Maritime Collision Detection and Advisory System (MCDAS) -
Improving Situation Awareness and Enabling Lean Manning

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Synopsis
This paper maps the three levels of Situation Awareness (i.e. perception, comprehension and projection) in maritime navigation to the different watchkeepers’ roles (Look-Outs, Radar/Navigation Specialist and Officer-Of-the-Watch) inside the bridge of a naval vessel. It can be shown that the Maritime Collision Detection and Advisory System (MCDAS) complement these roles by operating as a data processing system and decision support tool inside the bridge to improve situation awareness and subsequently becomes an enabler for manpower reduction. Implementation screenshots are shown to illustrate the system in operation and its space requirements.

Keywords: situation awareness; maritime navigation; collision detection; collision avoidance; lean manning.

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(1) Situation Awareness in Maritime Navigation

The commonly used definition model of Situation Awareness is that defined by Endsley’s [1]. His definition is based on an information processing approach that establishes a model comprising of three levels of Situation Awareness as follows:

- First level: perception of the elements in the environment within a volume of time and space
- Second level: comprehension of their meaning
- Third level: projection of their status in the near future

In the maritime navigation domain, the first level involves the perception (detection by equipment or/and humans) of elements (ships, land mass, water depth, hazardous zone) in the environment (navigation area, voyage plan). The second level deals with the comprehension of their meaning (relative position and speed, integration of these information) while the third level focuses on the projection of their status in the near future (risk assessment of imminent collision). This is summarised as shown below:

![Figure 1: Three levels of Situation Awareness in Maritime Navigation.](image)

(2) Roles of Watchkeepers in Situation Awareness

The three levels of Situation Awareness are embedded within the different watch keepers' roles inside the bridge and summarised as follows:

<table>
<thead>
<tr>
<th>Watchkeeper</th>
<th>Role Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Look-out</td>
<td>(1) Visually detects targets. (2) Reports bearing of these targets to OOW.</td>
</tr>
<tr>
<td>Radar/Navigation Specialist</td>
<td>(1) Monitors Radar, AIS, ECDIS displays. (2) Alerts the OOW of any Closest Point of Approach (CPA). (3) Reports the range and bearing of these targets to OOW.</td>
</tr>
<tr>
<td>Officer-Of-the-Watch (OOW)</td>
<td>Correlates information from Lookouts, Radar/Navigation Specialist and assess risk of collision</td>
</tr>
</tbody>
</table>

Table 1: Three types of watchkeepers and their roles in the bridge.
A typical layout of the bridge onboard a naval vessel and the positions of the above mentioned watchkeepers are shown below:

![Figure 2: A typical bridge layout and the positions of the watchkeepers.](image)

(2.1) **Look-Outs**

The primary role of the Look-Out involves visual detection (*perception*) of targets using his naked eyes and sometimes with the use of binoculars. Once he has identified a target that presents risk of collision with his own ship, he reports the bearing (*comprehension*) of the identified target to the Officer-Of-the-Watch (OOW). As shown in Figure 2, one Look-Out is positioned and assigned to focus on the port side while the other is positioned and hence assigned to focus on the starboard side of the naval vessel. The view below shows what the Look-Out perceives from his assigned view of responsibility.

![Figure 3: Field of view seen from the eyes of the Look-Out.](image)

The level of comprehension of the Look-Out on the relative bearing of the targets to his own ship is often qualitative based on his own judgment. Generally speaking, a Look-Out is not required to report the bearing information of the targets with high precision.

(2.2) **Radar/Navigation Specialist**

The Radar/Navigation Specialist focuses on monitoring the displays (*perception*) from the Radar, Automatic Identification System (AIS) and Electronic Chart Display and Information System (ECDIS). The common parameters being monitored include Closest Point of Approach (CPA) time and range, relative positive and bearing to own ship (*comprehension*). He alerts the OOW with these parameters when he has identified targets that present risk of collision with his own ship. The Radar/Navigation Specialist's perception typically revolves around monitoring displays adhering to the formats shown below:
The comprehension of this watchkeeper on the relative position and bearing of the targets to his own ship and the CPA is often quantitative and aided by the system which computes these parameters automatically when the targets of interest are manually selected. In some implementation, these parameters are computed automatically even without the operator's selection of the targets. In either cases, the quality of the Radar/Navigation Specialist's comprehension will be subjected to the capabilities of the system. Since the Closest Point of Approach (CPA) is computed by the system, this watchkeeper is relying on this system to perform the task of Level 3 Situation Awareness (projection) as well since the system projects the region of collision (if any) in the near future.

(2.3) Officer-Of-the-Watch (OOW)

The Officer-Of-the-Watch plays a significant role in the bridge with regard to maritime navigation. In most cases, he may be positioned in the front centre of the bridge and equipped with a gyrocompass as shown in Figure 2. Under such positioning, he can visually detect targets (perception) since he has a visual frontal field of view. With the aid of the gyrocompass, he can also check the relative bearing of the target of interest to his own ship (comprehension). He also integrates the information received from the Look-Out and Radar/Navigation Specialist and develop a mental model that allows him/her evaluate the risk of collision in the near future (projection). Once he has decided that this risk exists, he quickly computes a new course and speed with the aim of avoiding this possible imminent collision.

(2.4) Information flow among the watchkeepers

The information flow among the watchkeepers is summarised below.

Figure 4: Radar display and Electronic Chart Display and Information System (ECDIS).

Figure 5: Information flow among the watchkeepers.
(3) Improving Situation Awareness

A research report released in March 2015 by Rotterdam Mainport University of Applied Sciences [2] made the following recommendations and conclusions to enhance situation awareness in maritime navigation:

(a) Data processing is one area that can enhance situation awareness.

(b) A data processing and decision support system can be implemented on a bridge and the data from all the different systems be presented to the watch officer in a clear way so that he can interpret the critical information easily.

(c) Data processing has the future possibilities of reducing crew size.

The Maritime Collision Detection and Advisory System (MCDAS) is one such data processing system that can improve situation awareness in maritime navigation and possibly reduce crew size in the bridge. It improves situation awareness by:

(i) Operating as a data processing in the bridge that handles Situation Awareness at Level 1 (perception), Level 2 (comprehension) and Level 3 (projection). It constantly scans the horizon during day and night, correlates the information received from Radar, AIS, GPS, Camera, ECDIS, and projects the status of collision in the near future.

(ii) Operating as a decision support tool that constantly computes avoidance action even for collision with multiple targets in heavily congested waters.

(iii) Presenting a clear integrated display showing vital information required for collision detection and avoidance, hence reducing overall human fatigue in the bridge.

The next few sections will describe in detail how this system works.

(3.1) Mimic Look-Out's perception and comprehension

The figure shown below shows the camera view of the system display which mimic what the Look-Out sees and reports.

![180 degrees front camera panoramic view](image1)

Figure 6: Left: Wide camera view with target bearing marker. Right: Zoom-in camera view of the target.

The wide camera view on the left mimic what the Look-Out sees from his position inside the bridge. The target bearing marker provides a higher precision quantitative feedback compared to the what the Look-Out can originally provide. The zoom-in camera view on the right mimic what the Look-Out sees using his binoculars. This view allows him to ascertain whether the target is static or moving with a particular heading.
(3.2) Mimic Radar/Navigation Specialist’s perception and comprehension

The figure shown below shows the electronic chart within the system display which mimic what the Radar/Navigation Specialist sees and reports.

![Electronic Chart](image)

Figure 7: ECDIS display integrated with radar, AIS, GPS and Automatic collision warning.

Both the Radar Automatic Radar Plotting Aids (ARPA) and AIS targets are shown as overlays on the ECDIS. Automatic collision warning is presented as a line from the target which presents risk of collision with own ship, hence the Radar/Navigation Specialist knows exactly the target that will collide with his own ship in the near future. This feature is useful especially when there are imminent collision with multiple ships.

(3.3) Mimic OOW’s perception, comprehension and projection

The figure shown below illustrates the full system display which integrates information from the Look-Outs and Radar/Navigation Specialist through the automatic target correlation between the camera view and the electronic chart display.

![180 degrees front camera panoramic view and Zoom-in camera view](image)

Figure 8: Full System Display.
The full System display relieves the OOW from the need to form a mental picture to evaluate the risk of collision in the near future. Another feature being offered is the function of a decision support tool which recommends the new heading and speed for avoiding collision based on COLREGs (Convention on the International Regulations for Preventing Collisions at Sea, 1972). This allows the OOW to consider this option before instructing the helmsman to execute these new navigation parameters. After the new heading and speed have been executed, the system continues to detect collision and recommends avoidance course and speed automatically. This increases the bridge watchkeepers’ efficiency and greatly reduces the fatigue of the OOW and his watchkeepers during critical moments of navigation when multiple ships change course and heading simultaneously in heavily congested waters.

(4) Reducing Crew Size

The introduction of such data processing and decision support tool to handle the different levels of Situation Awareness in the bridge allow us to consider the different manpower reduction options. Assuming a bridge crew of 5, there are three manpower reduction options that can be considered as follows:

*Figure 9: Manpower Reduction Option 1 - 20% reduction (with 1 Look-Out removed).*

*Figure 10: Manpower Reduction Option 2 - 40% reduction (with 2 Look-Outs removed).*
(5) Implementation Example

Recorded screenshots during sea trials are provided to illustrate the full system display in operation.

Figure 11: Manpower Reduction Option 3 - 60% reduction
(with 2 Look-Outs and 1 Radar/Navigation Specialist removed).

Figure 12: System Display for Day Navigation.
Figure 13: System Display for Night Navigation.

Figure 14: System Display for Night Navigation.
The following illustrations provides some insights on the physical space requirements inside the bridge and on the mast-top.

**Figure 15:** System Display (shown in red circle) inside the Bridge. Generally, a 23 inch Panel Personal Computer (Panel PC) suffices.

**Figure 16:** System placement on mast-top.
(6) Conclusion

The three levels of Situation Awareness (i.e. perception, comprehension and projection) in maritime navigation are embedded within the roles of Look-Outs, Radar/Navigation Specialist and Officer-Of-the-Watch inside the Bridge of the naval vessel. This paper describes how the Maritime Collision Detection and Advisory System (MCDAS) can complement these roles by operating as a data processing and decision support tool to improve situation awareness and subsequently becomes an enabler for manpower reduction. Implementation screenshots are shown to illustrate the system in operation and its space requirements.

(7) References


(2) Blankenstein (Principal) and van der Drift (Project Manager) (2015), "Enhancing Situation Awareness, A Research about improvement of situation awareness on board of vessels", A Research report by Rotterdam Mainport University of Applied Sciences.