SEMI-AUTOMATIC SHIP DETECTION USING PI-SAR-L2 DATA BASED ON RAPID FEATURE DETECTION APPROACH

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Abstract. Synthetic Aperture Radar (SAR) satellite an active sensor offering unique high spatial resolution regardless of weather conditions can operate both day and night time with wide area coverage. Therefore, SAR satellite can be used for monitoring ship on sea surface. This study showed on an alternative method for ship detection of SAR data using Pi-SAR-L2 (L-band, JAXA-Airborne SAR) data. The ship detection method is this study was consisted of eight main stages. After the Pi-SAR data was registered and speckle was filtered, then the land was masked using SRTM-DEM (Shuttle Radar Topography Mission-Digital Elevation Model) data since most ship detectors produced false detections when it applied to land areas. A ship sample image was then selected (cropped). The next step was to detect some unique keypoints of ship sample image using Speeded Up Robust Features (SURF) detector. The maximum distance ('MaxDist') of keypoints was also calculated. The same detector was then applied to whole Pi-SAR imagery to detect all possible keypoints. Then, for each detected keypoint, we calculated distance to other keypoint ('Dist'). If 'Dist' was smaller than 'MaxDist', then we marked these two (or more) keypoints as neighboring keypoints. If the number of neighbor keypoints was equal or greater than two, finally we marked these keypoints as 'Detected Ship' (draw rectangle and show its geographic position). Results showed that our method can detect successfully 32 'possible ships' from Pi-SAR-L2 data acquired on the area of North Sulawesi, Indonesia (August 8, 2012).

Keywords: *Ship detection, synthetic aperture radar, Pi-SAR-L2, keypoint, SURF detector*

1 INTRODUCTION

One of the main applications of remote sensing technology is the use of remote sensing data to support monitoring and surveillance of ocean and coastal areas. Ship detection and identification based on remote sensing data is a key part of any service or system dealing with maritime traffic, illegal fishery, or sea border activity, or with ocean and coastal management issues such as oil spill detection and monitoring (Tsagaris *et al*., 2008).

Synthetic Aperture Radar (SAR) system an active sensor offering unique high spatial resolution regardless of weather or other conditions can operate both day and night time with wide area coverage. Therefore, it can be used in sea surface ship monitoring. Owing to the corner reflection from ship structures or between ship body and ocean surface, ship targets are usually bright in SAR images (Huang *et al*., 2009).

To effectively detect ship targets from SAR data, appropriate object detection algorithms are essential. The CFAR (Constant False Alarm Rate) algorithm is widely used in the application (Array, 2011; Huang *et al*., 2009; Wang *et al*., 2008). The basic idea is to search pixel which is unusually bright when compared to pixels in surrounding area. This approach usually requires a long computation time and increases with the increase of the image dimension. On the other hand, in some monitoring applications such as illegal ship or fishery monitoring, a rapid ship detection system is needed for primary information to do a quick response.

In this paper, we presented an alternative method for ship detection of SAR data using rapid feature detection approach. The basic idea was to use rapid interest point (keypoints) detection using SURF (Speeded Up Robust Features) detector (Bay *et al*.,

2008) and then analyzed its positions. Using ship sample images, number of neighbor keypoints and maximum distance of their keypoints were calculated and then used as a parameter to determine whether the object in the whole SAR image was a ship or other objects.

In our experiment, Airborne Pi-SAR-L2 data was used. The data set was acquired through Airborne Pi-SAR-L2 campaign supported by the JAXA and Ministry of Research and Technology Republic of Indonesia.

2 MATERIALS AND METHOD

2.1 Data

The SAR data used in this study was Airborne Pi-SAR-L2 data, L-band (1.227 GHz), 2.4m resolution, full polarization covering the part of Lembeh Strait, Bitung, North Sulawesi, Indonesia (Figure 1). The data were acquired on August 8, 2012 and pre-processed (including orthorectification) by JAXA-EORC (Japan Aerospace Exploration Agency – Earth Observation Research Center).

As additional data, DEM (Digital Elevation Model) data was used to generate land-sea mask. Ideally, the DEM data had the same resolution with its SAR data so that the accuracy of resulting land-sea mask would be better. However, due to limitations of high resolution DEM data, we could only use the SRTM DEM data (Shuttle Radar Topography Mission Digital Elevation Model) with 90m resolution as shown in Figure 2.

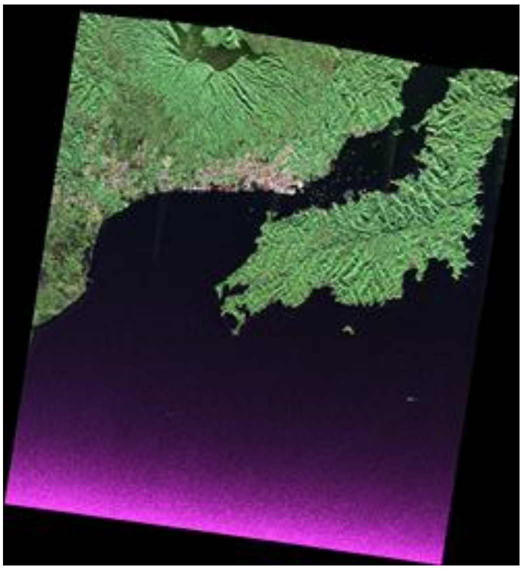
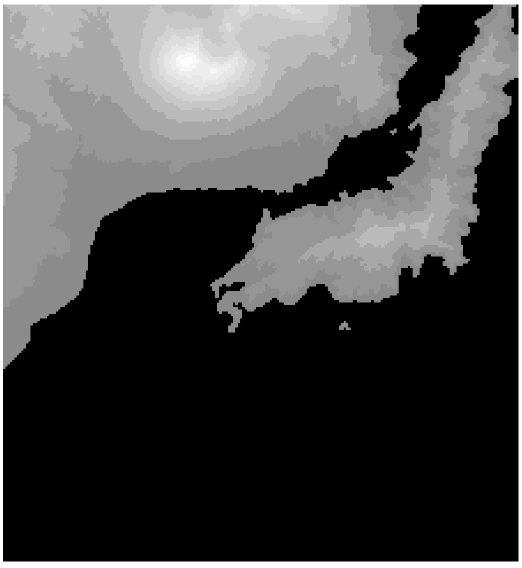


Figure 1. Pi-SAR-L2 data of the area around Lembeh Strait, Bitung, North Sulawesi, Indonesia.



a) SRTM-DEM

b) Land sea mask

Figure 2. SRTM-DEM data data of the area around Lembeh Strait, Bitung, North Sulawesi, Indonesia (a) and Land Sea Mask generated from the SRTM DEM (b).

2.2 Data Processing

The flowchart of the ship detection used in this study is shown Figure 3. Our ship detection method was consisted of eight main stages. After the Pi-SAR-L2 data and DEM data was registered, then speckle-filtering was done in order to reduce speckle noise. In this study, a Lee Filter with 3x3 window size was used. Larger windows provide more speckle smoothing but may smear fine details in the image.

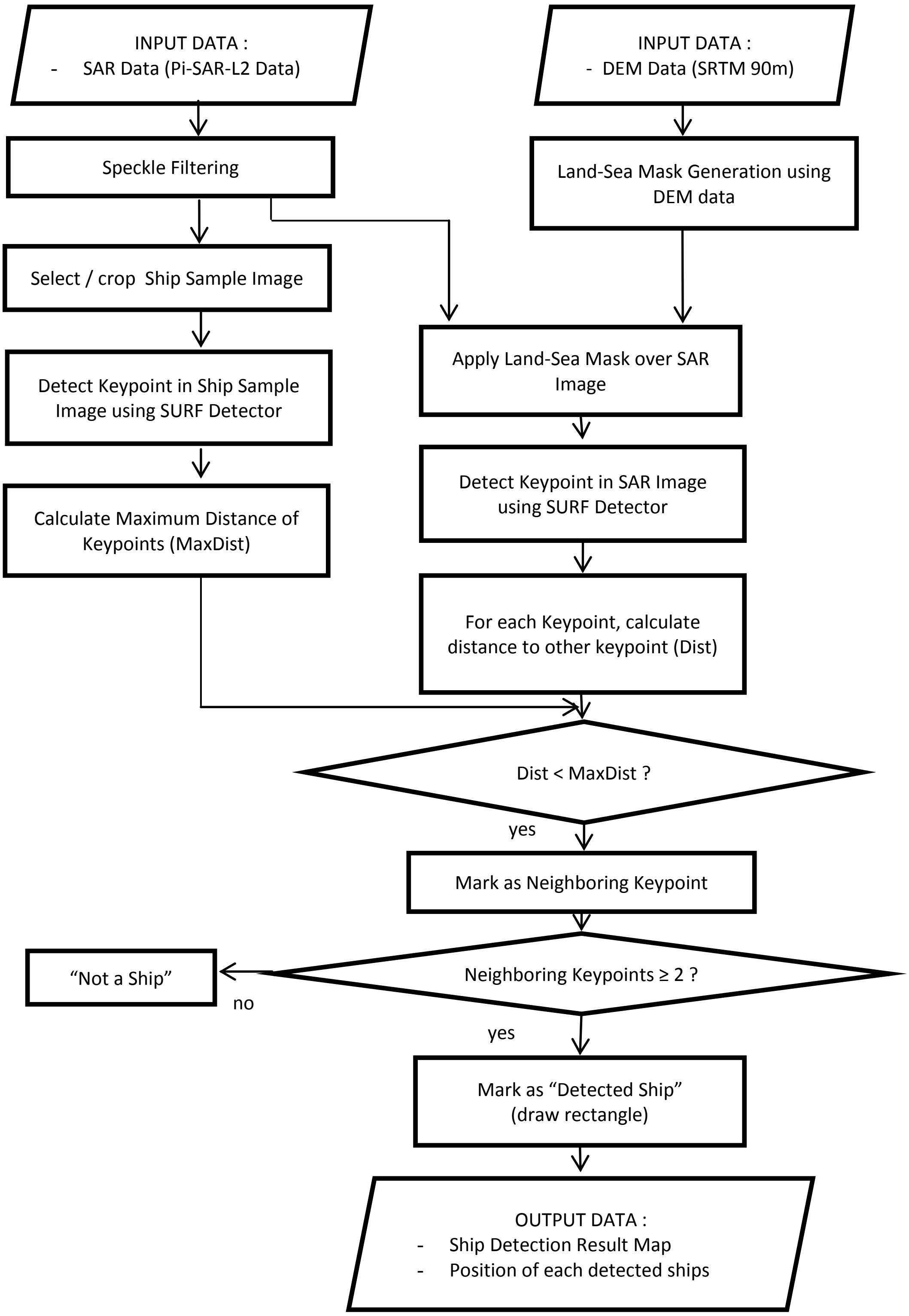


Figure 3. Flowchart of the ship detection method using SAR data.

The next step was land-sea mask generation using DEM data. This process was required since most ship detectors produce false detections when applied to land areas. In our experiment, a simple masking method was applied. If the elevation value was equal or greater than zero, the pixel value in SAR image was then turned into no data value. The result of land sea mask is shown in Figure 2-b (in this figure, black color indicates 'land' and white color indicates 'sea'). Using this mask, we masked-out the land area from whole Pi-SAR-L2 image and ensure that detection was focused only on the sea area.

A ship sample image was then selected (cropped). The next step was to detect some unique keypoints of ship sample image using Speeded Up Robust Features (SURF) detector that had been included in the OpenCV libraries (OpenCV Dev Team, 2012). The SURF method for detecting keypoints will be explained briefly in the following sub-section. By analyzing the detected keypoints from several ship samples, it was found that the position of keypoints were close together (clustered around the ship) and this could be used as a base to make a decision whether the object was the ship or not. From ship sample image, maximum distance of its keypoints was then calculated ('MaxDist') and will be used as a parameter to determine the presence of ships in the whole SAR image. The maximum distance was calculated by: 1) determining one keypoint and calculate Euclidian distance to the other keypoints; 2) moving to another keypoint and calculate Euclidian distance to the other keypoints, and so on; 3) finding the maximum value from whole calculated distance.

The same SURF detector was then applied to whole Pi-SAR image to detect all possible keypoints. Then, for each detected keypoint, we calculated distance to other keypoint ('Dist'). If 'Dist' was smaller than 'MaxDist', then we marked these two (or more) keypoints as neighbor keypoints. If the number of neighbor keypoints was equal or greater than two, finally we marked these keypoints as 'Detected Ship' (draw rectangle and show it geographic position). The number of neighbor keypoints was determined by trial and error. With a larger number, the number of detected ships decreased, while small number caused too many un-related objects (such as small objects, sea waves, land-sea boundaries, etc) identified as a ship. Experiences showed that the best result were obtained using 2~4 neighbor keypoints.

2.3 Keypoint detection method using Speeded Up Robust Features (SURF) detector

Speeded Up Robust Features (SURF) is an algorithm which extracts some unique interest points (keypoints) and descriptors from an image. Detailed explanation of this method can be found in Bay *et al.* (2008). In this study, we implemented only on the SURF keypoint detector and not on the SURF descriptor. The reason we were not implement SURF descriptor was based on our analysis that the position of keypoints detected from a ship object by SURF detector were close together (clustered around the ship) and this could be used as a descriptor to differentiate between ships or other objects. Brief description of SURF keypoint detection method was described in Bay *et al*. (2008) and Evans (2009).

SURF uses a hessian based blob detector to find interest points. The Hessian matrix is approximated using box filters calculated with integral images. The integral images, I_{Σ} of an image I is defined by the formula:

$$I_{\Sigma}(x,y) = \sum_{i=0}^{i \le x} \sum_{j=0}^{j \le y} I(x,y) \tag{1}$$

The entry in $I_{\Sigma}(x,y)$ then contains the sum of all pixel intensities from $(0,0)$ to (x,y). Using this integral image, the sum of pixel intensities inside a rectangular region of any size (Figure 4) can be calculated with only three additions (and four memory access) as follows:

$$\sum = A + D - (B + C) \tag{2}$$

This allow for fast and easy computation of convolutions with filters composed of rectangular regions, also called box filters. SURF use box filters as shown in Figure 5, as approximation for the second order Gaussian derivatives (entries of the Hessian matrix). The determinant of the Hessian is then approximated as:

$$\det\left(H_{approx}\right) = D_{xx}D_{yy} - \left(wD_{xy}\right)^2 \quad (3)$$

where D_{xx}, D_{yy}, and D_{xy} are weighted box filter approximations in the x, y, and xy-directions, and weight $w = 0.9$ is needed for energy conservation in the approximation. The determinant here is referred to as the blob response at location $\mathbf{x} = (x, y, \sigma)$. The search for local maxima of this function over both space and scale (σ) yields the interest points for an image. The detail algorithm can be found in Bay *et al*. (2008).

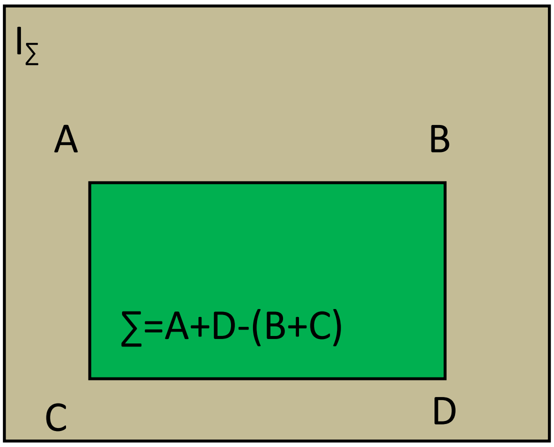
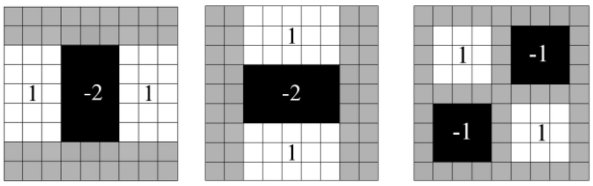


Figure 4. Calculation of a rectangular area sum using integral image.



D_{xx} D_{yy} D_{xy}

Figure 5. Box filter approximations.

3 RESULTS AND DISCUSSION

An example of the ship image and its keypoints detected by SURF method is presented in Figure 6. In this sample, ten keypoints were detected around the ships. Then, maximum distance of its keypoints was calculated (‘MaxDist’ = 29.8m).

The keypoints detection result of the Pi-SAR-L2 image is shown in Figure 7. We observed many detected keypoints. A ship-like object were surrounded by its keypoints (more than two keypoints). Many other single keypoints (without neighbor keypoints) were also detected, but these might be caused by small objects, sea waves, land-sea boundary, etc.

The final result of our ship detection method is presented in Figure 8 (neighbor keypoints=2, and maximum distance of its keypoints=29.8m). The rectangular were drawn around the detected ships (total 32 rectangles). The geographic positions of each ship were also computed by our method. However, to conserve the space, these results were not presented here. This tudy was succesfully deteceted of 32 ‘possible ships’ (Figure 8). We did the validation by visual interpretation due to the absence of field data and other data related to the real position of the ships at the same time. The visual validation showed that the possible detected ships were reasonably good as ships from their structure or geometry (Figure 8).

In this experiment, the processing time started from keypoint detection of sample image until generation of detection map was less than 3 seconds. The time processing for speckle filtering was not included here, as in our experiment; we used other proprietary software to do this step. In future work, we will include this step into our program.

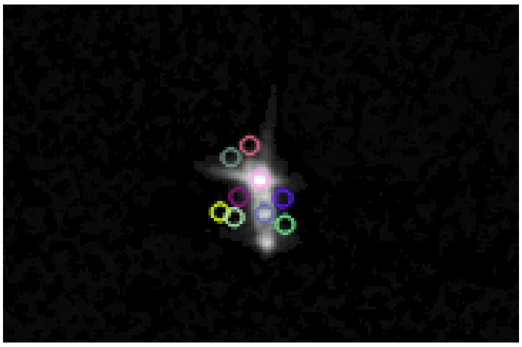


Figure 6. Ship sample image and its keypoints (small circles) detected by SURF method.

Figure 7. All possible keypoints (small circles) detected from Pi-SAR-L2 image (cropped area).

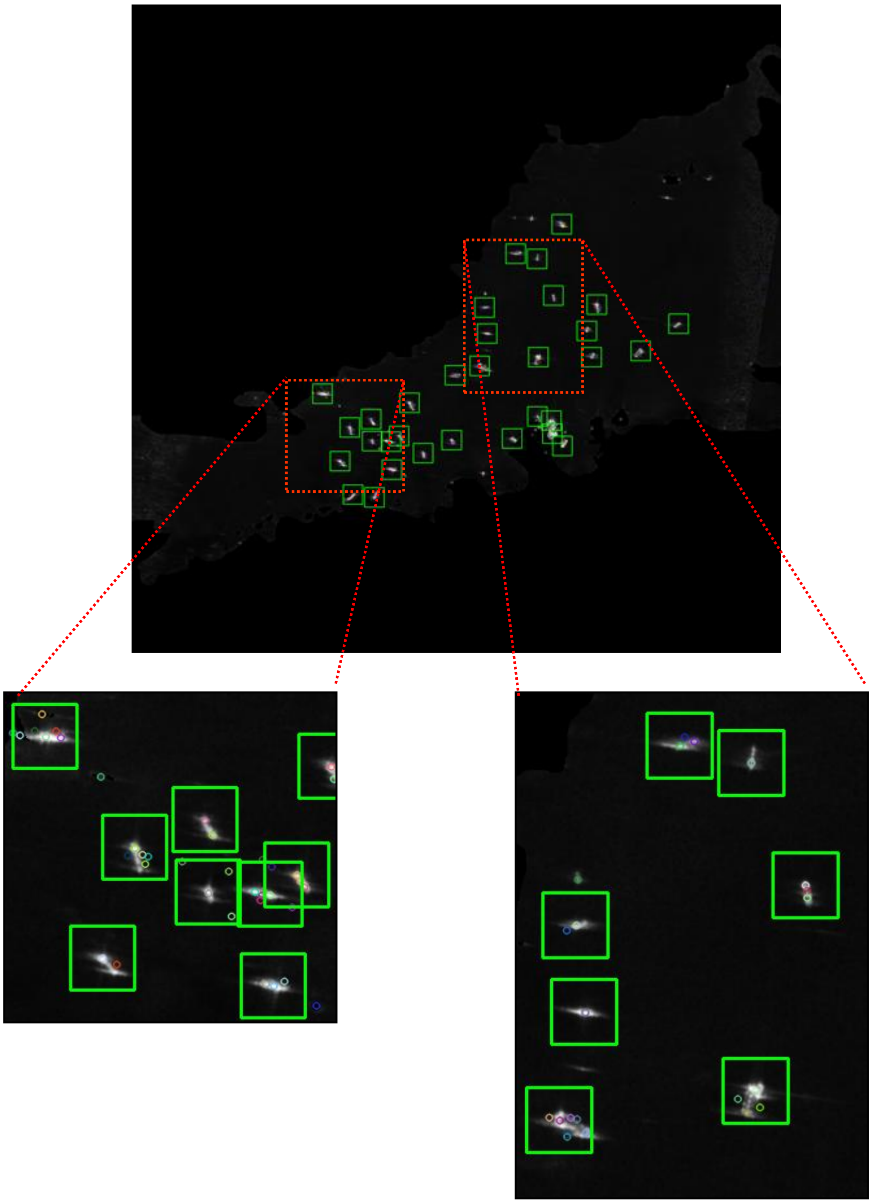


Figure 8. Ship detection result (rectangle).

4 CONCLUSIONS

Speeded Up Robust Features (SURF) model was succesfully detected 32 possible ships based on SAR data with fast and reasonably accurate by visusal interpretation. The accuracy of the model may be improved by including other SAR datasets (data from different SAR platforms, different band/wavelength, and different resolutions) and test the model in a more complex region.

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