OPERATIONAL APPROACH FOR SHIP DETECTION AND CLASSIFICATION

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1. INTRODUCTION

The necessity to control all the activities within the marine environment is nowadays vital for most official authorities. Besides protecting the ecosystem and providing safety and surveillance along the transportation corridors, illegal immigration and sustainable economic activities are also issues to cover. Since early nineties, a lot of efforts have been devoted to develop monitoring systems based on active on-board transponders (VMS or AIS), which track ship positions via satellite communications. But, the experience showed this approach does not have the enough independence and other alternatives were proposed. The one gathering more benefits is the integration of remote sensing, specially Synthetic Aperture Radar (SAR), with operational transponders as provides redundancy 7/24 all-weather monitoring capability and independence from the targets to track.

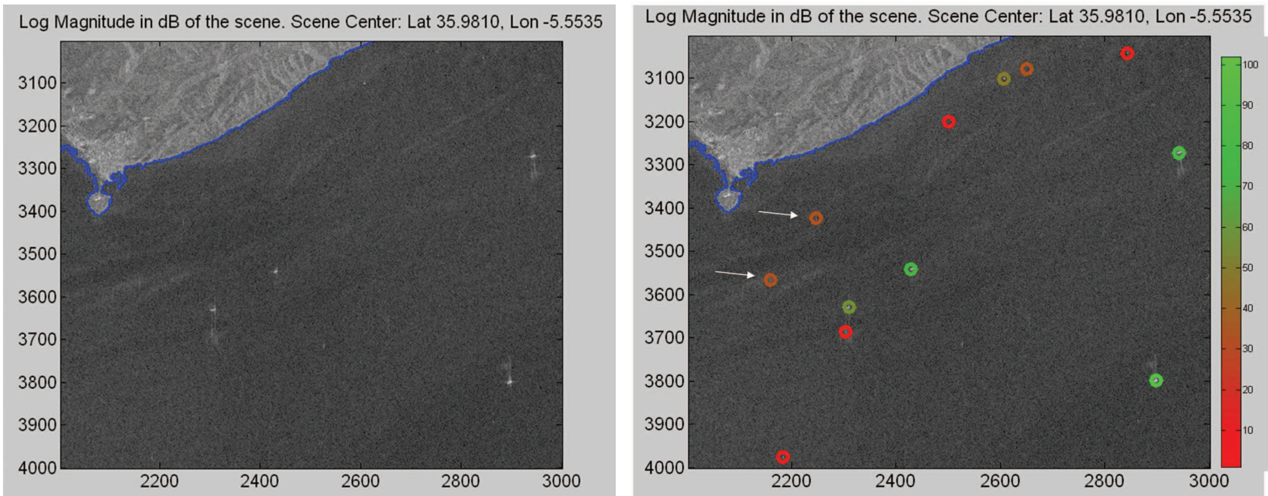
Ship monitoring with SAR is not evident as some constraints make ship signature isolation very difficult. The limited resolution, coherent speckle noise, land masking and image distortions due to the dynamic environment are the items affecting the most. They have been one of the main causes for which ship monitoring has been mainly restricted to ship detection of medium and large ships with no additional information regarding type of vessel, cruising velocity and expected course for historical reports. But the new generation of SAR sensors, as TerraSAR-X or Cosmo-Skymed, with increased resolution, polarimetric and revisiting time capabilities are changing this situation. On the one hand, the finer resolution allows to reduce the effect of speckle noise and, thus, to increase the chances for detecting small and less dispersive targets, of special importance in illegal immigration. On the other hand, the sensor configuration is closer to that proposed in recent works that would allow accurate and robust ship classification for a large range of classes [1] [2]. Both issues are crucial for advancing towards an AIS-redundant ship monitoring system based on SAR image analysis with minimum dependence on active transponders.

This work presents a ship monitoring system conceived to reach the previous objective, SAMONS (SAr-based MOnitoring of Ships). In its first version, the system presents a ship detection module based on wavelet processing and a classification module based on fuzzy logic. Unfortunately, data availability was up to now strongly limited and, only, single-pol ENVISAT and ERS images can be processed. This avoids to fully exploit the potentialities of the system. Certainly, the addition of polarimetry and finer resolutions will help to improve classification confidence, increase the range of ships detected, reduce the effect of speckle noise and perform course prediction with estimated velocities and historical reports. After a brief explanation of the main steps of the system, performance will be tested with some image snapshots and correlation with AIS information.

2. SYSTEM DESCRIPTION

The first version of SAMONS accounts five independent modules, which can be separately improved according to the needs.

1. **Data Import**. This module reads input image and extracts metadata information for geocoding and report generation.
2. **Land Masking**. This modules extracts the land of the scene. By now, land masking is based on shape files supported by a simple algorithm exploiting RCS. Advanced coastline isolation techniques based on wavelets are being integrated.
3. **Ship Detection**. This module uses wavelet processing for locating possible ship spots. Some rules and recombination of scales allow to notably reduce false alarms and focus on those points that are most likely to be assumed as ships.
4. **Ship Classification**. This module uses an external file to classify the located ship signature via fuzzy logic. On the one hand, ship signature is isolated by means of an iterative process based on Radar Cross Section (RCS) and morphology analysis. On the other hand, classification is performed by applying a set of decision rules fixed by the levels that certain



(a) (b)

Fig. 1. Snapshot of an HH ENVISAT image acquired with image precision mode at the Strait of Gibraltar (a) and the resulting detection results (b) where a detection confidence is assigned to each spot. Note the spots highlighted by white arrows, which may correspond to illegal cayucos cruising from South (Morocco) to North (Spain).

parameters acquire. These parameters are the mean RCS of bow, middle and stern sections within the signature [1], and the estimated length and breadth. For each reference ship, fuzzy logic defines the thresholds within the decision rule.

5. **Report Generation**. This module exports the result of image analysis in .txt and .xml formats. They provide information, among others, of the number of located ships, their geodesic position or the estimated bearing, length and breadth.

3. SHIP DETECTION PERFORMANCE EVALUATION

Fig. 3 shows an example of the detection results provided by SAMONS for an IMage Precision (IMP) HH ENVISAT image with a resolution of 30 m and pixel spacing of 12.5 m. Reflectivity image shows how all the spots that can be localized by eye-inspection are isolated by the system plus some additional ones that are more difficult to evaluate. All of them are labeled with a confidence value, which is updated by the analysis of RCS- and wavelet-related parameters. In general, large and high dispersive targets have a confidence close to 100 % whereas short and less dispersive targets have a confidence close to 0%. Also important are the two spots highlighted by the white arrows that seem to correspond to two wooden-made cayucos cruising from South to North trying to reach the beaches of Spain, close to Punta Tarifa. But with no ancillary information and improved resolution and polarimetric image capabilities, such asseveration is not easy to corroborate.

4. SHIP CLASSIFICATION PERFORMANCE EVALUATION

5. CONCLUSIONS

6. REFERENCES

[1] G. Margarit, Jordi J. Mallorqui, and X. Fabregas, "Single-pass polarimetric SAR interferometry for vessel classification," *IEEE Trans. Geosci. Remote Sensing*, vol. 45, no. 11, pp. 3494–3502, Nov. 2007. 1

[2] G. Margarit and Jordi J. Mallorqui, "Scattering-based model of the SAR signatures of complex targets for classification applications," *International Journal of Navigation and Observation, Special Issue on Modelling and Processing of Radar Signals for Earth Observation*, vol. 2008, no. ID: 426267, pp. 11 pages, Aug. 2008. 1

[1] These sections contain 1/3 of the total pixels conforming the ship signature. Stern section is defined as the external section having the highest mean RCS.