DYNAMIC POSITIONING CONFERENCE
October 13-14, 2015

Design 1 SESSION

Enabling technologies for Marine ADAS

Hazard Detection – the missing piece of the DP jigsaw

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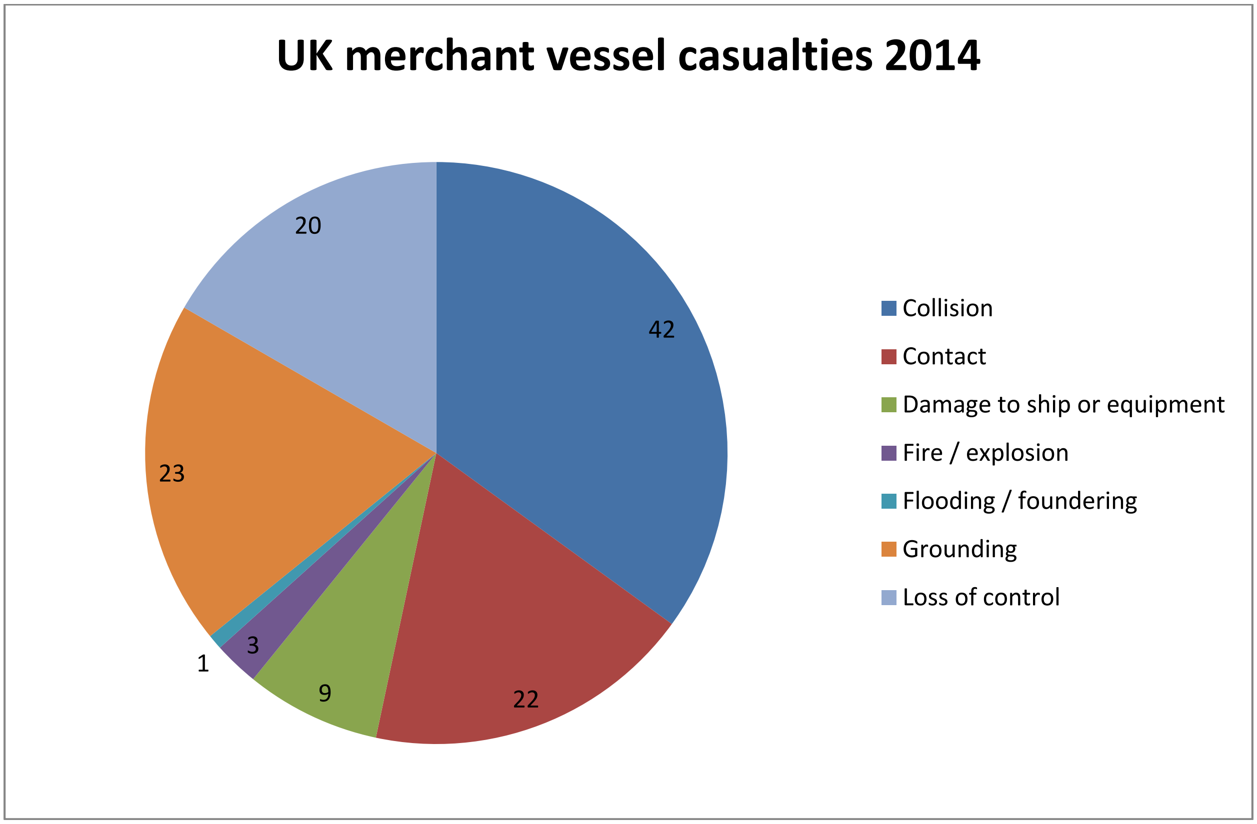
Abstract

Advanced Driver Assistance Systems are becoming a commonplace for cars. ADAS provides features such as Adaptive Cruise Control, Lane Departure Warning, Forward Collision Warning and parking assistance. Hazard awareness systems are emerging for ships providing analogous features such as drive-on warning, collision warning and berthing assistance. These systems are enabled by microwave and other sensors which look at the immediate vicinity of the vessel. We look at some example sensors and systems. We discuss how they might complement and integrate with Dynamic Positioning systems.

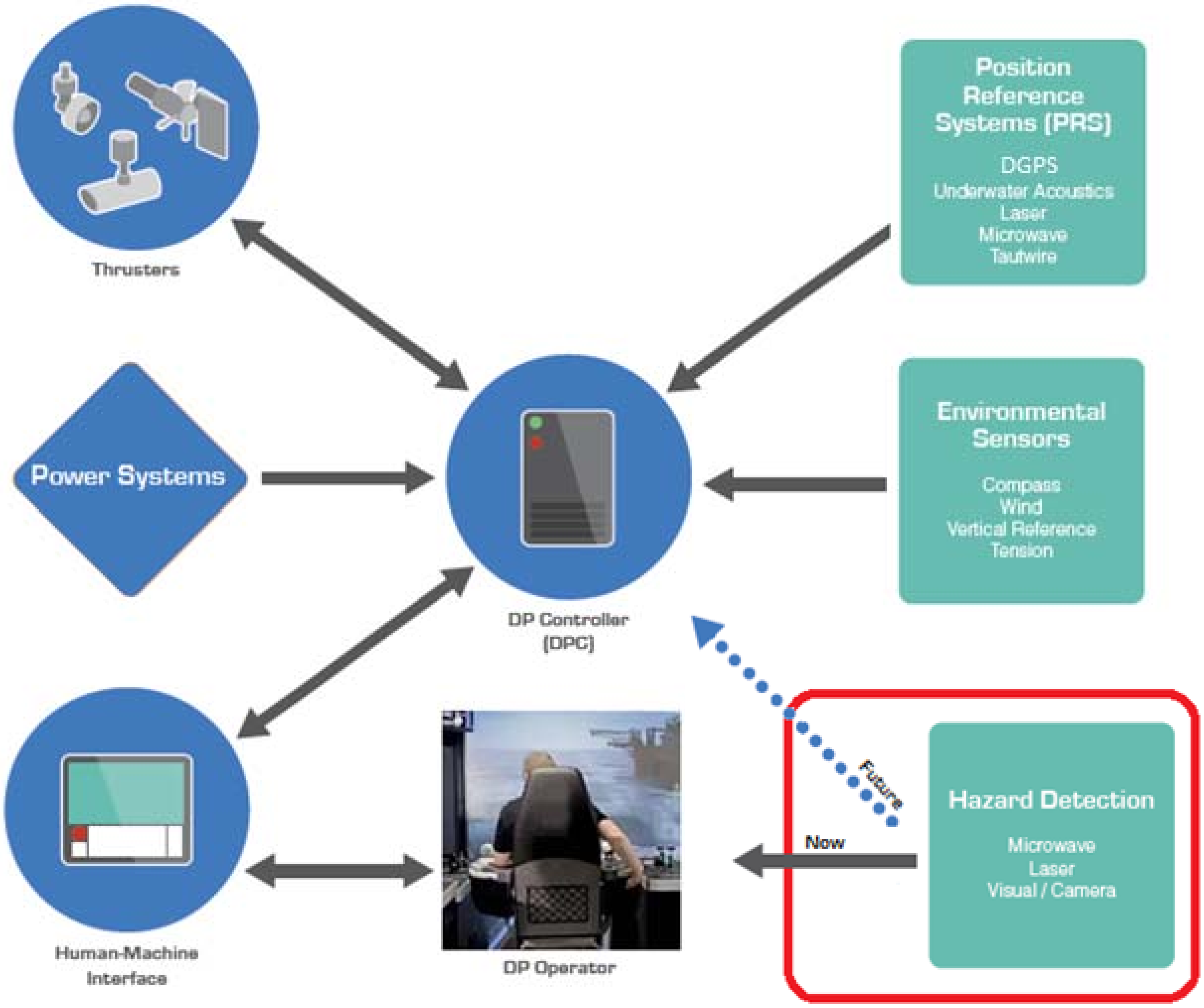
The Case for Hazard Detection

Enormous progress has been made on safety on recent years, both in merchant shipping [1] and the oil and gas industry [2]. The majority of injuries on UK merchant vessels are attributable to collision with other vessels and contact with other structures [3].



Figures taken from [3].

What is Hazard Detection?



The traditional DP approach is to use feedback from a highly accurate global positioning system to perform precision vessel maneuvers in the vicinity of an oil rig. In the PiLoNav project [4], a GPS receiver with inertial assistance is the source of position feedback for the automatic control of river barges – global accuracy with no local sensing to support precision movement over a wide operating area. Such an approach is not only dependent on high accuracy of global position. It also relies on a comprehensive map where the absolute position of all the features represented on the map must be known with high accuracy.

More recently a new approach is being taken. By analogy with recent developments in automotive technology, we could characterize this as “Marine ADAS”.

In the AUTOSEA project [5], the system envisaged uses a multitude of sensors to look at the area around the ship. The project takes its inspiration from self-driving cars rather than ADAS and concentrates on collision avoidance for autonomous vessels on the open sea. We take a similar approach, although we’re rather more concerned with safety in close maneuvering.

What is ADAS?

The International Road Transport Union offers the following definition:

> Advanced Driver Assistance Systems have been designed to help the driver in the driving process with the aim of improving road safety.
>
> These supporting systems constantly monitor the vehicle surroundings as well as driving behaviour to detect potentially dangerous situations at an early stage. In critical driving situations these systems warn and actively support the driver and, if necessary, intervene automatically in an effort to avoid a collision or to mitigate the consequences of an accident.
>
> Examples of these systems are Adaptive Cruise Control, Autonomous Emergency Braking Systems, Lane Departure Warning Systems, Collision Avoidance Systems, Night Vision, Traffic Sign Recognition, Blind Spot Detection, Driver Drowsiness Detection, to name but a few.

Within the broad field of Advanced Driver Assistance Systems, it's useful to classify the systems according to origin of the information:

Look at the vehicle
These are systems which monitor the internal condition of the vehicle, giving warnings and taking action. For example: ABS, traction control, tyre pressure monitoring, crosswind stabilisation, hill descent, etc.

Look at the driver
For example, driver drowsiness detection, alco-lock.

Look around the vehicle
These are systems which process data from vehicle-mounted sensors to provide information about the surroundings of the vehicle to the driver and, were appropriate, to take control action.

Listen to other vehicles
Platooning, co-operative collision avoidance.

Listen to the Highways Agency
Traffic information, electronic road signs, etc.

Read a map
Sat-nav, local speed limiting, wrong-way warnings, etc.:

Intelligent sensor systems which look around the vehicle provide the following capabilities:

- Adaptive Cruise Control
- Automatic headlight control
- Collision avoidance and Pre-crash
- Intersection assistant
- Lane departure warning
- Blind spot monitor
- Parking assistance
- Automatic parking
- Traffic Sign Recognition

Marine Hazard Detection System Capabilities

By analogy with ADAS we can identify a number of capabilities that we need from a marine Hazard Detection System:

Drive-on protection
A vessel is holding station near an offshore structure. Due to sensor failure, actuator failure, a software error or operator error the vessel begins to drive towards the structure. If the condition is not detected in time, a collision may result with all of the dangers and costs that would follow.

An appropriate sensor system can detect the hazard and warn the crew. For this to be useful, we require both a low false alarm rate and a high probability of detection of a hazard. We can imagine that the drive-on protection system could take control of the vessel once a hazard is detected so that it can automatically drive away from the collision, but this would require an extremely high level of integrity in software and hardware from the hazard detection subsystem.

A similar drive-off risk arises when the vessel is tethered to the platform through a pipe or cable.

Collision avoidance
A vessel is moving at moderate or high speed among other vessels, floating debris, buoys, etc. We want a system which can give a warning of a collision risk so that the vessel can take appropriate evasive action.

Traffic surveillance
This capability focusses on a fixed platform, a slow moving vessel or a station-keeping vessel. One or more smaller vessels are moving in the vicinity. We want to monitor those vessels from the platform and give a warning of unauthorized movements or of collision risks.

Gap maintenance
A vessel is operating near an offshore structure. It is required to maintain a minimum gap. The sensor system measures the gap and gives a warning if the gap is too small. It may also give a warning if the gap is too large.

We can go beyond a mere monitoring system to use the feedback to maintain the gap within limits automatically.

For instance we might make a couple of measurements of the gap between the stern of a vessel and an offshore wind turbine tower. We can use this feedback to control the position of the vessel relative to the tower, with gyrocompass feedback used to control the heading of the vessel.

In another example we can use the feedback from the gap monitoring system to control a support vessel to follow a weathervaning FPSO or a pipe-laying vessel.

Berthing assistance
A vessel approaches a quay or similar fixed structure. The vessel needs to get very close, possibly making contact, but any contact needs to be at very low speed.

The sensor system provides feedback on the position and speed of the vessel relative to the dock.

Automatic sign recognition
We could imagine a system analogous to the automatic sign recognition systems found in automotive ADAS which processes camera images to read channel buoys and other markers.

It’s not clear that this would add much value for a vessel that is already equipped with GPS and electronic charts.

Depth monitor
A vessel in shallow water may be at risk from grounding. Hydro-acoustic depth sounders are already common place. Simple single beam devices are very well established. Echo locators which deliver an image of the sea bed ahead of the vessel are readily available.

Sensor modalities

We can classify sensors by their modality, that is, the physical principle that they rely on:

- Radar
- Lidar
- Camera
- Infrared
- Ultrasonics
- Hydroacoustics

Radar

ARPA (Automatic Radar Plotting Aid) systems provide hazard detection for vessels on the open seas. Current systems typically use data from pulsed radars operating in the X band, which limits their usefulness in close maneuvering, due to their relatively poor minimum range and range resolution. The high peak power of a pulsed radar is also a problem for operation near an oil production platform.

Microwave radar recommends itself for use in a marine short range hazard detection system for the same reasons that it has proven popular for automotive ADAS. It provides a robust all-weather sensing capability.

The K and W bands are more attractive for hazard detection than the X and S bands commonly used for marine navigation radar. We don’t need long range or high power and resolution tends to improve with frequency. On the other hand, development costs rise with frequency. The choice of radio frequency is further limited by spectrum management regulations. The band from 24.05GHz to 24.25GHz gives the best compromise.

Lidar

It is commonly believed that optical systems are vulnerable to bad weather. In practice when operating over tens of metres, this is seldom a problem. The build up of dirt on the external optical surfaces of the device is more of an issue. Cleaning may not be enough. A wiper system may be necessary, but this too will need maintenance. Lidar has been largely eliminated from automotive ADAS in recent years, and it may not be any more successful in marine hazard detection.

Camera

Cameras can be used in three different ways:

CCTV
An independent CCTV system used alongside the hazard detection system.

Integrated CCTV
A unified display showing feedback from other hazard detection sensors overlaid on the video image.

Machine vision
Computerised interpretation of the video sequence to estimate the position of objects in the scene. This may extend to a multi-modal sensor data fusion system which combines information from different types of sensor.

Like lidar, a camera system is somewhat vulnerable to weather conditions and to dirt or water film on the window. Lighting conditions around the vessel are highly variable which presents a challenge for a camera system, although extra lighting in sensitive areas can often fix this.

Infrared

A thermal imager working at a wavelength of around 10nm can detect anything warm in the scene. This makes it useful for security applications since it can detect an intruder, whether through body heat or the heat of an engine. It doesn’t do so well at picking out cold obstacles; a harbour wall, the leg of an oil platform, etc. So it’s less useful for obstacle detection.

Ultrasonics (in air)

Car parking sensors operate at 40 to 50 kHz. The maximum detection range is in the range 2.5m to 5.0m.

It’s probably the case that automotive ultrasonic sensors have insufficient range to be useful in vessel operations. More powerful sensors will be able to see further, but a big price rise is to be expected once we move away from the mass produced devices supported by the car industry.

Breakers and white caps are believed to be significant sources of ultrasonic background noise [7]. There is very little experimental data available on the effect above the water. This may limit the effectiveness of in-air ultrasonic sensing in rough weather. Further experiments would be required.

RangeGuard

RangeGuard is a 24GHz FMCW radar available from Guidance Marine which is packaged for the marine environment. The range resolution is 0.75m. Range to a point target can be measured much more accurately: down to the nearest inch. It has high sensitivity and low noise, essential for detecting objects challenging to short range microwave radar, such as the bow of a ship.

The “spot” version of the sensor emits a narrow circular beam, 11° wide. This is useful for making precision measurements.

The “flood” version of the RangeGuard sensor a wide 110° beam in azimuth, shaped to give a crisp edge to the beam. It’s usually a better choice for obstacle detection, but it can also be better for gap monitoring.

These are single beam sensors. Multi-beam and imaging sensors are quite feasible. Useful angular resolution (of the order of 10°) is readily achievable in a small device. We can expect affordable devices suitable for the marine environment to become available before very long.

Is it a good idea?

More instrumentation doesn’t necessarily lead to safer operations. Operators can find themselves looking at the instruments when they should be looking out of the window. With a high false alarm rate, users can get used to ignoring the sensor displays. On the other side of this coin, users can become overly reliant on the sensors to detect all hazards and become inattentive. Users can feel “out of the loop”. These factors must be addressed by careful user interface design which keeps users feeling that they are in control, and where enough information is presented to direct the user’s attention to the hazard, but not so much that it keeps them from using their eyes.

It’s also well-known that better safety systems don’t always lead to safer operations due to the phenomenon of behavioural adaptation [8]. Users who feel safer will take more risks, reducing the safety benefits somewhat as they take other benefits, such as increased speed.

The hazard detection system will record warnings along with other ship data at the time. This can promote compliance. This doesn’t necessarily require any formal process. The mere feeling of being watched can lead users to stick to the rules.

Conclusion

Hazard detection systems are beginning to emerge which plug an important gap in traditional DP. Some gaps in sensor coverage have recently been filled, particularly where close maneuvering is concerned. An integrated approach which supports rather than replaced the operator promises to promote situational awareness and safe and efficient operation. Given the enormous progress than analogous systems have made in the automotive field, we can expect Hazard Detection Systems to be an important trend in marine technology in the coming years.

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