika typer av väderförhållanden. Färjorna är 80 meter långa och ca 30 meter höga och 15 meter breda. Den som navigerar befinner sig på en höjd av 15 meter över vattenytan. Alla färjorna har en prediktor som indikerar aktuell kurs, denna är 500 m lång i 3D-världen.

Din uppgift är att köra en färja i farleden under 10 minuters tid. Du kommer att köra sträckan 7 gånger under lite olika väderförhållanden. Du använder pil-tangenter för att manövrera farkosten, pil upp – pil ned för att öka – minska hastighet och höger – vänsterpil för att svänga höger eller vänster. Mellan varje körning kommer vi att ställa 15 frågor om hur du uppfattar den förstärkta verkligheten, dessa frågor kommer att alltså att upprepas sju gånger. Du får gärna kommentera saker eller ställa frågor medan du kör.

Avslutningsvis ställer vi några fler frågor där du får tillfälle att jämföra dagens navigationsmöjligheter med dem som en eventuell förstärkt verklighet skulle kunna tillföra. Sammanlagt kommer denna del av utvärderingen att ta mindre än 2 timmar.

Vi spelar in det du säger på band, men materialet kommer endast att användas av oss som underlag för utvärdering av möjligheter och svagheter med konceptet förstärkt verklighet. Jag vill poängtera att lösningen som vi har här med en plexiglasskiva där informationen projiceras bara är temporär och uppställd för att vi ska kunna testa själva konceptet. Plexiglasskivan med sin film blir lite för ogenomskinlig och upplyst, dessutom består den av fyra sektorer med holografisk film, vilket gör att färgerna varierar lite mellan dessa. På en verklig brygga kanske man skulle ha speciella glasögon, en liten skärm framför ena ögat eller rentav en liten projektor som projicerar bilden på näthinnan.

Avsikten med hela övningen är att få dina synpunkter på vårt förslag, inte att testa din prestation.

Appendix II.

Scenario questions in Swedish

1. Hur bedömer du graden av ljusstyrka/konstrast på farledslinjer i den förstärkta verkligheten?

Mycket för låg	För låg	Varken för låg eller för hög	För hög	Mycket för hög

2. Hur bedömer du färgen på farledslinjer i den förstärkta verkligheten?

Mycket för ljus	För ljus	Varken för ljus eller för mörk	För mörk	Mycket för mörk

3. Hur viktigt anser du att det är att se farledslinjerna i den förstärkta verkligheten?

Totalt likgiltigt	Ganska likgiltigt	Varken likgiltigt eller angeläget	Angeläget	Mycket angeläget

4. Hur bedömer du möjligheten att läsa av farledslinjerna korrekt i mörker?

Mycket lätt	Lätt	Varken lätt eller svårt	Svårt	Mycket svårt

5. Hur bedömer du möjligheten att läsa av farledslinjerna korrekt i dimma?

Mycket lätt	Lätt	Varken lätt eller svårt	Svårt	Mycket svårt

6. Tror du att farledsmarkeringen i den förstärkta verkligheten kan påverka din situationsmedvetenhet i positiv eller negativ riktning, t.ex. göra att man blir mer uppmärksam eller avleda uppmärksamheten från annan viktig information?

Mycket negativt	Negativt	Varken negativt eller positivt	Positivt	Mycket positivt

7. I vilken situation skulle detta kunna inträffa?

8. Hur bedömer du att farledsmarkeringarna stödjer uppfattning om vad som kommer att hända en stund framöver?

Mycket dåligt	Dåligt	Varken dåligt eller bra	Bra	Mycket bra

9. Hur bedömer du tjockleken på strandlinjen i den förstärkta verkligheten?

Mycket för tunn	För tunn	Varken för tunn eller för kraftig	För kraftig	Mycket för kraftig

10. Hur bedömer du färgen på strandlinjen i den förstärkta verkligheten?

Mycket för ljus	För ljus	Varken för ljus eller för mörk	För mörk	Mycket för mörk

11. Hur bedömer du att graden av ljusstyrka/kontrast på strandlinjen i den förstärkta verkligheten?

Mycket för låg	För låg	Varken för låg eller för hög	För hög	Mycket för hög

12. Hur bedömer du möjligheten att läsa av strandlinjen korrekt i mörker?

Mycket lätt	Lätt	Varken lätt eller svårt	Svårt	Mycket svårt

13. Hur bedömer du möjligheten att läsa av strandlinjen korrekt i dimma?

Mycket lätt	Lätt	Varken lätt eller svårt	Svårt	Mycket svårt

14. Hur bedömer du att strandlinjen stödjer uppfattning om farvattnen och vad som kommer att hända en stund framöver?

Mycket dåligt	Dåligt	Varken dåligt eller bra	Bra	Mycket bra

15. Hur viktigt anser du att det är att se strandlinjen i den förstärkta verkligheten?

Totalt likgiltigt	Ganska likgiltigt	Varken likgiltigt eller angeläget	Angeläget	Mycket angeläget

Avslutande frågor

16. Hur lätt eller svårt tror du att det skulle vara att lära sig använda farledslinjer i den förstärkta verkligheten?

Mycket lätt	Lätt	Varken lätt eller svårt	Svårt	Mycket svårt

17. Hur upplever du storleken på prickar i den förstärkta verkligheten (5m höga, 1 m radie)?

Mycket för små	För små	Varken för små eller för stora	För stora	Mycket för stora

18. Hur upplever du storleken på lysbojar i den förstärkta verkligheten (6 m höga, 3 m radie)?

Mycket för små	För små	Varken för små eller för stora	För stora	Mycket för stora

19. Hur upplevde du att rörelsen i den förstärkta verkligheten motsvarade dina huvudrörelser?

Mycket dåligt	Dåligt	Varken dåligt eller bra	Bra	Mycket bra

20. Hur upplevde du att rörelsen i 3D-världen motsvarade dina huvudrörelser?

Mycket dåligt	Dåligt	Varken dåligt eller bra	Bra	Mycket bra

21. Vilken information av den vi visat idag anser du är viktigast för säker navigering?

22. Från vilket instrument eller vilken display (ev utifrån) får du denna information på bryggan?

23. Vilken information av den vi visat idag anser du är näst viktigast för säker navigering?

24. Från vilket instrument eller vilken display (ev utifrån) får du denna information på bryggan?

25. Varierar den viktigaste informationskällan på bryggan beroende på olika situationer som t.ex. vilket väder som råder eller i vilka farvatten du befinner dig?

26. Hur bedömer du att du fördelar din tid mellan olika informationskällor?

27. Hur ofta växlar du mellan olika informationskällor?

28. Kan du beskriva en situation då du skulle gå från info-X till info-Y (anpassa till tidigare svar)?

29. Vilken orientering föredrar du för kartinformation presenterad på skärm, north-up eller head-up?

30. Föredrar du olika orientering av kartinformation i olika situationer?

31. Kan du beskriva en situation då du skulle gå från head-up till north-up?

32. Tror du att ditt sätt att navigera skulle ändras om du hade tillgång till den förstärkta verkligheten vi visat idag?

Inte alls	Ganska lite	Varken lite eller mycket	Ganska mycket	Väldigt mycket

33. Om ja, hur skulle den ändras? Fördelning av tid mellan olika presentationer, t.ex. radar - omvärld - sjökort?

34. Tror du att den förstärkta verkligheten skulle ändra kvalitén (säkerhet, risktagande) på beslutsfattandet på bryggan?

Mycket sämre	Sämre	Varken sämre eller bättre	Bättre	Mycket bättre

35. På vilket sätt?

36. Om du skulle ha tillgång till farledsmarkering i en förstärkt verklighet hur tror du att din uppmärksamhet på omvärlden skulle förändras?

Mycket sämre	Sämre	Varken sämre eller bättre	Bättre	Mycket bättre

37. Om du skulle ha tillgång till farledsmarkering i en förstärkt verklighet hur tror du att din uppfattning om fartygets position skulle förändras?

Mycket sämre	Sämre	Varken sämre eller bättre	Bättre	Mycket bättre

38. Om du skulle ha tillgång till farledsmarkering i en förstärkt verklighet vad skulle du då anse om en alarmfunktion, dvs. Att du får en varning om du går utanför farleden?
39. Hur skulle varningen utformas på bästa sätt? Blinkande på förstärkt verklighet, starkare färg, ljud, annat sätt?
40. Vilka fördelar respektive nackdelar bedömer du att vårt förslag till informationspresentation medför för navigatören på bryggan?
41. Egna kommentarer
42. Examen
43. Erfarenhet i yrket
44. Nuvarande anställning

Appendix III

Colours chosen for objects on augmented reality display

Colours that were considered and decided on before the experiment. Finally the markings on the overlay were set to the same red and green colour. The route guidelines had transparency set to 200 to increase the contrast.

Used for	**Lightness**	**Saturation**	**Hue**	**R**	**G**	**B**
Red buoy	**120**	**217**	**236**	**243**	**12**	**35**
Green buoy	**120**	**217**	**84**	**12**	**243**	**35**
Too light red buoy	140	213	236	243	54	73
Too light green buoy	140	213	84	54	243	73
Too dark red light buoy				180	20	50
Too dark green light buoy				20	180	20
Too dark red buoy				180	20	50
Too dark green buoy				20	180	20
Red route guideline				200	10	30
Green route guideline				10	200	30

Appendix IV

Subjective measures

Questions asked to subjects after each scenario run. Some examples of the scale used are included.

1. How do you rate the brightness of the navigable channel in the augmented reality? (1 – much too low, 2 – too low, 3 - neither low nor high, 4 – too high, 5 – much too high)
2. How do you rate the colour of the navigable channel in the augmented reality? (1 – much too light, 3 – neither light nor dark, 5 – much too dark)
3. How do you rate the importance of the navigable channel in the augmented reality? (1 – completely insignificant, 3 neither insignificant nor important 5 – very important)
4. How easy would you estimate that it is to use the navigable channel correctly in darkness? (1 – very easy, 5 – very difficult)
5. How easy would you estimate that it is to use the navigable channel correctly in fog?
6. Do you think the navigable channel could have an impact on your situation awareness in positive or negative direction, e.g. make you more attentive or redirect attention from other important information? (1 – highly negative impact, 5 - highly positive impact)
7. In what situation could this happen?
8. How do you estimate that the navigable channel supports your perception of what will happen in the near future? (1 – very bad, 5 – very good)
9. How do you rate the thickness of the shoreline? (1 – much too thin, 5 – much too crude)
10. How do you rate the colour of the shoreline?
11. How do you rate the brightness of the shoreline?
12. How easy would you estimate that it is to use the shoreline correctly in darkness?
13. How easy would you estimate that it is to use the shoreline correctly in fog?
14. How do you estimate that the shoreline supports your perception of the waters and what will happen in the near future?
15. How do you rate the importance of the shoreline in the augmented reality?

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