SUSTAINABLE MONITORING OF SEA-VESSELS OVER BOSPORUS WITH USE OF GOOGLE EARTH ENGINE PLATFORM

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Abstract
Bosphorus is an important strait which connects Black Sea to the Mediterranean along Marmara Sea, and very strategic marine transportation line for commercial sea-vessels which carry economic good. Traditionally the statistics of vessels are under responsibility of Turkish coastline security Department. In this study, we develop a sustainable vessel monitoring system which allows user to monitor the sea vessels from the specific date which SAR satellite data are available. The system is based in Google Earth Engine Platform. Sentinel 2 images have been used to create water mask. Sentinel SAR image has been used to detect the vessels. The image has been preprocessed for angle correction to ensure the image all pixels to the same pixel size. Then, the median value of SAR pixel values of all image collection in Google Earth engine is calculated to allow the detection of any object on the sea, which shifts the pixel value from the median value. The method is implemented in Google Earth Platform and the user can select any date to monitor the vessels over Bosphorus including the information of number of total vessels.

Keywords: Ship detection, RADAR, Google Earth Engine

INTRODUCTION

The position and behavior information of the ships is important in particular for safety, environment, and border control of maritime (Kanjir et al., 2018; Máttyus, 2013). Large scale geospatial datasets which include SAR and optical images are significant for maritime monitoring (Bi et al., 2017; Kanjir et al., 2018),

In the last decade, research studies on ship detection from SAR images have been significantly increased. Liu et al. (2019) separated these studies into four groups. These are constant false-alarm rate (CFAR), the generalized-likelihood ratio test (GLRT), the saliency-based methods and the deep learning-based methods.

There are also existing online ship monitoring systems. For example, Shipping Explorer (Web1) uses AIS data (automatic identification system) to identify locations and provide detailed information about ships. Based on AIS, the system creates a map of ship movements in real time on the seas and oceans, allowing monitoring the positioning of ships and ports. In this system, there are additional layers in the application that contain information about air, wave and wind. The program allows searching of ships according to various criteria (ships, MMSI, IMO, type, registration information, destination, etc.). For example, it allows you to monitor all cruise ships go to some specific location. There are flexible configuration systems for notifications via SMS and email to track ship positions in real time. For example, you can be informed when your ship enters a certain area, changes its speed or course.

Another service is The MarineTraffic website (Web2) is a community-oriented project based on research collaboration between academics and developed by existing Information and Communication Technology (ICT). The main purposes of the service are; maritime telecommunications, simulation of ship movements to secure navigation and cope with critical events, interactive information systems design, design of databases that provide real-time information, statistical
processing of ports traffic with their applications in operational research, pollution identification studies, Design of effective algorithms for maritime assessment, estimation of estimated time of ship arrivals, weather forecast and maritime operations. The system provides free real-time information to the public via its website, along with the positions and movements of the ships, as well as other relevant information (e.g. traffic on the ports, travel details), especially on the coastline of many countries around the world.

The Find Ship (Web3) is a software which produced by Marine Toolbox. It is mostly for the amateur users. It is a program followed by users with sailors, yachts, sailboats and small boats. It is not as successful as other applications due to its high content and error margin.

There are several ship monitoring technologies. Automatic Identification System is one of them (Web4), and it is an obligatory to set up and use for commercial ships bigger than 300 Gros Tonalito according to the World Maritime Organization. AIS uses audio frequencies but cannot be perceived and understood as sound. AIS receiver and transmitter are required to read the broadcast. The AIS system maintains ship anchor status, destination and ETA next port (estimated arrival time) movement, name, port, speed, call sign, position (coordinates) of the ship, ship size, number of personnel and regularly sends this information to land stations. This information can be followed by any person. The transmission of this information is expressed as a maximum of 20 nautical miles in good weather conditions. On the other hand, Long Range Tracking and Identification (LRIT) is an international tracking and identification system established by IMO to provide a comprehensive monitoring system for ships around the world under the SOLAS agreement.

Apart from these tracking services and technologies remotely sensed images are other alternative to track and count the ships according to the image acquisition temporal resolution. In this study, we used Google Earth Engine Platform to detect the ships on the Bosporus, Istanbul-Turkey from an imperially selected date. The methodology is based on Wong et al. (2019)’s study with modifications in thresholding and integration of optical imagery to improve the quality of the results.

MATERIAL AND METHODS

Material

Google Earth Engine Platform (Web5) has been used to derive and process the datasets and visualization of the results. The platform is operated by JavaScrpit programming language in Google Servers as Cloud Computing platform and free of charge for the research purposes. There is a large geospatial data catalog that the user can call and process the respective datasets for different type of operations and research studies. The catalog includes satellite imagery datasets (Landsat, Sentinel etc.) in global scale, and some high resolution datasets in regional areas. The catalog also includes vector and atmospheric datasets to combine with any other assets provided by the users.

Figure 1. Google Earth Engine code editor

Three types of datasets have been used in this study, which are

- Sentinel 1 SAR Image
- Sentinel 2 Multispectral Image

Sentinel 1 SAR images have been used for the ship detection purpose. The properties of Sentinel 1 data are shown in Table 1.
Table 1. Specifications of Radar Image

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Sentinel 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image type</td>
<td>Synthetic Aperture Radar</td>
</tr>
<tr>
<td>Ground Sample Distance</td>
<td>10 m.</td>
</tr>
<tr>
<td>Data type</td>
<td>Ground Range Detected</td>
</tr>
<tr>
<td>Acquisition Date</td>
<td>2018-07-20</td>
</tr>
</tbody>
</table>

Sentinel 2 multispectral images have been used to create water area mask to process only the regions where have potential to have ships. Normalized Difference Water Index has been calculated with use the median values of the satellite images from the specific date range. The use of a single image will not be sufficient to calculate the NDWI value since the water pixels may be covered by other objects including ships. Therefore analysis of all pixels among a large data range would allow picking the consistent water pixel value with calculating the median value. The properties of Sentinel 2 data are shown in Table 2.

Table 2. Specifications of Optical Image

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Sentinel 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image type</td>
<td>Optical</td>
</tr>
<tr>
<td>Ground Sample Distance</td>
<td>15 m.</td>
</tr>
<tr>
<td>Acquisition Date Range</td>
<td>'2018-01-01', '2019-06-30'</td>
</tr>
<tr>
<td>Cloud Pixel Ratio</td>
<td>Max 5%</td>
</tr>
</tbody>
</table>

Method

The overall method has been compiled in Google Earth Engine Platform including use of open datasets and visualization. The general workflow is shown in Figure 2.

![Figure 2. Methodology for ship detection](image)

The method starts with loading Sentinel 1 SAR data from the specific date. The datasets are loaded with selecting respective polarization, filtered by acquisition date. Here, we have picked the date of 2018-07-20 imperially. The radar pixel values are needed to be corrected due to the radar imaging geometry. The pixel values closer to the sensor have less ground sample distance compared to the farthest part of the image. Angle correction makes the pixel size regular with same size in x and y direction. This is useful to process radar images for any further analysis (Wong et. al, 2019).
The presence of any ship cause brighter pixel compare to the other water surfaces. But the consistent radar pixel value for the water surfaces has to be calculated. This is done with calculating median value of the all available of radar imagery in Google Earth Engine data catalog. The median value allows detecting the consistent pixel value with excluding any object on the scene. This calculated image is called as Radar Reference Image. As expected that the ships stand on the water surface, multispectral satellite images have been used to detect the water surfaces to use as the regions to clip. The image contains median values of the selected image series is subtracted from the image which is specific date, to determine the objects, mainly ships. To identify the water surface, a mask has been created with use of Sentinel 2 multispectral image from a series of images between the dates of '2018-01-01', '2019-06-30' which are selected imperially. The median values of each pixel along the series have also been used to calculate the Normalized Difference Water Index.

The water index is calculated as following;

\[
NDWI = \frac{NIR - GREEN}{NIR + GREEN} \tag{1}
\]

NWDI value bigger than 0 indicates the water surface, so the areas where meet this condition are selected. Apart from the water surfaces from NDWI. The identified area is overlaid with the input SAR image.

For detection of the ships, the selected input SAR image have been subtracted from the Radar Reference Image. The values which are greater than zero have been selected as ship objects. Then, morphological dilation is applied to merge the segments which are very close to each other, and possible to belong to the same ship.

**RESULTS**

**Test Area**

Test area is the Bosporus strait in Istanbul-Turkey (Figure 3). The region is selected as region of interest and the corresponding images from the specific dates are called through Google Earth Engine Platform.

![Figure 3. Test area, The Bosporus Strait](image)

The used Sentinel 1 SAR image and its angle corrected version is shown in Figure 4.

![Figure 4. The used SAR image after applying angle correction.](image)
The generated mask from NDWI and reference image which was calculated with median of all available images, are shown in Figure 5.

![Figure 5. Mask derived from NDWI and SRTM(Left), Reference SAR image (Right)](image)

The subtraction from radar reference image from the selected radar image is used to derive the ships. The pixels which have values bigger than 0 are selected as ships. Morphological opening has been applied on the results to overcome the over segmentation. The detected ship polygons can be found in Figure 6.

![Figure 6. Detected ships overlaid with Google Maps](image)

The final detected objects are converted to the vector features, and the number of vector features indicates the total number of ships is calculated as 64 on the area of interest which is the Bosphorus strait in our study. For assessment of the study, the ships are manually counted as 72 on the radar image along the strait with human interpretation.

**CONCLUSIONS**

Radar images have a big potential to detect ships since the backscattering from ships compare to the water surfaces is remarkable, thus the ships are easy to identify. The monitoring of ships and other sea vessels is important for management purposes, and there are already existing monitoring services available.

In this study, we have aimed to detect the ships with use of remote sensing by cloud computing platform. Because satellite images are good source for monitoring of the ships, but with limitation of the sensor temporal resolution. But the advantage of the use of remote sensing, any ship can be detected regardless the AIS is switched on or not.

Radar images are useful for detection of the ships, which is already discussed in previous literature; we have used open source Sentinel 1 dataset. But the processing of radar image needs high performance computing environments. Therefore we have used Google Earth Engine Cloud Computing platform to eliminate the need of data download and process in the software packages. The whole processing has been performed in the cloud including data loading, integration with other datasets, processing and visualization. We have followed the suggestions of Wong et al.(2019) and extended the approach with inclusion of optical datasets to improve the detection results. The study will be extended to improve the detection accuracy with testing on different test sites.
REFERENCES


BIOGRAPHY

Nusret Demir

Nusret DEMİR currently works as a associate professor at the Department of Space Science and Technologies, and as vice dean at Faculty of Science of Akdeniz University. He received his bachelor’s degrees in Geodetic and Photogrammetric Engineering and Industrial Engineering, Msc degree in Geodetic and Photogrammetrical Engineering from Yildiz Technical University in 2001, 2003 and 2005 respectively. He had obtained his PhD degree at the Department of Geomatics Engineering from ETH Zurch in 2013. He worked as training systems specialist at Pilatus Aircraft Ltd, and founded ETEN R&D Ltd. company to research and development service to aviation industry in 2013. His research interests are remote sensing, mainly active systems LIDAR and RADAR, cultural heritage documentation, citizen science.

Bünyamin Akgül

Bünyamin Akgül is currently B.Sc. student at the department of Space Science and Technologies at Akdeniz University, Faculty of Science, Antalya-Turkey. His research interests are remote sensing, GIS and programming.