EVALUATION OF A HF-RADAR SHIP DETECTION ALGORITHM BY COMPARISON TO AIS AND SAR DATA

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Abstract: A ship detection and tracking algorithm for HF-radar is evaluated by comparison to Automatic Identification System (AIS) and satellite borne Synthetic Aperture Radar (SAR) data to provide an estimate of the detection and false alarm rate performance in a real operational scenario. This paper presents results from the HF-radar experiment that is ongoing since May 2009 and operates two HF-radar systems operating at 12.5 MHz in the Ligurian Sea. Preliminary results show the effectiveness of the HF-radar as a long range (~140 km) and continuous time coverage surveillance asset, despite its low spatial resolution. The performance of the HF-radar ship detection and tracking algorithms are evaluated by comparison to AIS and SAR. In addition the performance of the algorithms will be investigated with respect to environmental parameters such as wind, waves and currents, resulting from the HF-radar system as well as numerical model results and *in situ* data.

1. INTRODUCTION

Effective maritime situational awareness (MSA) requires exploitation of all available data to identify a single, consolidated surveillance picture that identifies anomalies of interest. Additionally, the selection and operation of limited surveillance resources must be made so as to optimize anomaly-detection performance. The NATO Undersea Research Centre (NURC) MSA project is developing a maritime surveillance system (MSS) capability that includes vessel ground truth and contact simulation, sensor processing, data fusion, anomaly detection, sensor management, and performance evaluation. In support of MSS development, NURC is studying a number of prototype surveillance systems. Current maritime surveillance capabilities are based on a mix of cooperative, e.g. MSSIS network AIS, and non-cooperative, e.g. coastal and high frequency (HF)-radar, active and passive sonar and satellite borne synthetic aperture radar (SAR) sensors.

It is of interest to characterize sensor performance for all available sensors types, to include the detection range, receiver operating characteristic (ROC) detection performance curves and localization accuracy. The performance characterization of sensors and ship detection algorithms in terms of false alarm rate detection probability as well as contact positioning error is one of the keys to achieve improved surveillance capabilities. One of the main interests of the NURC MSA project is the optimization of detector parameters and the test of new detector architectures in operational scenarios [1][2].

The HF-radar is one of the main assets being investigated, due to its low level of maturity for ship detection (today HF-radars are especially used for ocean surface current and wave measurements), with interesting complementary characteristics with respect to other sensors of interest, like continuous and long distance coverage and improved target velocity estimation through Doppler analysis. The paper presents results from a NURC experimentation involving two HF-radars operating at 12.5 MHz in the Ligurian Sea of the Mediterranean Sea. The HF-radar ship detections and tracks are compared to AIS data, which represent the ground truth. Several satellite borne SARs data have been collected in the area, which are used for target confirmation, in particular in case of tracks, which are not within the AIS data.

2. THE NURC HF MARITIME EXPERIMENT

NURC is funding and conducting an extensive research activity for characterizing and optimizing ship detection algorithms for the HF-radar in collaboration with University of Hamburg, Germany. Two Wellen Radar (WERA) systems [3][4][5] have been installed at the Italian coast and are operating since 8. May 2009. They are intended to operate until end of December 2009 on an operational basis to monitor ocean surface currents and waves, and to develop and improve HF-radar ship detection and tracking algorithms. Both radar systems transmit with 30 W (via four antennas) and a receive the backscattered signal by an antenna array consisting of 16 antennas. In Fig. 1 the Ligurian Sea setup is depicted showing the overlap area in which the current and wave retrieval is performed as well as the range.

The general aim of this project is the simultaneous collection and analysis of sets of satellite borne SAR, HF-radar, AIS and environmental data in order to achieve an improved understanding of ship detection processors and to link detection performance with the environmental conditions. This will be the base to subsequently improve the detection performance proposing new processing schemes and sensor configurations.

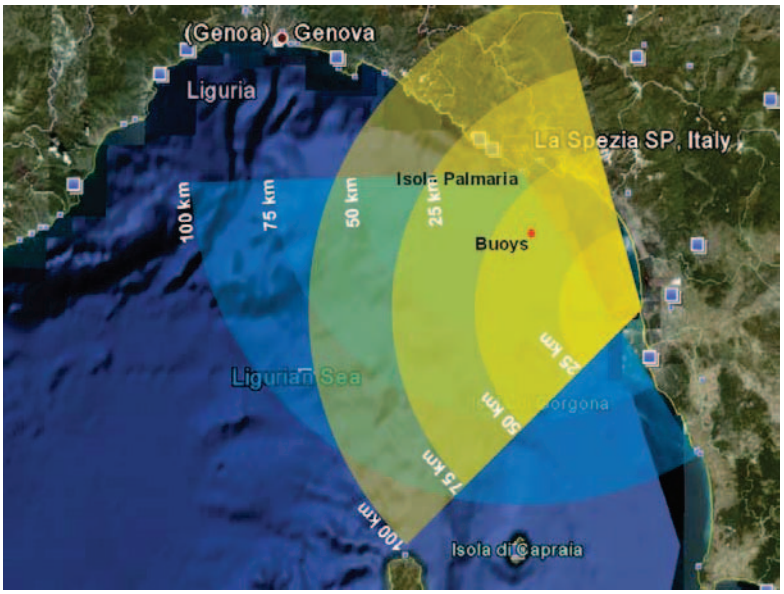

Figure 1: Map depicting the HF setup in the Ligurian Sea. The red dot shows the location of a Meteo and a wave rider buoy, which were deployed for validation purposes.

3. DATA PROCESSING AND RESULTS

HF-radar returns received by each element of the receiving array are arranged and processed for beam forming and ship detection so as to have a scan every 30 sec over the area of surveillance. The detection algorithm is a constant false alarm (CFAR) detector working in the Doppler-Range space. Tracks are formed using a scan, contact based tracker and visualized on geo-referenced maps. The detection performance evaluation has been performed using AIS contacts and the assumption that these represent ground truth.

Figure 2 shows an example of radar tracks (blue lines) with AIS tracks (green dots) superimposed for comparison. The picture shows a good match between AIS and HF-radar tracks. Detection and false alarm rate are automatically evaluated associating radar contacts and AIS contacts through a minimum distance criterion and a threshold test. The proportion of associated radar contacts with respect to the total number of AIS contacts provides an estimate of the detection rate. Not associated radar contacts are considered false detections and are used to estimate the false alarm rate. When available, SAR images are also used to confirm acquired targets. The preliminary results on a limited number of radar scans are promising, but they need to be confirmed by extending the analysis to a larger data set. A complete statistical analysis will be presented in the final version of the paper.

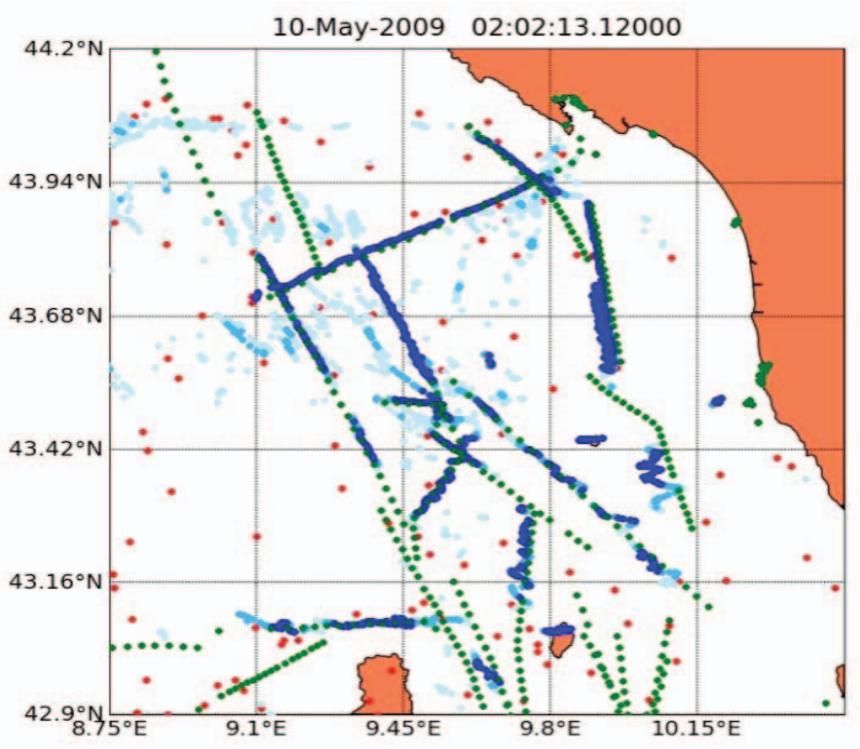

Figure 2: HF-radar tracks (blue dots) compared with AIS tracks (green dots). The confidence level of HF-radar tracks increases from light blue to dark blue. Red dots represent false detects in the considered scan.

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