# Ship Detection from Sentinel-1 Imagery through Thresholding and Clustering Method

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**ABSTRACT**

Maritime surveillance has been a significant issue for protecting illegal activities at sea and conserving marine resources. However, the Automatic Identification System and V-Pass, a fishing boats' position reporting system, have a limited transmission distance and a high dependency on volunteering message reporting. Therefore, satellite imagery-based ship detection has emerged in maritime surveillance in recent decades. This study proposes a ship detection approach through the combination method of thresholding and clustering (TCM). Sentinel-1 imageries were used, that freely available at and provided by the Copernicus Open Access Hub that operated by European Space Agency (ESA). Ships at sea are detected through TCM after completing preprocessing procedures, including thermal noise removal, terrain correction, and masking out of a land area. The proposed method shows a high detection speed and is expected to contribute to maritime surveillance.

## 1. Introduction

Maritime surveillance has become a rising issue because of the need to conserve the ocean environment and prevent illegal activities at sea, illegal fishing, hijacking, oil spill, and stowaways. Although there are automatic position tracking systems such as the automatic identification system (AIS) and a unique system, V-Pass that tracks fishing vessels in Korea, the AIS contains many limitations resulting from system failure(Kazimierski and Stateczny, 2015; Emmens et al., 2021), transmission error(Harati-Mokhtari et al., 2007; Greidanus et al., 2015; Emmens et al., 2021), and sometimes the misuse of seafarers(Harati-Mokhtrai et al., 2007; Johansson et al., 2013; Emmens et al., 2021). Furthermore, the transmission distance is the major problem in monitoring and supervising the broad sea area. Thus, remote sensing technology has introduced maritime surveillance over the last two decades. This study aims to suggest a simple method of detecting ships from synthetic aperture radar (SAR) imagery, especially sentinel-1 using thresholding images and clustering the detected positions.

## 2. Data

Sentinel-1 Interferometric Wide Swath Single Look Complex (IW SLC) product is chosen to detect ships at sea due to its short revisit period (and thus, the up-to-date scenes are uploaded frequently). IW SLC product consists of images that record the radar image and metadata that contain various information such as satellite movement, reference coordinates on scan area on Earth's surface, and the relation between satellite and the scan area. This paper uses the Sentinel-1 image on Jan. 09, 2018, 09:22:56 – 09:23:15 UTC.

## 3. Methodology

### 3.1 Preprocessing

Sentinel-1 IW SLC images require preprocessing procedure before detecting ships at sea. Although the procedure is complicated for beginners, SNAP, a satellite image processing software, can be a help to step into the first stage of maritime surveillance with satellite images. Preprocess procedure includes the following steps; noise removal, radiometric calibration, and geometric correction. There are many noises in SAR images due to an electric problem with a sensor and irregular backscatter (backward reflection) from irregular (not even or flattened) scan areas(Ouchi, 2010). Those noises can be removed through predefined noise information and image filters. Geometric correction is the process that converts the geometrical arrangement of a satellite image to well-known projections such as longitude and latitude, or Universal Transverse Mercator (UTM). Consequently, IW Ground Range Detected (GRD) image is obtained through the process with SNAP.

The GRD image should be rescaled in the dB scale because low values have the highest proportion in the image,

and thus the image cannot be interpreted in visual inspection (Eq. 1, Fig. 1a, b).

$$dB = \log_{10}(\sigma^0) \times 10 \quad \text{(Eq. 1)}$$

$\sigma^0$: calibrated backscatter coefficient

The dB scale image is better to recognize, and the distribution becomes similar to the normal distribution (Fig. 1c, d). The final step of preprocessing before ship detection is removing the land area from the image(Fig. 1e) since it has bright values like ships at sea. The land removal procedure is called land masking, and is conducted with the function '*mask*' in python library {sckit-image}(Bradski, 2000).

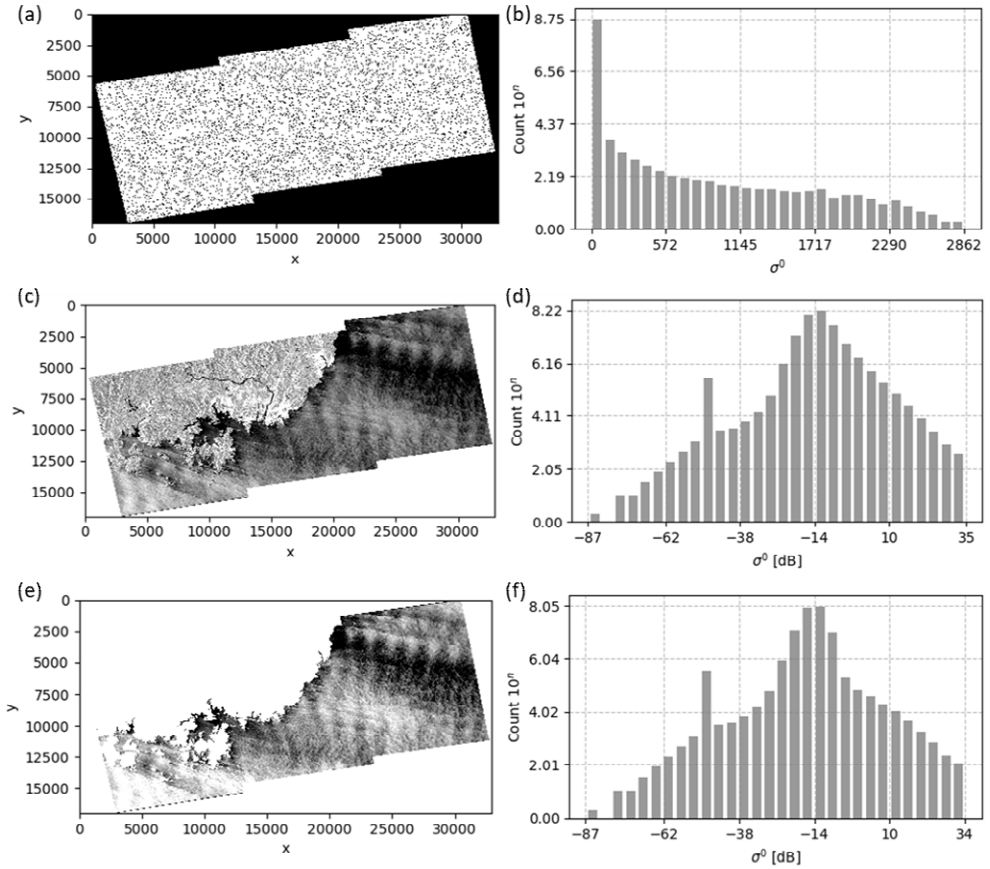


Figure 1. Preprocessing of Sentinel-1 image. (a, b) IW GRDH image. (c, d) dB scaled image. (e, f) land removed image.

### 3.2 Thresholding and Clustering

Ship detection can be made with a simple method; the combination of thresholding and clustering. Beforehand the SAR image should be smoothed through image smoothing filters such as mean filter, median filter, and gaussian filter. Here, the gaussian filter is applied to smooth the image(Fig. 2a). The smoothed image is used to remove the local trend and generate a de-trended image where the local trend is removed(Fig. 2c).

The thresholding value is computed with Eq. 2, and the pixels over the thresholding values(Fig. 2d) are extracted as suspicious ship pixels (Fig. 2e).

$$T = \mu + 5\sigma \quad \text{(Eq. 2)}$$

μ: mean of pixel values in image

σ: standard deviation of pixel values in image

Among the suspicious ship pixels, the righteous ship pixels should be selected as valid ship pixels, as seen in Fig. 2c. Density-Based Spatial Clustering of Applications with Noise (DBSCAN) algorithm can be used as a clustering algorithm. DBSCAN is a practical algorithm to cluster meaning groups with search radius(epsilon, ε)

and the minimum number of samples. Furthermore, it filters out the rest member of the suspicious pixels. The DBSCAN is conducted by the module *DBSCAN* in python library {scikit-learn}(Pedregosa et al., 2012).

The pixels, after thresholding and clustering, are geometrically averaged both on the x- and y-axis. Then, the centroid of detected ships in the SAR image is determined(Fig. 2f).

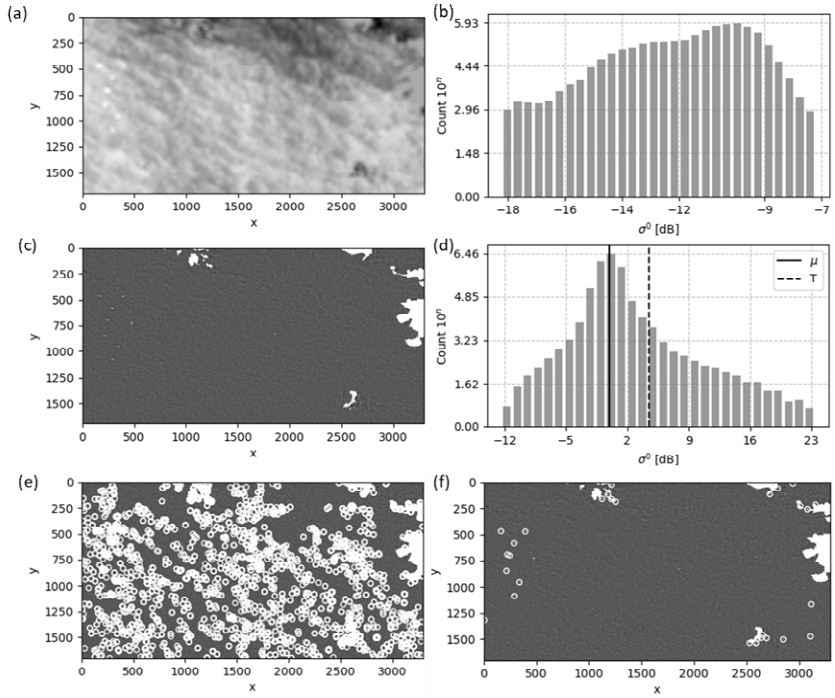


Figure 2. Ship detection. (a, b) Gaussian-smooth image. (c) de-trend image. (d) thresholding. (e) ship suspicious pixels through thresholding. (f) valid ship pixels after clustering.

## 4. Results and Conclusion

The combination method of thresholding and clustering shows the feasibility of ship detection from Sentinel-1 images. The proposed method is simple to understand and useful for detecting ships with shorter computation duration compared to the conventional SAR ship detection algorithm, such as Constant False Alarm Rate (CFAR). However, the algorithm still has a weak point in handling the large size noise in SAR imagery. To deal with the matter, a statistic-based noise filter should be studied and researched further.


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**Author's Biography**

Ho-Kun Jeon currently works at the Marine Bigdata Center, Korea Institute of Ocean Science and Technology (KIOST). He is on a Ph.D. at the University of Science and Technology (UST), majoring in Ocean and Coastal Engineering. He has a unique career as a navigation officer in merchant ships. The background enables him to study further maritime matters related to vessel operation. His current research field is marine safety and environment spatial and temporal analysis with remote sensing data.