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Communicating intended routes in ECDIS: Evaluating technological change

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ABSTRACT

Misunderstanding each other's intentions is one of the most common causes of shipping accidents. By sending out a number of waypoints ahead and displaying them on the Electronic Chart Display and Information System (ECDIS) a ship's intentions would be clearly visible for other ships. Displaying ships' intentions would be a major change compared to navigation today. It could be very beneficial but it could also have unintended consequences. This paper reports on findings from an evaluation looking for unintended consequences of change using system simulation.

During the simulation an unanticipated behavior was observed. Bridge crews started to click and drag waypoints too negotiate crossing situations ahead of time. The behavior could be compared to agreeing over the VHF. However further research is needed to evaluate this new behavior and how it aligns to COLREGS.

1. Introduction

"What is your intention?" is a common question over the VHF when two ships are in doubt of each other's intentions. Misunderstanding each other's intentions is not seldom the cause of accidents at sea. Even worse is when ships in doubt do not ask for intentions, but instead make a presumption. Liu and Wu (2003) studied 100 collision reports from the maritime authorities of the UK, USA, Australia, Canada, New Zealand and Sweden. They found that communication problems were one of the most prominent causes of accidents at sea. The most frequently identified causes were lack of communication and misinterpreting information. Underlying human factor issues, they concluded, were the reluctance of navigators to exchange information.

Why this reluctance to communicate, that is mentioned by Liu and Wu? Is it lack of situation awareness, shyness, or lack of language skills? On a debriefing after a previous simulation one of the officers participating mentioned "a culture of silence" and "a well-run ship is a silent ship" (Lützhöft et al., 2010) Could there be an attitude implying that talking on the VHF is unnecessary if everybody follows the International Regulations for Preventing Collisions at Sea, abbreviated COLREGS (IMO, 1972)? A reason for not communicating could of course be that no one onboard thinks that the situation is unclear, not realizing that they have misinterpreted the intentions of the other vessel. Look at the following example.

In a tragic accident in 1979, the captain of a US coast guard cutter mistook the navigation lights and radar echo of an approaching vessel for being a slow going vessel with the same course as the coast guard vessel. The cutter was rapidly approaching the other vessel and the captain thought that the other ship was moving very slowly, maybe fishing. The captain yielded to port to overtake the vessel on the correct side according to the COLREGS. No VHF communication was established because the passing was routine. But for a head-on situation the cutter should have yielded to starboard. In the subsequent collision the coast guard vessel sunk and 11 crew members were killed (Perrow, 1999).

In old types of relative radar systems, misinterpretation of information was possible if the target were not plotted over time. With modern true motion systems a target will display a course-speed vector – if the target is tracked. This tracking needs to be indicated manually. The new Automatic Identification System (AIS) will display the target with a course-speed vector on both radar and electronic chart (if turned on), but only as an extrapolation of current speed and course (and sometime current turn rate). Displaying a course-speed vector of a target ship could have prevented the coast guard cutter accident above. But even with modern equipment some types of misunderstandings would be hard to prevent as for example the following situation.

In 1979 the Liberian bulk carrier *Artadi* collided with the French ferry *St-Germain* in the Dover Strait in bad visibility. *Artadi* was proceeding NE in the traffic separation scheme (see Fig. 1). The ferry was spotted in good time on the radar of the *Artadi*. Coming from starboard, *St-Germain* was the stand-on ship according to rule 15 of the COLREGS. The pilot and master of the *Artadi* expected her to keep speed and course and started to make a starboard turn to give way. However, on-board the *St-Germain* the intention was

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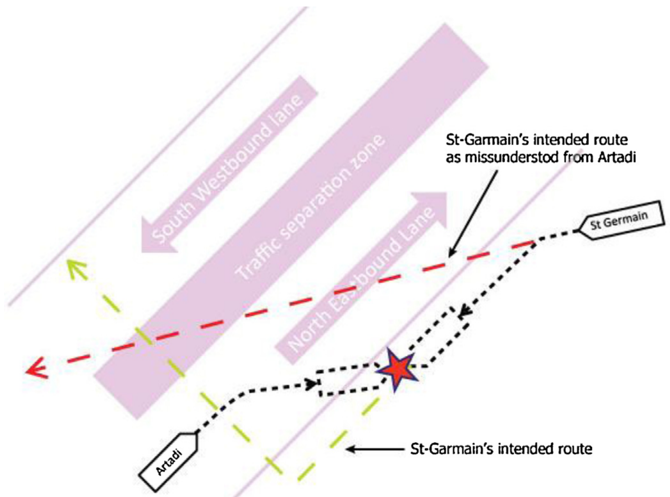

Fig. 1. Misunderstanding intentions: the collision of French train ferry *St-Germain* with Liberian bulk carrier *Artadi* in the English Channel, 1979.

not at all to cross the traffic separation scheme diagonally in front of *Artadi*, but instead to turn port and follow outside the boarder of the NE going traffic lane until the traffic cleared and she could make the crossing at a right angle (according to rule 10c). In the subsequent collision two persons were killed (Kwik, 1984; Office of the Commissioner for Marine Affairs, 1979).

When ships are heading into conflicting situations they are expected to solve the situation using COLREGS. COLREGS are supposed to unambiguously label one of the ships the stand-on vessel and the other the give-way vessel. But due to misunderstandings this is not always the case, as can be seen from the two situations described above. If the situation is unclear, ships are supposed to use the VHF to solve the ambiguity. But if there is a misunderstanding, then the ambiguity might not be recognized by the responsible bridge officers, until it is too late.

The study by Liu and Wu (2003), presented above, indicated that more verbal communication over the VHF might mitigate misunderstandings between ships. In his seminal book *Cognition in the Wild* Edwin Hutchins (1995) wrote "verbal descriptions typically fail not because they don't provide enough structure, but because they provide the wrong kind of structure. The difference between the right and the wrong kind of structure is determined both by the nature of the task and the other structural resources that are available" (p. 230). Hutchins here describes the phone communication between the recorder in the chartroom of a navy vessel and the pelorus operator on the bridge wing. The recorder could only see the chart and the pelorus operator could only see the beach line. Based on the chart the recorder decided the next land mark, which was determined by an optimum bearing angle, but for the pelorus operator the problem was how to identify the landmark picked out by the recorder, and their only line of communication was the telephone line. In this case being able to go to the bridge wing and point out the landmark might have been a better form of communication.

When ships communicate over the VHF, talk is often kept short and to the point. Lengthy descriptions are avoided due to the one or very few channels that should be open and available to all ships. Short and to the point communication might be suitable for short-term tactical information about upcoming maneuvers to port or starboard, but it is not suitable for communicating intentions of long range route information. Furthermore, if such long-range information would be available it might give other ships in the area a chance of looking ahead and plan future passages of narrows and avoid close counter situations. First, the structure of the verbal voice communication makes it complicated to communicate precise geographical information without starting to read lengthy numerical coordinates. Second, the voice communication has to be stored in memory until it can be recorded by pen and paper or through tape; but with a tape recorder it has to be played again and the memory problem reappears. If talk is not the best way to communicate intentions, what is? Is there some way of making intentions of ships more clear?

In 2006 the International Maritime Organization (IMO) started a strategic initiative named e-Navigation defined as the collection, integration and display of maritime information aboard and ashore by electronic means to enhance navigation and increase safety at sea for the protection of the marine environment (IMO, 2008). One approach to e-Navigation is to look at what information is available but not used and how this information can be put in use for the benefit of safety. The EfficienSea project (2011) within the Baltic Sea Region Program has the aim to support efficient, safe and sustainable maritime traffic on the Baltic Sea. One activity within this project has been devoted to develop new decision support features in the Electronic Chart and Information Display System (ECDIS). The feature focused on in this paper is the possibility to exchange routes between vessels and between vessels and shore-services, such as pilots and VTS.

Every ship is by regulations forced to do a berth-to-berth route plan before leaving port (ICS, 2007). This intended route resides locked in the navigation system of each ship. By enabling vessels to send and receive each other's intended routes (using AIS binary messages), and display them on their own ECDIS, a possibly to decrease the risk for conflicting situations appears. Further, by making it possible for shore-based services to send routes to vessels, pilots and VTS operators can assist ships unknowingly heading into danger, a situation not quite uncommon. In this way it is possible to create a unified navigation team by joining the ship's bridge team and the shore-based VTS team by new technology to share information. However, one might argue that by sending out an intended route and then not following one may instead create a new type of accidents. To explore possible consequences of route exchange a system simulation was conducted at Chalmers University of Technology in Sweden.

In the work mentioned above Hutchins (1995) presented his framework of *distributed cognition*. He argued that thinking and decision making, not only take place inside of the individual's head but that it is also socially distributed among the members of a society or a group, and among the individuals and cognitive tools of the so-called sociotechnical system.

Rooted in this perspective on human cognition, this paper considers the whole navigational crew on the bridge of a ship as a system, and, in a larger context, also tries to look at the larger system consisting of all the ships in an area together with the shore-based VTS. This approach is anticipated to generate valuable insights on what processes and artifacts might be helpful to increase safety.

New technology or new procedures are introduced with an intended performance optimization in mind, for instance, safer traffic or cognitive off-loading. The long term goal is increased efficiency but change also opens up for unintended consequences. There is of course no guarantee that such unintended consequences will be triggered during a simulation, but exploring the consequences of change in an environment seeking to some degree mimic the complexity of a real environment will hopefully result in some new knowledge of possible behavior.

The research question in this study was focused on what are the unexpected consequences of introduction of route exchange, meaning the ability for ships to show intended routes and the ability for a VTS center to send out suggested routes to specified ships.

Fig. 2. (Left) Captain and pilot on the simulator bridge. (Right) The VTS operator (right) and the observer (left).

2. Methods

Based on this notion a so-called *system simulation* (Lützhöft et al., 2010) was conducted at the simulator center at Chalmers University of Technology. A system simulation is a complex simulation involving more than one live ship and shore-based services. In this simulation two ships were assigned to pass through the Sound (Öresund) between Sweden and Denmark. The vessels were a small tanker and a large cruise ship. Several other "non-playing" target ships was also trafficking the area. The whole simulation was video monitored and ship movements recorded as well as radio communication, and bridges activities.

Between Sweden and Denmark 33,000–35,000 ships over 300 GT pass the Sound every year (not counting the many ferries going back and forward across the Sound). In later years there have occurred between 50 and 70 incidents every year where VTS operators have be forced to take action mostly to warn ships with too deep draughts or who were heading for shallows (Garbebring, 2011).

A normal voyage through the Sound from two nautical miles north of the Helsingborg–Helsingör ferry crossing in the north to the passage of Drogden lighthouse in the southern Sound takes about 2.5 h. A full day was booked in the simulators at Chalmers University of Technology allowing for two passages, one from each direction for the two ships.

Only the two playing ships (and some non-playing targets used to trigger situations) had the ability to send intended routs. This would mimic the situation in an early period of technology change when only a small part of all ships would be within the system.

The tanker, *T.C. Gleisner*, was manned by two active Sound pilots, one acting as captain, the other as watch officer. The other ship, the coursing ship *Royal Princess* was manned by one professional captain and one pilot acting as watch officer. Both bridge crews were well familiar with the Sound. The VTS center was manned by a professional Sound VTS operator (see Fig. 2).

The simulation started in the morning at 9 o'clock with 30 min of voyage planning when the waypoints of the passage were programmed into the prototype chart.

The prototype ECDIS called *ee-INS* was prepared by the Danish Maritime Safety Administration (DAMSA) as a part of the EfficienSea project. The prototype allowed a number of waypoints ahead of the present leg to be transmitted. In the prototype setup the maximum number of waypoints transmitted was 8 using AIS binary messages. This was done in the same moment the crew chose to make its route "active" (which would then allow the autopilot to follow it). At any moment changes to the route could be made by dragging existing waypoints or by adding new waypoints and dragging them. Once changes had been made, the route had to be made active once again. The crews were instructed in how to add and change a route as a part of the system familiarization and to be able to plan the initial route. They were however not instructed to use route changes to negotiate close quarter situation while under way.

The VTS chart system also had the same ability to send out specially designed routes or routes from a library to a designated ship.

On each of the bridges and in the VTS station a researcher/observer took notes and asked questions, movement of ships and VHF communication was recorded and the data collected in the VSL Site Observer^{TM} software for further analyses.

3. Results

The findings reported here are limited to an unanticipated new behavior of the bridge crew that used new technical feature in an unintended way. Fig. 3 illustrates the situation. The tank ship *T.C. Gleisner* was southbound in the Sound and was approaching the narrows at the ferry crossing between Helsingborg and Helsingör. Several ferries cross the Sound here every hour and they might suddenly appear from the two ports on either side.

According to COLREGS ship should give way to other ships on their starboard side. But because of the narrow strait the ferries normally give way for all passing traffic or delay their departure to fit an opening in the traffic flow. This is however a behavior that has no support in COLREGS and may cause misunderstandings. When *T.C. Gleisner* was approaching the ferry crossing from the north the ferry *Tycko Brahe* was departing from Helsingör, on the tankers starboard side. As the ferry started she broadcasted her intended route, a straight line over to Helsingborg (Fig. 3, left photo). The intention of *Tycko Brahe* was picked up by *T.C. Gleisner* some 6–7 min away. Being the give-way ship according to COLREGS (rule 15) *T.C. Gleisner* then changed her course to go astern of *Tycko Brahe* by adding a waypoint and dragging it west to just outside the port entrance. She then made the route active and it was automatically broadcasted to all ships that had the "show intended routes" switched on (see Fig. 3, middle photo). But the practice in the Sound is that the ferries give way for passing traffic so *Tycko Brahe* adds two new waypoints to her route and drags one of them behind *T.C. Gleisner* showing her intentions to turn port outside the pier head and go astern of the tanker. *T.C. Gleisner* accepts this by dragging her new waypoint back to resume her previous route.

A similar feature named "suggested routes" was also tested. This feature would allow a stakeholder, here the Vessel Traffic Service (VTS) to send out a route segment consisting of 8 waypoints to a designated ship.

The VTS used this feature to send new routes to one ship with too deep draught to pass the Sound altogether (which instead was reroutes via The Belt, and a ship with a planned course leading

Fig. 3. An example of negotiating a conflicting situation using intended routes: Own ship *T.C. Gleisner* (red pointer) is the black symbol somewhat west of her (red) track in the upper left part of the screen in the left figure. *Tycko Brahe's* (green pointer) green track shows, in the left figure, that she first intends to go straight across the strait in front of *T.C. Gleisner*. In the middle *T.C. Gleisner* has published her intentions to go astern of *Tycko Brahe* (in accordance with COLREGS) by inserting a new waypoint and moving it west. This will bring *T.C. Gleisner's* track very close to the port entrance and in the right figure *Tycko Brahe* has offered to yield and go astern of *T.C. Gleisner*, who has accepted by moving her waypoint back to her original track. Photos of *T.C. Gleisner's* ECDIS screen 13:49, 13:54 and 13:55 respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

directly aground (these two scenarios was based on real situations). These tests went smoothly without surprises.

On issue that becomes apparent was the on-screen cluttering at the VTS. On the on-board ECDIS only one intended route at a time would be displayed as the operator right clicked another ship's icon and chose "Show intended routes". However, at the VTS station all ships intended routes would be displayed at only one time leading to a cluttered display where the individual route of a single ship could be hard to distinguish (see Fig. 4). Some kind of solution that reduces the number of simultaneous on-screen tracks will have to be found. On-board the ships, the own ships track is by regulation red and other ships tracks are green. Maybe tracks should only be visible when clicking on a ship to query its intentions? This is something that needs to be developed further.

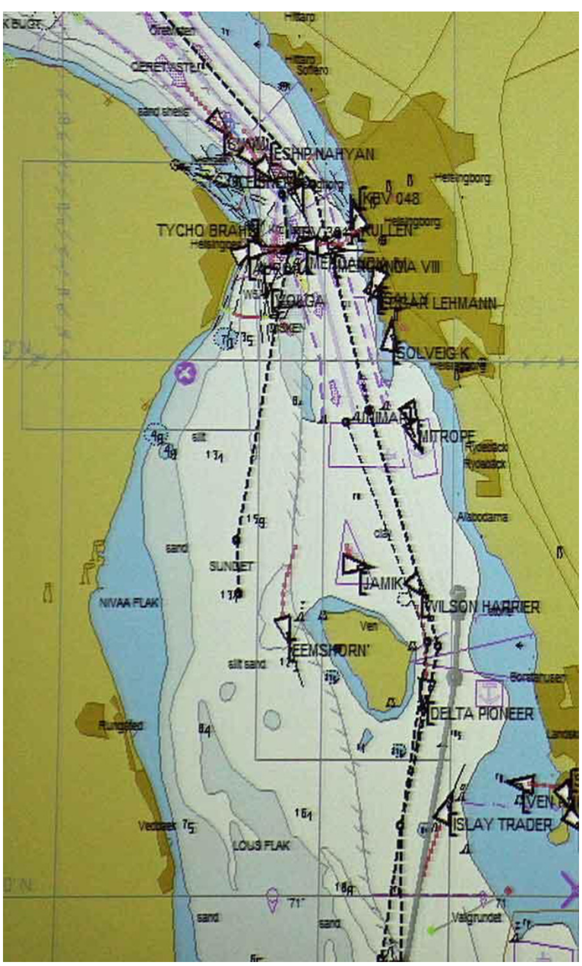

Fig. 4. A photograph of the VTS screen illustrating the clutter of different intended tracks – it is difficult or impossible to see which track belongs to witch ship.

4. Discussion

The behavior of the bridge crew of the tanker and the ferry came quite surprising for us. The participants had not been instructed to use the *intended route* feature for anything else than take note of each other's intentions.

Today ships use the VHF radio to agree on counter COLREG behavior (for instance a meeting starboard to starboard). Such behavior is not recommended but is still common practice. Using *intended routes* to negotiate a meeting situation between two ships could serve just the same purpose, only the risk of misunderstandings might be less because the route intentions of both ships are displayed graphically, not only for the upcoming maneuver but also for the following. Possibly could this behavior lead to collision avoidance being done well ahead of a close quarter situation. This might give operators a second chance if an intended maneuver fails.

However there might be hidden traps that will need to be investigated carefully. Doing collision avoidance ahead of time using intended route feature might lead to complicated situations in congested waters with many ships present. As one close quarter situations is resolved others might be created. Also showing intentions and then not carry them out might be very dangerous comparable to flashing the turn lights on a car and then not turning.

An issue brought up by the participant was that there definitely was a time when negotiations using the ECDIS had to be abandoned for old fashion collision avoidance looking out of the window.

5. Conclusions

Findings from the evaluation suggest that the *intended route* feature well serves its purpose.

It can also serve as a less ambiguous ground for route negotiations, even if this behavior was not intended from the start. Subjects were generally positive to the tool. But issues were raised as for instance on the cluttering of the chart in the VTS display and on that in very tight and time constrained collision situations none of the ships will have time to click intentions into the ECDIS.

Another concern raised by the VTS operator was the question of responsibility for the route exchange. As an example the VTS operator was contacted by one of the vessels asking him to send a suggested route to the other vessel to keep out of his way. As it is today the VTS is only entitled to give information services while the executive decisions on navigation remain the responsibility of a ship's captain and the navigating crew. Sending routes from shore might eventually require to move some of this executive decision making power to shore to be able to avoid unnecessary negotiations in critical situations.

Results from the simulation were promising and solutions for the problems encountered will have to be found until the next iteration of the route exchange service.

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