Use of Sentinel- 1 data for Maritime Domain Awareness : Preliminary results

Charou E.
Institute of Informatics & Telecommunications, NCSR Demokritos, Agia Paraskevi, Greece

Bratsolis E.
Technological Educational Institution of Athens, Aigaleo, Greece

Gyftakis S.
Giannakopoulos T.
Perantonis S.
Institute of Informatics & Telecommunications NCSR Demokritos, Agia Paraskevi, Greece

***Abstract*—** In this work the utility of Synthetic Aperture Radar (SAR) data acquired from the SAR instrument on-board the recently launched ESA's Sentinel-1 to Maritime Domain Awareness (MDA) is studied. The limitations of the currently used Automatic Identification System (AIS) for ships is presented. The use of space based SAR sensors for MDA is discussed and the recently available ESA's Sentinel1 satellite is considered in more detail. An automatic methodology for ship detection from Sentinel 1 is presented and applied in the environmentally important sea straits between Kythera and Elafonisos islands, Southern Greece. Preliminary results show that Sentinel1 has a significant role to play in MDA.

Keywords*—*Maritime Domain Awareness, Ship detection, Sentinel1, SAR

I. INTRODUCTION

Maritime domain concerns all areas and things of, on, under, relating to, adjacent to, or bordering on a sea, ocean, or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, and vessels and other conveyances. Maritime domain awareness (MDA), refers to the effective understanding of anything associated with the maritime domain that could impact the security, safety, economy, or environment. Request for maritime surveillance has increased, particularly in the field of maritime security and safety. Towards this end coastal-based surveillance systems are widely used e.g., automatic identification system (AIS). AIS transmits identification, position , status, heading and other characteristics of the vessel [1][2]. The transmission is realized either directly from vessel to shore, or via relay using transponders on nearby vessels or received using Satellite AIS systems (S-AIS).

In the frame work of our ongoing project “AMINESS: Analysis of Marine Information for Environmentally Safe Shipping” (www.amines.eu) AIS data are used to extract user-friendly data analytics regarding environmentally safe shipping [3] . A Policy Recommendation tool is being developed and will be available to policy makers and general users.

However, AIS data has limitations when used on MDA. The International Maritime Organization (IMO) requires AIS to be carried by all ships with gross greater than 300 tons on international voyages, by all ships with gross greater than 500 tons on any route, and Passengers ships of any size built after 2002. Therefore only a small fraction of vessels (~200.000 of the 17.000.000 register worldwide) are required to carry AIS. Moreover AIS based surveillance depends on the cooperation with the ship as it can be turned off or turned to transmit misleading [4]. Maritime surveillance and observation of these non-cooperative ships become very important.

Satellite imagery gives the possibility to overcome these limitations. Nowadays, satellite images at a variety of modes are available and can be selected. Although considerable work has been done using optical Visible and Infrared (VIS+IR) satellite data to provide ship surveillance over wide regions [5], [6]. [7], [8], Synthetic Aperture Radar (SAR) is a very well suited instrument for this purpose due to its all weather and day / night imaging [9][10][11][12].

The rest of this paper is organized as follows: section II presents a general description of SAR data while section III describes the data and methods used. The experimental results and conclusions are presented in section IV

II. SAR DATA DESCRIPTION

SAR systems map the earth's surface to produce final output images which are based on the properties of antenna arrays and pulsed waves. Strip mapping SAR consists of a large antenna which is synthesized from many small antennas and remains fixed with respect to the radar platform so that the large antenna illuminates a strip of the ground.

This technique is used to improve the azimuthal resolution. As the platform moves, a sequence of closely spaced pulses is emitted and the returned waveforms are recorded. An image is computed after the coherent sum of reflected monochromatic microwaves. The resulting signal is complex, with phase uniformly distributed on $[0,2\pi]$ and a magnitude having large random variations.

For one pixel, the returns of these points are added vectorially and result in a single vector, which represents, in a complex format, the amplitude A_s and the phase φ_s of the measured power of the total echo, returned from the site *s*.

The image is distorted by a strong granulation, called speckle. Speckle noise exists in all types of coherent imaging systems and its presence reduces the resolution of the image and the detectability of the target. Speckle noise is not only signal dependent but is also spatially correlated and reduces the effectiveness of image reduction. Speckle reduction is becoming a routine process in SAR image applications. It is well known that speckle is multiplicative noise. In consequence, a number of filtering algorithms dealing with multiplicative noise have been proposed.

Quantitative evaluation of a filter includes several procedures. Among these the most important are:

1. Preservation of the mean;

2. Reduction of the standard deviation;

3. Preservation of edges; and

4. Texture preservation

Polarimetric SAR architecture involves transmission and reception of Radar waves using a particular polarization. Depending on the type and number of polarizations used this architecture can be divided into different categories:

- Quad-pol or full polarimetry: Orthogonal dual transmission (H and V), coherent dual receive (HH, VV, HV and VH)

- Dual pol and compact polarimetry: Dual or single transmission and dual linear receive.

Hybrid polarimetry is a part of compact polarimetry where circular polarization is transmitted and two coherently linear polarizations are received.

A polarized wave experiences a change in its state of polarization when it interacts with a target. There are many ways in which the state of a polarized electromagnetic wave can be represented mathematically. Decomposition techniques help in interpreting the scattering information embedded in the polarization of a backscattered wave. Basically, polarimetric decomposition techniques work by splitting the polarized backscatter information from each SAR image pixel into a combination of different scattering mechanisms which help in the physical interpretation of the area under observation or the physical properties of [13][14][15].

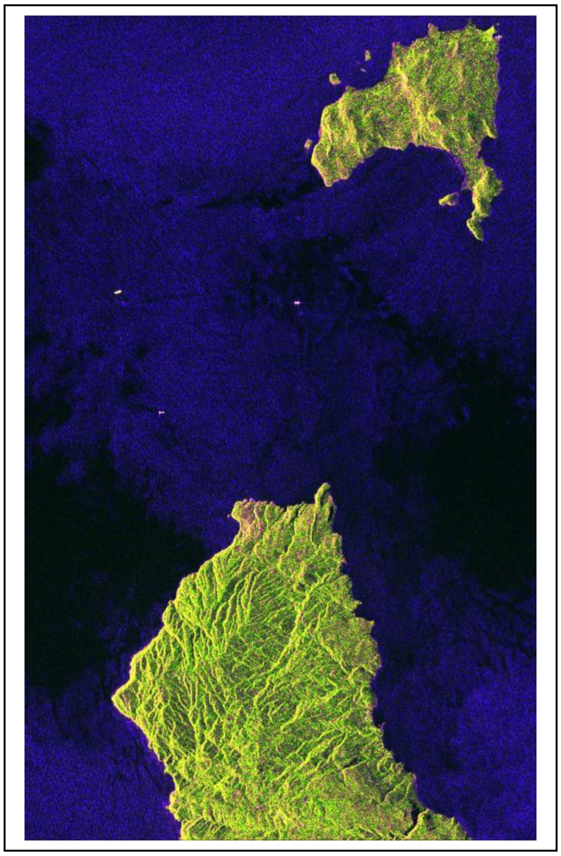
Historically it was difficult to obtain SAR data as they are expensive. With the advent of ESA's Sentinel mission which is freely distributed it is becoming easier. The SENTINEL-1 mission comprises a constellation of two polar-orbiting satellites, operating day and night performing C-band synthetic aperture radar imaging, enabling them to acquire imagery regardless of the [16]. The Sentinel family of satellites is being developed to meet the operational needs of Europe's environmental monitoring program, Copernicus. The information provided by the Earth-observing missions will provide a wealth of information for various services that help improve daily life and address the environmental consequences of climate change.

III. DATA AND METHODS

A. *Data used*

A Sentinel 1 image, taken on 29/3/2015 at start time16h 22min 45sec UTC and stop time 16h 23min 10sec UTC was downloaded from the Hellenic National Sentinel Data Mirror Site. A subset covering the environmentally important Natura channel between the Cythera and Elafonisos islands , South Greece was extracted.

Fig.1 Study area



B. *Ship Detection Methodology*

Ship detection systems consist of the following four major operations [9].

1 **Pre-processing**: calibration of the source image to make pre-screening easier and more accurate.

2 **Land sea masking**: generation of land mask to masking out the land pixels and ensure that detection is focused on the area of interest.

3 **Pre-screening**: detection of bright points by using a moving-window adaptive threshold algorithm.

4 **Discrimination**: rejection of False Alarm based on object dimensions.

For prescreening, the classical and robust constant false-alarm-rate (CFAR) algorithm was applied. The basic idea is to search pixel which are unusually bright when compared to surrounding area as ships in SAR images appear as bright areas compare to the sea. The object detection is performed in an adaptive manner. For each pixel under test there are three windows, namely target window, guard window and background window surrounding it. The target window size is about the size of the smallest object to detect, the guard window size is about the size of the size of the largest object and the background window size should be large enough to estimate accurately the local statistics

The operator computes background mean μ_b and standard deviation σ_b using pixels in the background window.Next computes the mean value μ_t of the target window. If$\mu\ t > \mu_b + \sigma_b * t$, then the center pixel is detected as part of an object, otherwise not an object. All windows are moved by one pixel to detect the next pixel.

IV. RESULTS

For our experiments the Sentinel-1 Toolbox (S1 TBX) was used. S1 TBX is a new open source software for scientific learning, research and exploitation of the large archives of Sentinel and heritage [17]. The object detection procedure of Sentinel1 Toolbox was used to detect ships on sea surface from Sentinel 1 imagery. A land mask was created using the SRTM 3sec DEM. After masking out the land pixels Adaptive thresholding was applied. The following parameters were set:

target window size = 100m

guard widow size= 200m

background window size= 800m

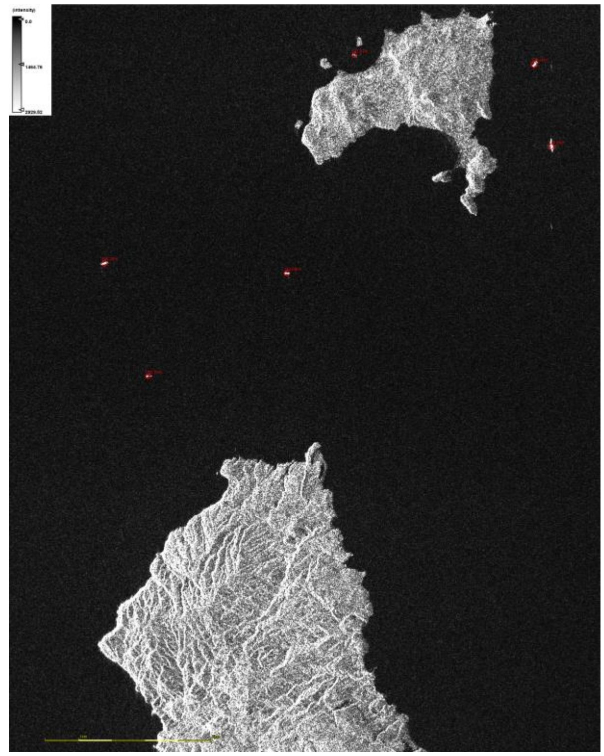
The position and length of the ships detected are shown in Table 1. Figure 2 shows the ships (in red circles) detected by the methodology in the area of study. An initial qualitative evaluation of the results shows that the Sentinel 1 data could play a significant role in the maritime domain awareness.

TABLE I. SHIPS POSITION AND LENGTH

Longitude	***Latitude***	***Ship length***
22°52'05" E	36°25'25" N	164,29m
22°53'24" E	36°23'42" N	150,15m
22°55'46" E	36°25'48" N	162,99 m
23°00'32" E	36°28'39" N	148.88m
22°59'53" E	36°29'56" N	184,10m
22°56'16" E	36°29'34" N	141.62m

In the future work, the ship detection results based on AIS data will be included and compared to the results found when the SENTINEL1 data were used.

Fig.2 Ships (red color) detected on Sentinel1 satellite data



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