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AIS and Radar Data Fusion in Maritime Navigation

Key words: radar, AIS, navigational data fusion

The introduction of Automatic Identification System (AIS) was a great step to improve maritime safety. It was an extra source of navigational data in addition to radar. The problems of radar and AIS navigational data fusion are descussed in this article.

Fuzja danych AIS i radaru w nawigacji morskiej

Słowa kluczowe: radar, AIS, fuzja danych nawigacyjnych

Znacznym krokiem w kierunku podwyższenia bezpieczeństwa nawigacji było wdrożenie systemu automatycznej identyfikacji statków (AIS) jako dodatkowego dla radaru źródła danych nawigacyjnych. Problemy fuzji danych radaru i AIS zostały przedstawione w artykule.

Introduction

Integration of the following components: RADAR and AIS, offers the opportunity to build more sophisticated systems for safe navigation. The idea of integration is based on the exploitation of synergies between both components.

An acronym for Universal Shipborne Automatic Identification System, AIS is a maritime mobile band VHF broadcast system that can send both dynamic and static ship information such as MMSI, call sign, position, course, and speed to other AIS transponders and base stations. Recent years have seen AIS functionality expand to include the sending of a variety of additional information, such as ETA, waypoints, data from navigational aids such as buoys and lighthouses, rate of turn, time stamp, ship type, type of cargo, draught, dimensions, passengers, and text messages.

An AIS transponder consists of one receiver and two transmitters. Two frequencies, 161.975 MHz and 162.025 MHz (VHF 87B & 88B), are dedicated for AIS use. A GPS System provides the transponder with ship position as well as time synchronization. Working together, an AIS shipborne transponder sends data, based on a specific protocol, at regular intervals, which is received by other shipborne transponders as well as VTS AIS base stations.

AIS is clearly a progressive step forward, enhancing existing radar and assisting navigation. However, it was not conceived and developed as a tool to improve port business – and here, authorities are still calling for ideas on how to "make money" from the information collected from shore-based AIS installations. The investment for the shore-based installations along Germany's coastline is calculated at 12.5 m € (Source: Lopos Technologies Gmbh Hamburg).

1. Radar

Radar (ARPA) is the most traditional data source in maritime navigation. Modern vessels are usually equipped with two marine radars and very often both of them are able to track a target. Errors of radar tracking and information delay especially during target maneuvers are well known. According to IMO (A.823.(19)) regulations, ARPA should calculate the target speed and course within three minutes period. The same or even more time consuming is speed vector calculation after target or own ship maneuver. The target speed vector calculating delay may become mission-critical, particularly during encounters in narrow fairways.

One of the great advantages of the radar complement such as AIS is its ability to detect targets in place where radar would not be able to detect targets because of obstruction or shading of the radar beam.

It has been argued (Pettersson, 2003) that with an AIS display presenting AIS ships, the officer of the watch will forget to fine-tune the radar to detect small craft. It is important to emphasize that the radar is and will remain one of the most important instruments on the bridge, even in the future. It is important that the officer of the watch knows the difference between the radar and the AIS, and realizes the importance of tuning the radar to detect small craft without AIS onboard.

2. Automatic Identification System

AIS (Automatic Identification System) is going to be mandatory equipment for seagoing ships. AIS implementation onboard ships began on July 1 2002 under revised SOLAS rules and will finish in 2008. Navigators should be yet aware that even after 2008 not all ships will be carrying AIS. All ships below 300 gt are exempted from carrying AIS. For ships sailing in domestic waters, this threshold is even increased to 500 gt. However, it should be stressed that there is potential negative impact on safety when AIS is required for some types of vessels while not for others.

The functionality of AIS has been sufficiently defined by IMO, ITU and IEC. AIS provides additional information received from other ships. This information includes the following:

Static information:

- Identification,
- Dimensions,
- Type of ship.

Voyage related information:

- Draught,
- Hazardous cargo,
- Destination,
- Route plan.

Dynamic information:

- Position,
- Course,
- Speed,
- Navigational status.

Themain problem during simultaneous target tracking by more than one sensor (radar and AIS) is that each track source will create its own track and will be presented separately (Figures 1 and 2).

3. Radar – AIS data fusion

From now on, ships have two sources for the display of own and other ships positions: radar and its complement: AIS. Following simple logic, if one system is the complement to the other, they should have similar and compatible results. AIS-positions should “complement” radar echos (i.e. the ship, displayed on the radar or ECDIS screen, is expected in only one position).

The display error between two moving objects is dependent upon the positioning accuracy of each object plus the vector of relative horizontal translation of these objects during the up-date interval, as a function of their relative speed.

This error is “controllable” only if all participants are positioning the own object within comparable quality. AIS displays original positions calculated and/or referenced by sensors, differing by type and make aboard ships: GPS – DGPS – GPS/WAAS – LORAN – EUROFIX. Updates are dependent on traffic situation, speed, traffic density, type of cargo (dangerous goods).

Therefore, only under optimal conditions – i.e. an update rate of AIS-signals for all participants at 2 sec – is the distance between two objects displayed within 10m accuracy. The delay between positioning and display of the position may become mission-critical, particularly during encounters in narrow fairways.

Original Image of Radar + AIS on the Hamburg VTS display
Ship's equal speed 5 kn - unchanged direction

Difference of Radar vs. AIS signature: > 10 m

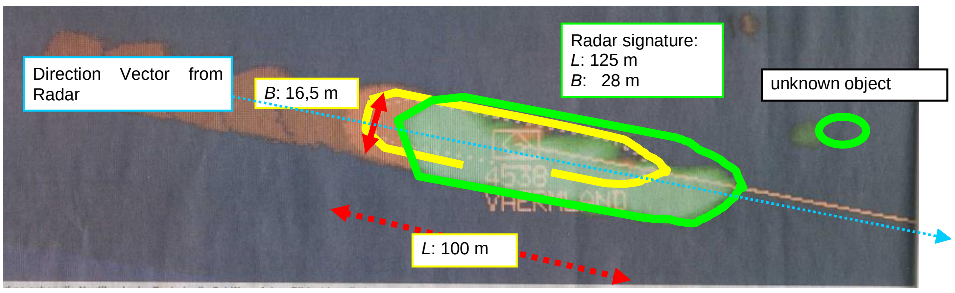

Fig. 1. Radar-AIS display divergence (Source: LOPOS Technologies GmbH Hamburg)
Rys. 1. Rozbieżność prezentacji radar – AIS (Źródło: LOPOS Technologies GmbH Hamburg)

To match AIS and ARPA-targets on the display of such a device, AIS-data do not need to be updated within the same intervals as radar. It is assumed that once marked with the AIS-data, they will follow the ARPA-target at any interval. If the transmitted AIS position should be fused with the (filtered) radar echo, not only the update rate < radar update (i.e. 3 sec) must be secured, but also clear regulations and standardised (verifiable) algorithms for the data fusing process.

A situation where different tracks of the same object are observed is unacceptable for a watch officer or VTS operator. AIS and radar tracks should not be displayed separately. The integration radar and transponder information becomes a typical problem of track fusion. Both information sources should be used for the estimation of target position and movement. One of the solutions is extended Kalman filtering. A new approach in nonlinear state estimation is neural filtering. Some interesting results of neural networks introduction for nonlinear tracked targets state vector estimation was presented in (Stateczny, 2001; Stateczny and Uruski, 2003).

After a filter decision that the different tracks describe the same target one target with one speed vector should be presented on the navigator’s display. By integration of both measurements within one tracking filter, the accuracy, availability and reliability of the tracking results will be increased (Sandler M., Gern T., Zimmermann R, 2003). It should also be noted that the fusioned target track can display higher target dynamics than with radar alone.

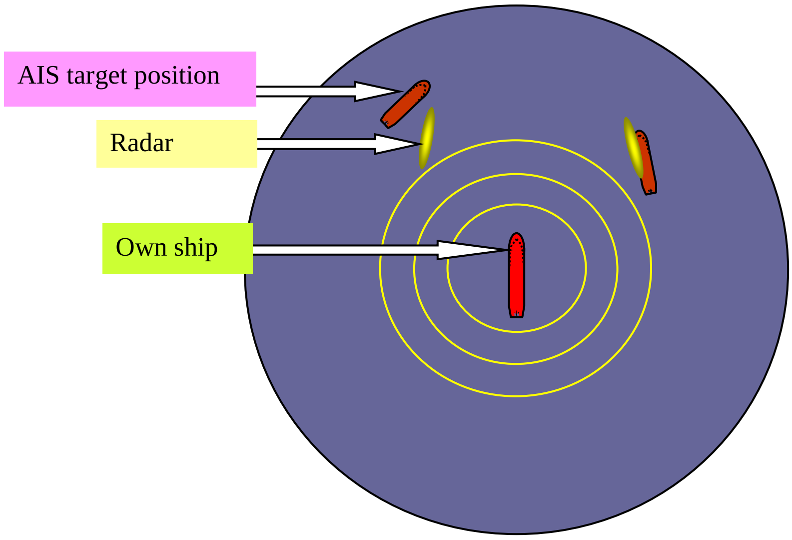

Fig. 2. Radar-AIS display divergence radar – AIS (Source: LOPOS Technologies GmbH Hamburg)
Rys. 2. Rozbieżność prezentacji radar – AIS (Źródło: LOPOS Technologies GmbH Hamburg)

Another problem is the different reference system. ARPA, according to an IMO regulation, is usually sea stabilized, while an AIS position is ground stabilized. It means that the IMO should prepare another modification of "ARPA performance standards…".

There is also a symbolic conflict between ARPA, ECDIS and AIS symbols. Symbols for vessel tracking were previously published by IEC and recognized by IMO for radar/ARPA and ECDIS. It makes many watch keepers negatively react to new AIS symbols and find the display (for new symbol reason) cluttered.

Final remarks

The introduction of AIS is a large step forward toward improving maritime safety and VTS efficiency, with significant benefits for both VTS Centres and vessels. However, it should be clearly said that AIS cannot replace radar for several important reasons. The most important reason is that a radar can obtain an image including each targets (vessels, buoys, coastline, islands and others) even without AIS receivers. The main advantage of AIS is that it allows navigators to "look around the corner" in narrow passages which means that they can also recognize vessels which due to insufficient radar coverage would normally not be detected. Thanks to radar and AIS data fusion, the watch officer will receive more complete navigational information, even on objects untracked by its own ship's ARPA.

In the author's opinion the next step to enhance navigational safety in the costal area is the introduction of Active Vessel Traffic Information and Management System (Stateczny, 2003 and 2004).

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