COLLISION AVOIDANCE AT SEA - PRACTICE AND PROBLEMS

Morten NIELSEN

Computer Science Department
Center for Human-Machine Interaction
Aarhus University, Denmark
mnielsen@inv.au.dk

Johannes PETERSEN

Oersted•DTU, Automation
Center for Human-Machine Interaction
Technical University of Denmark
jop@oersted.dtu.dk

ABSTRACT
The paper reports from our field studies of maritime operations where the objective was to understand the present practices and problems of collision avoidance as seen from the perspective of the navigating crew. An initial analysis intended as input for design of enhanced collision avoidance support is presented. Focus is on problems of observation and communication.

KEYWORDS
Maritime collision avoidance

INTRODUCTION
The potential human, environmental, and economical consequences of collisions at sea are grave. Yet the means available for maintaining the desired degree of safety are relatively limited. The issue of how to support navigators in avoiding collisions is central to maritime safety, and the subject matter is increasingly pressing as the already giant vessels are still growing in number and size.

Enhanced support for collision avoidance at sea must be rooted in reality. That is, we must understand the present practices and problems of collision avoidance before we can hope to propose truly useful safety enhancements. The present paper seeks to contribute to such an understanding.

We base our analysis of collision avoidance at sea on empirical studies. We go aboard one of the world’s largest container carriers, and follow her during departure from Felixstowe (UK) and the subsequent approach to Rotterdam (NL).

The objective is to understand collision avoidance as seen from the perspective of the navigating crew: To understand what information the crew need in order to perform safe collision avoidance, and to analyze some of the central obstacles to achieving the desired information—an initial analysis which is intended to provide part of the foundation for a structured conceptualization of information requirements in collision avoidance at sea.

Collision avoidance involves two or more seagoing vessels that have to cooperate and coordinate their individual operations to avoid ending up in the same place at the same time. In order to avoid colliding with other vessels the crew need to know certain things about their own vessel, and they need to know certain things about the foreign vessels involved in the collision avoidance scenario. The present paper deals in particular with the second matter—the information needed about the foreign vessel(s).

One central characteristic of contemporary collision avoidance is that collision avoidance is performed with a good deal of knowledge about own vessel, and only limited knowledge about the foreign vessels. All larger vessels are fitted with VHF radios yet direct contact between two vessels is often not possible because the name or call-sign of the foreign vessel is unknown. VHF communication facilitates explicit verbal negotiations, but often the vessels have to coordinate the passing maneuvers by means of observation only—they can see each other, but no direct contact is possible.

The paper illustrates and analyzes the practices and problems of both modes of collision avoidance: During the departure from Felixstowe we will witness collision avoidance based purely on observations, while the approach to Rotterdam will illustrate the potentials and pitfalls of verbal interaction between two large container carriers.

The paper is divided into four sections: One introduces the container carrier M/S Sally Mærsk and our field work aboard. Section two provides empirical examples of real-world collision avoidance. Section three discusses the practices and problems illustrated in the examples, and elaborates on aspects of collision avoidance that may not be directly observed in the examples. Section four concludes the paper.
**M/S Sally Mærsk**

The M/S Sally Mærsk is one of the largest container carrier ever build. She is 347 meters long, 48 meters wide, and carries more than 7000 containers when fully loaded. That is, 104750 ton driven to a max of 25 knots by an engine in excess of 74000 horsepower (BHP metric).

Figure 1. The slightly smaller sister-ship M/S Knud Mærsk.

Our studies of cooperation and coordination in maritime operations have been ongoing for more than five years. We started out in 1996 by observing mariners training in high fidelity full-mission ship simulators. A year later, we performed our first real-world study onboard the container carrier M/S Majestic Mærsk. Later followed the M/S Knud Mærsk, and during the summer of 1999 we conducted our latest study onboard the M/S Sally Mærsk. In total we have been fortunate to spend more than four months—around the clock—doing field studies onboard some of the most impressive vessels in the merchant marine.

Our aim has been to understand cooperation and coordination as seen from the perspective of the actors on the command bridge. The constellation of the cooperative ensemble is highly variant according to different operational phases. In open sea (from sunrise to sunset) there will be only one actor on the bridge—and the work is only temporarily cooperative when foreign vessels enter the sphere. Things start happening when the vessel moves from open into coastal waters: First the bridge will be manned with two actors, then three. A pilot will embark. Lookouts will be positioned on deck. Tugboats will arrive. The Vessel Traffic Control will enter the scene, and when the vessel is within the actual harbor area the cooperative work arrangement will have grown to 20 or more actors directly engaged in the operations.

Field data have been collected via first hand observation, and a technical setup which allowed us to capture a relatively full and coherent picture of the activities on the bridge, the performance of the vessel, the weather conditions, foreign vessels, activities on deck, etc.

![Figure 2. General bridge layout.](image)

During the latest study onboard the Sally Mærsk we had six video cameras mounted on the bridge: four on the central bridge and two (mobile) cameras mounted in the bridge wings. The actors wore wireless microphones, and all communication between the actors on the bridge along with intercom, walkie-talkie, and VHF communication was captured and synchronized online with the video recordings. All the Sally Mærsk’s planned and actual tracks were plotted in sea charts. The paper charts, along with video recordings of the vessels digital replay system, created an important basis for detailed discussions of individual maneuvers and the mariners explanations on why a particular actor said or did in a certain situation. It is this material that we will draw on in the following.

**COLLISION AVOIDANCE PRACTICE**

In the following we will present two short examples of real-world collision avoidance, each intended to illustrate practices and particular problems within contemporary collision avoidance. Firstly, we follow the Sally Mærsk during a departure from Felixstowe where she meets a ferry in the narrow lane of the harbor. In this case collision avoidance is performed on the basis of observations only (see Nielsen, 2000b) for a full description of the example). Then, we move on to Rotterdam where the communication between Sally Mærsk and the large container carrier Sealand Atlantic illustrates shortcomings of VHF communication.

**The ferry (observation)**

We enter the scene off Felixstowe as Sally is well into the lane leading larger vessels to and from the harbor. The lookouts on deck have been relieved of their duties and operations are performed solely from the bridge which is manned by four actors: master, pilot, chief officer, and helmsman.

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1 See (Nielsen, 2000a) for further details on maneuvering characteristics of the Sally Mærsk.
Figure 3. Sketch of the lane leading larger vessels to and from the harbor. The planned track for Sally Mærsk is represented by the dotted line running within the grayed lane.

There has been no traffic so far but now at buoy no. 2 (see figure 3) it becomes evident the Sally will probably have to pass another vessel while in the lane. The other vessel turns out to be a ferry with no pilot on board. Traffic in and around the Felixstowe harbor is regulated by the Vessel Traffic Management Service (VTMS), and the pilot carries a list of times and names for planned arrivals and departures. Unfortunately, the ferry is not on the list since it does not have a pilot onboard. This means that the name of the inbound ferry is unknown to the pilot onboard the Sally Mærsk, and consequently that any information about it will have to be obtained by observation only—VHF communication is not an option, simply because the name of the ferry is not known.

There are two basic questions for the crew onboard the Sally Mærsk to answer: where can the ferry go, and where does it intend to go. The first question has to do with the ferries maneuverability and draught: how fast it can accelerate, turn, stop, etc., and whether its draught allows the ferry to leave the deep water lane. Intentions refer to the planned inbound track of the ferry—the specific choice made within the space of possible tracks. In cases where VHF communication is not an option the ferries possibilities and intentions have to be derived from the observations that can be made from the bridge of the Sally Mærsk.

While the ferry is still at a distance the radar is the primary means of observation. The ferry shows up on the radar at time 04.28 UTC—first as a green dot, and then after having been marked by the master, as a target with a vector indicating the ferries speed and course. Furthermore, the radar provides the following numerical readings for the target: distance to target, bearing to target, the targets course and speed, and two calculations which are directly related to collision avoidance, namely CPA (closest point of approach) and TCPA (time to closest point of approach).

Marking the ferry is part of a wider traffic survey performed on the radar by the master. Initially the radar is set to cover a three mile range, then it is zoomed out to six miles to look for more distant vessels, and eventually the radar is zoomed in to three miles again. At time 29.30, after the master has surveyed and marked the relevant vessels in the area off the Felixstowe harbor, the pilot steps up to him and identifies the vessels on the radar by pointing first to the real vessel (in the water), then in turn to the corresponding targets on the radar:

| Time 04.30.29 | 1 Pilot okay ... ferry coming in there [pointing out the view to the high-speed vessel] |
| 2 Master yes he is right here |
| 3 Pilot small ship there [pointing out the view to the ferry] |
| 4 Master yes |
| 5 Pilot and the dredger [pointing out the view to the dredger] |
| 6 Master no that is the dredge. |
| 7 Pilot That is the dredger and there is a small ship coming in or ... I'm not quite sure what course he is gonna take but we will see in a minute |
| Time 04.30.29 | 8 Master Looks like he is mostly on the western side of the fairway |
| 9 Pilot yes |
| 10 Master yes |
| Time 04.30.29 | 11 Master but sometimes when the draft allow them to (text) [the ferry] |
| 12 Pilot (text) cuts straight over and all sorts of things year [the ferry] |
| 13 Master yes I have seen that happened |
| 14 Pause |
| 15 Master he coming in without a pilot... [the ferry] |
| 16 Pilot he is coming without a pilot year he is gonna pick up a Pilot ... in here to go to Ipswich witch is sometimes a bit of a problem cause they don't always ... [the ferry] |
| 17 Master year I can imagine |
| 18 Pilot ... realise exactly where they should be in the channel [the ferry] |
| 29 Master mmm mmm |

Fragment 1. The initial conversation on the traffic situation between pilot and master. Comments regarding the ferry are marked with boldface.

According to the International Regulations for Preventing Collisions at Sea’ (IMO, 1995) Sally and the ferry should meet port to port in the lane. However, at present, there are several signs indicating that this may not become the case. Two
of these signs are that the ferry is presently positioned at the western side of the lane, and that its radar vector (indicating the ferry’s course) for some time has been, and still is, in parallel with the western edge of the lane indicating that the ferry is on a steady course. Sally is positioned for a port to port passage but both vessels are presently positioned at the same side of the lane. This will have to change if a collision is to be avoided.

The conversation in Fragment 1 reveals some of the doubts regarding the possible and planned movements of the ferry. The master statement in line 8 indicates concern about the ferry’s present position at the same side of the lane as Sally. Yet, in line 11 the master states that he has seen ferries leave the lane and head directly for the harbor entrance—and therefore the ferry’s position may not be a problem after all.

The crew of the Sally Mærsk is faced with a number of possible scenarios: The ferry may turn east and move to the correct side of the lane, it may continue at the west side and force Sally to go out of the way. As indicated in Fragment 1 (line 10-12) vessels the size of the ferry sometimes leave the lane altogether, go due west, and head directly for the harbor entrance. And finally, the ferry may continue its present course into the curve and thus end up at the north edge of the curve before it initiates a port turn and follows the lane towards the harbor entrance. Presently, there is just no way of determining the ferries intentions. The present signs do not look particularly promising but there is still time for things to change. The pilot does not speak again until shortly after the ferry has entered the curve.

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<tbody>
<tr>
<td>1</td>
<td>Pilot</td>
</tr>
<tr>
<td>2</td>
<td>Master</td>
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Fragment 2. Time 04.33.56

At time 04.35.19 the pilot orders the rudder ten degrees to starboard. He is now content with the course of the ferry and decides to maneuver the Sally Mærsk into a port to port pass with the ferry.

Figure 5. Time 04.35.19

After having observed the effect of his command for about half a minute the pilot issues a new rudder command in order to achieve a higher turn rate: the rudder is moved another ten degrees to starboard. At time 04.36.30 the Sally is more or less on the desired course and the pilot issues the course command ‘one zero five’.

Figure 6. Time 04.36.58

Figure 7 show the final stage of the meeting between the Sally Mærsk and the ferry. Sally stays at the center of the lane throughout the curve, while
the ferry sails the curve at the very edge of the lane.

**Sealand Atlantic (communication)**

EuroPort in Rotterdam has one of the busiest container terminals in the world, and during the approach it becomes clear that Sally Maersk can not commence directly to the designated berth as it is presently occupied by another vessel. The VHF message concerning a further delay is received by the Rotterdam pilot on the bridge of the Sally Maersk less than five miles off the harbor entrance. In response to the delay it is decided to perform a 360° turn before heading towards the harbor entrance.

![Diagram](image)

Figure 8. The meeting between Sally Maersk and the Sealand Atlantic.

The maneuver is critical because Sally will block the fairway during part of the maneuver. No vessel will be able to pass during that period, and the maneuver should thus only be performed if no vessel needs to pass. As seen from the pilots perspective, traffic conditions were clear prior to the maneuver. Yet just after having initiated the 360° turn to port, the Sally Maersk is contacted on the VHF radio by the outbound Sealand Atlantic. As it turns out the two giant container carriers will meet in the narrow channel and the VHF communication serves to negotiate the details of the passage.

The bridge of the Sally Maersk is manned by the master, pilot, first officer, and helmsman. It is the pilot who picks up the VHF when Sally is contacted by the Sealand Atlantic:

| 1 | Atlantic | Sally Maersk, the Sealand Atlantic [VHF] |
| 2 | Pilot | Sally Maersk [VHF] |
| 3 | Atlantic | Yeah, good afternoon Captain, are you turning to port now, are you over? [VHF] |
| 4 | Pilot | Yes, I’m turning slowly to port, yes [VHF] |
| 5 | Atlantic | Okay, we, we are, we will be steering our course of about two nine zero, and we will stay to the north of you, if that is agreeable with you [VHF] |
| 6 | Pilot | yeah fine, I will be following the deep draft route outside [VHF] |
| 7 | Atlantic | Yeah, and you can give us a red to red passing, please, port to port [VHF] |
| 8 | Pilot | port to port, yeah fine okay [VHF, talking to the Sealand Atlantic] |

Fragment 3. Initial VHF communication between Sally Maersk and Sealand Atlantic.

Sealand Atlantic knows that Sally Maersk is turning to port. But clearly the crew is unaware that Sally intends to perform a full 360° turn and not just a small course adjustment. Sealand Atlantic expects to meet Sally Maersk on opposite courses, and from this perspective the proposed port to port meeting is by the book. The port to port maneuver should however not make sense to the pilot onboard Sally Maersk who should know that the Sealand Atlantic will come to overtake Sally Maersk rather than meet her on opposite courses. Initially the pilot of the Sally Maersk does not realize the misunderstanding, but the master does:

| 9 | C officer | ( ) |
| 10 | Pilot | We are steering around slowly, slowly |
| 11 | Pause | |
| 12 | 1 officer | I presume he means that he will ... |
| 13 | Master | Yeah, but how can he ... ( ), he will overtake us probably ... |
| 14 | Pilot | Yeah, I don’t know |
| 15 | Master | yeah, no, so um port to port |
| 16 | Pilot | Sealand Atlantic, the Sally Maersk [VHF] |
| 17 | Atlantic | Sally Maersk, Sealand Atlantic [VHF] |
| 18 | Pilot | Um, you want to pass us on our starboard side, on the north side? [VHF] |
| 19 | Atlantic | Roger, I like to ... I heard you were turning to your port to go back in, I ( ) in with the dredger, otherwise we are going red to red, over [VHF] |
| 20 | Pilot | I think red to green with us [VHF] |
| 21 | PilotSt | Sealand Atlantic, Pilot Maas [Pilot Station Maas Approach on the VHF] |
| 22 | Atlantic | Pilot Maas [VHF] |
| 23 | PilotSt | The, the Sally Maersk is turning to port, so you can proceed her north of her, over [VHF] |
| 24 | Atlantic | she is gonna turn to port, okay thank you, thank you, Sally Maersk [VHF] |
| 25 | Pilot | yeah ... port to port, red to red not possible |
| 26 | Master | that is not possible |
| 27 | Pilot | has red side to our green side |

Fragment 4. The initial misunderstanding is remedied by the master of the Sally Maersk.

Fragment 4 shows that the basic characteristics of the meeting between Sally Maersk and the Sealand Atlantic are never explicitly entered into the conversation between Sally’s pilot and the Atlantic. Sally’s pilot does not mention that his vessel will be heading west when she meets Atlantic, and that the Atlantic will thus overtake her rather than meet her on opposite courses.

In the end the vessels passed well clear of each other but the means of collision avoidance were no doubt lacking the needed degree of precision and robustness. We shall return to the meeting between Sally Maersk and the Sealand Atlantic in the below.
**COLLISION AVOIDANCE PROBLEMS**

In a collision scenario it is the navigator’s job to assess the possibilities for collision avoidance *in situ*. This requires information on the maneuverability and spatial constraints of both the foreign vessel and his own vessel. By spatial constraints we understand the characteristics of the waterways—the space available for maneuvers given the actual water depth and the draught of the vessel, the traffic separation schemes and other traffic which must be taken into consideration when performing collision avoidance. A vessel’s maneuverability denotes its ability to accelerate, stop (stopping distances), and to turn at different speeds and loading conditions. See Petersen and Nielsen (2001) for an analysis of factors determining the maneuverability of ships.

Prior to the *in situ* traffic assessment in potential collision situations, i.e. while the vessel is still at quay or before it enters the restricted harbor area, the navigator must plan ahead. This involves collecting information on the waterways and the expected traffic situation before his vessel actually enters the waters in question. For an outbound vessel the primary source of information prior to departure is the pilot and the pilot station or the VTMS.

In the following we will first look into the information available for planning ahead, and then we will turn to the *in situ* assessment of traffic and possible collision scenarios and consequent collision avoidance.

*What is known ahead*

The traffic flow in and around larger ports is regulated by the pilot station or so-called vessel traffic management service. Vessels the size of the Sally Maersk do neither enter nor leave a port at will. They report their expected time of arrival or departure to the VTMS and get assigned a slot in the traffic flow.

The traffic flow is planned with the safety objective of ensuring ample distance between vessels and in order to avoid that in and outbound vessels meet in untoward places such as particularly narrow passages and curves. The initial planning is performed by the VTMS and implemented by the pilots in cooperation with the navigating crew onboard the individual vessels.

The VTMS is dependent on information from in and outbound vessels in their planning efforts. Vessels must report their expected time of arrival or departure well ahead for them to be entered into the equation. If an outbound vessel fails to report, and the traffic flow does not allow for immediate departure the vessel will be held at the quay until it can safely proceed outwards. Unfortunately, the VTMS does not possess the same degree of control over inbound traffic.

*First of all, the efforts of the VTMS are constrained by the limited means of direct communication at sea.* The identity of an inbound vessel must be known to the VTMS before they can contact the vessel over the VHF, satellite telephone, or via the fax. And this information is not always available nor obtainable.

When a vessel is planned to enter the harbor with a pilot on board it is in the vessel’s own best interest to let the VTMS know where they are at well and when they expect to arrive well before pilot embarkation. Otherwise, there may be no pilot available and the vessel will have to wait. However, for vessels that are not required to take a pilot the story is quite a different one. There is no real incentive for these vessel to advice their arrival before they arrive at the area covered by the VTMS. Neither are they required to, as they are not requested to identify themselves before they arrive at the first buoy in the traffic separation scheme off the harbor. The problem with these vessels is that they may fail to report their identity and thus be incomunicado for all practical purposes; or they may report but already have entered the lane. Either way, these vessels can not be entered into the plans the same way as is the case with outbound vessels.

The planned traffic flow and information about unidentified inbound vessels is made available to the pilot before he embarks the vessel. And the part of this information considered relevant for the journey at hand will later be provided to the master who discusses the plans for the approach or departure with the pilot.

The pilot remains in radio contact with the VTMS throughout his stay on the ship. And the quality of his work relies in important ways on the information he receives from the VTMS. For example, if another vessel has made a change of plans which affects the plans for the pilot’s vessel—then the pilot should be provided with this information from the VTMS.

However, not all vessels report a change of plans to the VTMS—and other vessels fail to report the change of plans in sufficient detail. This, of course, means that the desired information will not be provided to the affected vessels by the VTMS.

And then there is the possibility that the VTMS holds information of relevance to a specific vessel but fails to provide it to her for one reason or the other, say, because the VTMS fails to realize that the information is at all relevant to the vessel.

Thus, even the best of plans and VTMS services are no substitute for observations made during the actual journey. The pilot and crew must stay alert throughout the journey and keep a good lookout for
traffic at all times. The examples from Felixstowe and Rotterdam are proof hereof.

**Problems of observation**

What can navigators learn about a foreign vessel by observing it, and why can they sometimes not get the information they need?

There are of course a multitude of answers to this question and it is not our claim to provide them all since the contents of the answers are highly dependent on a myriad of specific conditions varying across different situations. Rather, we will limit our self to a brief account of the most basic information types needed in a collision scenario, i.e. the intentions of the foreign vessel and its possible future tracks, and the problems sometimes experienced in achieving the desired information.

The first observable representation of a foreign vessel provided to the navigator is the green dot on the radar display indicating the distant vessel. He can now mark the dot, and moments later the radar will provide information on the speed and course of the vessel, the distance and course to the vessel, and the crucial information regarding closest point of approach and time to closest point of approach. It is based on this information that the navigator will perform his initial evaluation: whether this vessel poses a potential risk of collision or not.

The radar remains an important source of information even for vessels at relatively close range. But as distance decreases the view from the bridge becomes a still more important source of information for the navigator—provided, of course that the weather is clear.

The radar information is central in the assessment of the foreign vessel’s intentions: The radar logs the continuous movements of the other vessel and displays previous positions as a trail of small dots on the display. The chain of dots signify a course tendency to the observing navigator, and he can utilize this information as an possible indicator of future movements.

One overall assessment needed when narrowing down a foreign vessel’s possible future movements is to determine where it can actually go without grounding. This involves a comparison between at least two parameters: the vessel’s draught and the water depth of the local waters. The latter information is available in a highly precise format in the sea chart and tide tables, while the navigator can only guess about the draught of the vessel he is observing. An experienced navigator will, however, be capable of a qualified guess based on the observable characteristics of the vessel: its size, the type of vessel (bulk or container carrier, gas or crude oil tanker, ferry, etc.)—but the fact remains that he can never know for sure via observation only. This was the case with the ferry off Felixstowe: sometimes—if the water depth allows for it—they leave the lane and head directly for the harbor entrance; the problem was however that the navigator had no means of determining if the water depth did indeed allow for the direct path to the harbor or if the vessel had to stay within the deep water lane. Speculation is in place but only in case of very large or small vessels can the navigator feel certain about his judgment.

Let us assume that a foreign vessel that is a potential candidate for a collision scenario and further, that it can not exit the lane it is presently in. Then there still remains a number of possible tracks that the vessel can chose to follow within the lane. Ideally, international and local conventions like the international collision avoidance regulations (IMO, 1995) and the local traffic separation schemes should allow the navigator to determine the legally possible movements. However, in the context of determining the possible movements of a foreign vessel, measures like traffic separation schemes have only symbolic value—they can (provided the needed water depth) be violated with no physical consequences for the vessel. So, this too is a rather uncertain assessment.

The only device on the bridge which gives explicit indications regarding the future position of a foreign vessel is the radar: The orientation of the vector of the foreign ship indicates its course while the length of the vector indicates its speed and thus where it will be positioned within a given period of time. However, this information is only indicative in the case of a steady course, and vessels on collision course quite naturally tend to change course before they meet steel to steel. When they do, a number of shortcomings in contemporary merchant marine radar systems may come into play. Most significantly, since the radar works on relative data in the relation between own and foreign vessels, it sometimes have severe difficulties in calculating reliable vectors when both vessels are turning at the same time—and sometimes this results in a complete loss of vector and a consequent loss of numerical course and speed data as well.

Finally, there are cases like the Sealand Atlantic’s radar observation of the Sally Mærsk, where the radar is functioning according to specifications but where the representation of the foreign vessel may be misleading rather than assisting collision avoidance. Notice that we are assuming a fully functional and precise radar:

In Rotterdam the Saeland Atlantic initially misunderstood the intentions of the Sally Mærsk. This misunderstanding may well have included the representation of Sally Mærsk provided by the radar. Sealand Atlantic was outbound at slow speed and Sally Mærsk was inbound, headed for the
The Sally Mærsk is inbound for Rotterdam. There are four actors on the bridge: master, chief officer, pilot, and helmsman. The auto pilot has been switched off and steering is now performed manually. All are silent. Then the pilot speaks: starboard twenty. The helmsman speaks: starboard twenty. And all are silent again.

Fragment 5. Rudder command.

The communication between the pilot and the helmsman is characteristic of high workload situations; such as an approach and departure from port. Only the rudder command is explicitly spoken. Other elements like, receiver, the status of the message (command), desired time of implementation, etc. are left out. Following (Halliday, 1994) and (Andersen, 1997) we will say that the explicit elements constitute the focus, while the implicit form the background for the communication.

The distribution between focus and background in the communication between the pilot and helmsman can be illustrated by means of a typical sentential schema.

<table>
<thead>
<tr>
<th>Subject</th>
<th>TAM</th>
<th>Verb</th>
<th>Object</th>
<th>Manner</th>
<th>Time, place</th>
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<tbody>
<tr>
<td>someone</td>
<td>do</td>
<td>acting on</td>
<td>something</td>
<td>in some way</td>
<td>somewhere</td>
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Table 1. Sentential schema. TAM is short for tense, aspect, modality.

A sentential scheme consists of a set of slots following one another in a more or less fixed sequence. Each slot can be filled with a particular kind of linguistic material, e.g. nouns, verbs or adverbs. Each set of elements within a category form a so-called paradigm.

In the communication between the pilot and the helmsman only one paradigm is in focus. The remaining paradigms are backgrounded. Only the manner slot is filled-in explicitly, the rest are left ‘blank’.

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<th>Verb</th>
<th>Object</th>
<th>Manner</th>
<th>Time, place</th>
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<tbody>
<tr>
<td>helmsman</td>
<td>should</td>
<td>turn</td>
<td>wheel</td>
<td>starboard</td>
<td>twenty</td>
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Table 2. Focused paradigm is grayed.

The overall purpose of the communication between the pilot and the helmsman is the desired accomplishment of a physical task, i.e., turning the rudder in order to change the vessel’s course. Safe operations rely on detailed and specific communication about the vessel, the navigating crew, and the surrounding world—that is, communication about the cooperative work arrangement and the common field of work. Safe operations are not maintained by having someone steer some course somehow—it is achieved by having specific individuals do certain tasks in particular ways. In the present case, having the helmsman turn the rudder to the twenty degrees starboard position.

If we view oral communication from this perspective it follows that one explicitly filled-in paradigm must at the same time constrain the contents of the other paradigms to exactly one member. Rudder commands are examples hereof, and serve to illustrate the principle of focus and background as a means of reducing communication workload and complexity (Carstensen & Nielsen, 2001).

Elaborate use of backgrounding calls for a high degree of flexibility in the communication. Communicating parties must be able to quickly and flexibly change the distribution of focused and...
backgrounded paradigms when paradigms, initially in the background, demand explicit focus.

The communication in fragment 3 between Sally and the Sealand Atlantic indicates the considerable use of backgrounding in communication between vessels. Negotiations are characterized by the exchange of short and concise messages rather than elaborate explications of possibilities and intentions.

Flexibility in terms of effortless changes between focus and background are needed and indeed available in the case of spoken communication. Consider the changes in focus and background performed from fragment 3 to fragment 4. Initially, the principal assumption—that the vessels are going to meet head-on—was kept in the background during the communication between the pilot onboard the Sally Mærsk and the Sealand Atlantic. However, in fragment 4 the master of the Sally Mærsk turns focus on the initially backgrounded by questioning the head-on assumption. In fragment 4, line 9, the master states that the Atlantic will overtake Sally, and from this point on the plans agreed to by the pilot no longer make sense: Atlantic can not both overtake Sally and meet her port to port. The building misunderstanding is thus prevented by the change from focus to background—effortlessly.

There are important points to be made in relation to changes from background to focus. Firstly, they often occur when a misconception or misunderstanding is experienced; secondly, the opportunity for recovery from misconceptions and misunderstandings is dependent on the availability of certain information (Andersen et al., 2000). The consequence of this, in relation to the approach to Rotterdam is that the misunderstanding could probably only be cleared up by the navigating crew of the Sally Mærsk. The crew onboard the Sealand Atlantic simply did not possess any information that could lead them to consider that the Sally Mærsk could be in the process of performing a 360° turn (and not just a course correction).

Arguably, the circumstance, that collision avoidance is often based on limited, imprecise and rudimentary information is rooted in the fact that there is no easy way of making the desired information available—neither for the sender, nor for the receiver—within the medium of spoken communication. Sending and receiving all the relevant information between two vessels via the VHF would be extremely labour intensive and time consuming—not to mention the fact that much of the relevant information is not easily represented in verbal language in the first place. That is, the representations available on the instruments would have to be ‘translated’ into a usable format for spoken interaction: say, a 360° turn represented by a circle on the sea chart would have to be communicated as a (rather high number of) successive positions constituting the circle—and these would in turn have to be plotted in the sea chart onboard the receiving vessel.

The difficulties involved in providing the desired collision avoidance information via VHF becomes even clearer if we consider the difference between the information needed in order to understand the intention of the foreign vessel—vs.—the information needed in order to crosscheck the received intention. Comparatively, the latter would be desirable but requires more information.

The principle of crosschecking information obtained from different sources is implemented whenever possible in general navigation. When fixing the vessels position, for example, the navigator will compare the GPS based position plots with plots based on radar information (bearing and distance to objects like buoys and landmarks). And in doing so he achieves a higher degree of certainty regarding the vessel’s position.

When engaged in collision avoidance it is often not possible for the navigator to crosscheck information. Recall that the crew of the Sally Mærsk had experienced that ferries off the Felixstowe harbor sometimes leave the lane and go directly for the harbor entrance—but that the crew had no means of checking if this was indeed a possibility for this particular ferry.

Sealnd Atlantic experienced a similar problem with the Sally Mærsk. Sealnd’s radar information, and the information they initially received from the pilot on board the Sally Mærsk matched. Both information sources indicated that Sally’s intention was to make a minor course adjustment and head for the harbor entrance. Both indications were wrong however, since Sally was in the first stages of a 360° turn. The pilot of the Sally Mærsk confirmed on the VHF that his vessel was in a port turn but did not specify the ‘magnitude’ of the turn—and it was basically due to this bit of lacking information that a misunderstanding with grave potential arose.

Had the Atlantic known Sally could actually not enter the harbor right away, that her rudder was hard aport (indicating a larger course change), and that her speed and rate-of-turn were low because Sally was killing time, then maybe the Atlantic’s crew would have been able to tell that they could not go port to port with the Sally Mærsk but that they would overtake her.

The present practice of collision avoidance at sea does not require the pilot to provide the vast amount of information needed in order to allow the foreign vessel to crosscheck the proclaimed intention—and nor does the communication medium support the exchange of this magnitude of
information in a timely and effortless manner. Consequently, only a minimum of information is passed between vessels, and the error potential will presumably not be reduced in any significant way until this shortcoming is remedied.

CONCLUSION
The paper set out to indicate problems in the present practices of collision avoidance at sea—problems, as seen from the perspective of the crew performing the task of collision avoidance.

The two real-world examples of collision avoidance that were presented, and the subsequent discussion of problems related to observation and communication, indicate that contemporary collision avoidance suffers from limited, ambiguous, and rudimentary information about foreign vessels. The problems are most significant when vessels are prevented from communicating directly via the VHF. Yet our data also suggest that spoken communication may not be the ideal medium for all types of information exchange in collision avoidance—due to issues of lacking persistency (Andersen et al., 2000; Carstensen & Nielsen, 2001), format differences between instruments and ‘speak able’ information, labor-intensiveness, etc.

The examples of collision avoidance indicate the need for different types of information and that the actual information requirements are variant across collision avoidance scenarios. This suggests that future means of enhanced collision avoidance should be flexible in terms of the information made available to the navigating crews in different collision avoidance situations.

However, further analysis of a wider set of vessels and collision avoidance situations are needed, along with a more structured and conceptually founded approach to collision avoidance, before any conclusions can be drawn on how to best redesign the practices of collision avoidance for enhanced safety at sea.

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