# Dark Ship detection: SAR Images


M. S. Prasad
*Amity Institute of Space Science & Technology,*
*Amity University, Noida*
India
msprasad@amity.edu

Shivani Verma
*Amity Institute of Space Science & Technology,*
*Amity University, Noida*
India
sverma2@amity.edu

Yulia A. Shichkina
*Saint Petersburg Electrotechnical University "LETI"*
Saint Petersburg, Russia
shichkina@co-evolution.ai



***Abstract*—The robust detection of ships is one of the key techniques in coastal and marine applications of synthetic aperture radar (SAR). SAR images can be analysed for keeping a track on "dark vessels" used for Illegal, unreported, and unregulated (IUU) fishing. The term "dark vessel" typically refers to a ship that operates without transmitting its location or other identifying information, often with the intention of avoiding detection or surveillance. This can be for various reasons, such as for military, intelligence, or illegal activities. Smaller ships may be more manoeuvrable and able to operate in areas where larger ships may have difficulty navigating, making them potentially suitable for clandestine or covert operations. Thus, smaller ships can be referred to as "dark vessels" in certain contexts. This paper combines a well-established ship detection method (using CIFAR detector) with modern machine learning for classification (large_ship vs. small_ship) based on length estimation.**



***Keywords—SAR, ship detection, detector***


## I. Introduction

Illegal, unreported, and unregulated (IUU) fishing, including overfishing and destructive fishing practices, can have numerous harmful impacts on marine ecosystems, local economies, and global seafood supply chains.

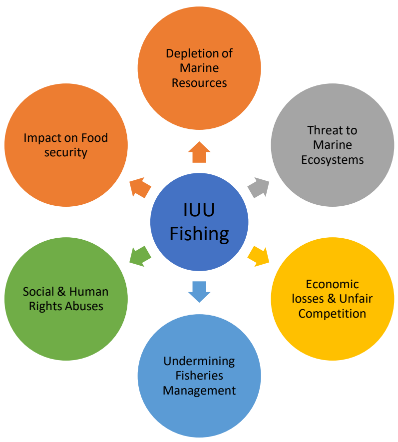



Fig. 1. Impact of IUU Fishing

IUU fishing can result in overfishing, where fish populations are harvested at unsustainable levels, leading to the depletion of marine resources. This can disrupt marine ecosystems and result in the loss of biodiversity, as well as impact the livelihoods and food security of coastal communities that rely on these resources for their subsistence and economic well-being. It also involves use of destructive fishing practices, such as dynamite fishing, bottom trawling, and driftnet fishing, which can cause significant damage to marine habitats, including coral reefs, seafloor habitats, and other sensitive marine areas. These destructive practices can result in habitat destruction, bycatch of non-target species, and long-term damage to marine ecosystems, affecting their resilience and ability to recover. IUU fishing can result in economic losses for legal and regulated fishing operations, as illegal fishing vessels often operate outside of established fishing regulations, such as fishing quotas, gear restrictions, and seasonal closures. This can create unfair competition for legitimate fishers and disrupt local fishing economies, resulting in lost revenue, reduced profitability, and increased costs for monitoring and enforcement. IUU fishing also undermines effective fisheries management and conservation efforts, as it bypasses regulations and controls put in place to ensure sustainable fishing practices. IUU fishing has also been associated with social and human rights abuses, including forced labor, human trafficking, and exploitation of vulnerable workers.

Synthetic Aperture Radar (SAR) imagery has been increasingly used in detecting and monitoring illegal, unreported, and unregulated (IUU) fishing activities due to its unique capabilities. SAR is a remote sensing technology that uses microwave energy to acquire images of the Earth's surface, and it has several advantages for detecting IUU fishing compared to other imaging techniques, such as optical imagery or passive microwave sensors.

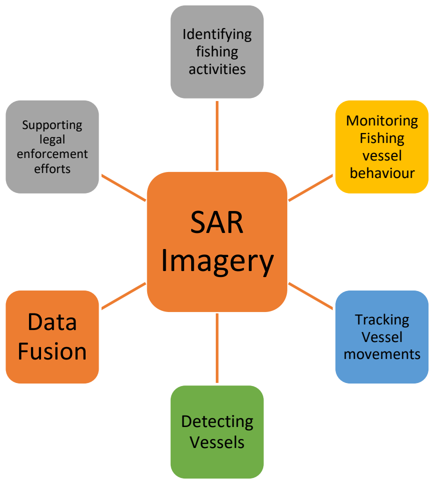



Fig. 2. Applications of SAR Imagery

SAR imagery can provide all-weather and day-and-night monitoring of vessels, including small fishing vessels that may not be easily visible in optical imagery. Also, SAR images can be used to detect and track vessels in near real-time, providing information on vessel movements, location, and behavior. SAR images can also reveal fishing activities by detecting specific vessel signatures associated with fishing operations, such as the presence of fishing gear, such as trawl nets, fishing lines, or fishing buoys, or the characteristic patterns created by vessel movement during fishing operations. These signatures can be used to identify and differentiate between fishing vessels and other types of vessels, helping to detect potential IUU fishing activities. Changes in vessel patterns or unusual behavior can be detected using SAR imagery and can trigger further investigation. SAR images can be used to track vessel movements over time, allowing for the identification of vessel routes and hotspot areas for fishing activities. By integrating multiple data sources such as AIS and VMS, SAR imagery can provide complementary information for detecting IUU fishing activities, improving the accuracy and reliability of the detection process. High-resolution SAR images can be used as evidence in legal proceedings, supporting the identification of IUU fishing activities, tracking vessel movements, and establishing patterns of illegal behavior.

Thus, SAR imagery can play a crucial role in detecting IUU fishing activities by providing all-weather, day-and-night monitoring of vessels, identifying fishing activities, monitoring vessel behavior, tracking vessel movements, integrating with other data sources, and supporting enforcement efforts.

This paper discusses the detection and classification of ships in SAR Image. An automatic ship detection and classification method has been proposed that effectively highlights the targets by diminishing the background and speckle noise and also separates the targets from background.

The paper has been organised as: Section I gives the Introduction; Section II gives the literature review; Section III gives the Proposed Methodology; Section IV gives the details of the SAR Image Preprocessing steps and the AI model used and Section V concludes the paper.

## II. Literature Review

Many works have concentrated on target detection in SAR images. The constant false alarm rate (CFAR) detectors are mostly widely used. [1–4]. Another method used for target detection is by using image decomposition or transform [5–7]. Tello et al recommended the application of Discrete wavelet transform to SAR image [7], and to ensure accurate detection, the statistical differences in wavelet coefficients between ships and the marine clutters around them were taken into account. Some more strategies rely on feature extraction and selection. Kaplan in [8] advocated using the extended fractal feature, which is sensitive to both contrast and object sizes, to find ships. In [9], target recognition for SAR images was given genetic programming by utilising the “human vision system” technique to dentify regions that stand out from their surrounds. The study of Bhanu et al. [10] concentrated on choosing discriminative features using a genetic algorithm, but the chosen features were unable to discriminate target and clutter when the intensity of the clutter was greater than that of the targets.[11] concentrated on publications, publishers, deep learning types, improved and amended deep learning techniques, impacts, proactive approaches, key parameters, and applications in ship detection by SAR images, as well as extract current research directions, limitations, and unsolved challenges to give understanding and suggestions for future research.

## III. Proposed Methodology

The proposed methodology has been shown in the block diagram shown in Fig. 3.

Synthetic Aperture Radar (SAR) imagery from the Sentinel-1 mission conducted by the European Space Agency (ESA) has been used as input which comprises a constellation of two polar-orbiting satellites (S1A and S1B) with a repeat cycle of 6 days operating in all weather conditions day and night.

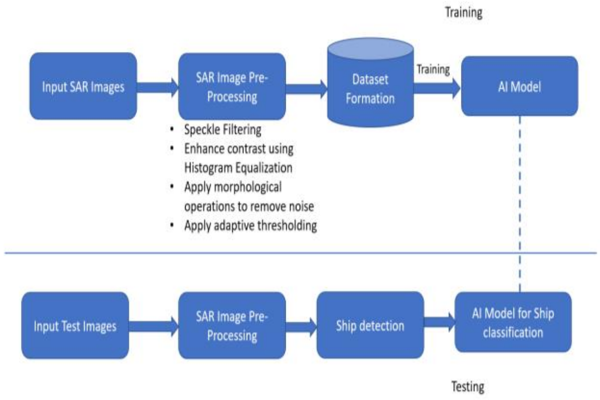



Fig. 3. Proposed Methodology

The input SAR images are subjected to pre-processing steps before using them for training and validation of AI model. 64114 images have been used for training and 19225 images have been used for validation. Details of AI Model have been provided in Section V. The trained model is then used for detection and classification of ships in test images.

## IV. SAR Image Pre-Processing

Synthetic Aperture Radar (SAR) images require pre-processing to address several challenges associated with SAR data acquisition and characteristics. SAR images are different from optical images as they are acquired using microwave energy and have unique properties, such as speckle noise, radiometric and geometric distortions, and layover/shadow effects, which can affect the quality and interpretation of the images. Pre-processing is necessary to correct or mitigate these issues and improve the accuracy and reliability of SAR image analysis.

The input SAR image was subjected to the following pre-processing steps:

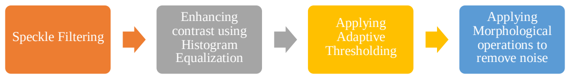



Fig. 4. SAR Image Pre-processing steps

The outputs for each step have been shown below:

Fig. 5 shows the original SAR Image, which is first subjected to Speckle Filtering.

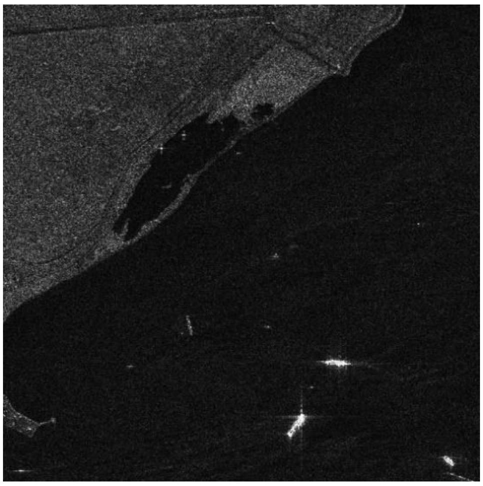


Fig. 5. Original SAR Image

Speckle filtering in synthetic aperture radar (SAR) is a technique used to reduce the noise or speckle effect that appears in SAR images. SAR images often suffer from speckle, which is a form of multiplicative noise caused by the interference of coherent radar waves reflected from a rough surface. Speckle noise can degrade the visual quality and interpretability of SAR images and can also affect quantitative analysis and classification tasks.

There are several methods commonly used for speckle filtering in SAR images, including:

- Lee Filter
- Gamma Map Filter
- Frost Filter
- Median Filter
- Wavelet-Based Filters

This paper uses Median filter method to achieve Speckle Filtering. Median Filter replaces each pixel's value with the median value of all the pixels in a local window.

Otsu's Adaptive Thresholding

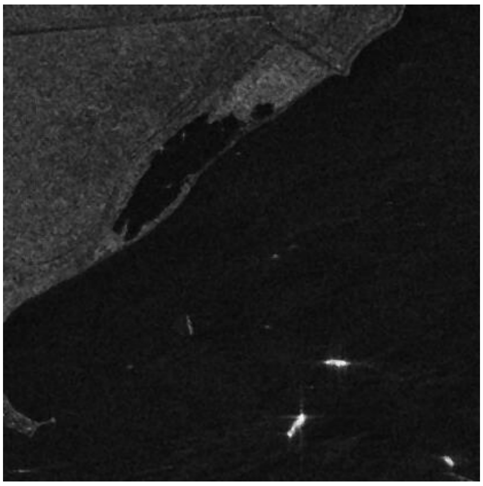


Fig. 6. Output after applying Speckle Filtering

The next pre-processing step is Histogram Equalization. Histogram equalization is a technique used in image processing to enhance the contrast of an image. It works by redistributing the intensity values of an image's histogram to cover the entire intensity range, which can help reveal details and improve the overall appearance of the image.

Fig. 7. After enhancing contrast using Histogram Equalization

Adaptive Thresholding accounts for variations in illumination, contrast, and noise levels in an image. There are several methods for adaptive thresholding:

- Mean Adaptive Thresholding
- Gaussian Adaptive Thresholding
- Otsu's Adaptive Thresholding
- Median Adaptive Thresholding

Gaussian Adaptive Thresholding has been used in this paper. Instead of using the mean intensity, a weighted average based on a Gaussian distribution is used to compute the threshold value for each pixel. This method gives more importance to the pixels closer to the center of the local neighbourhood.

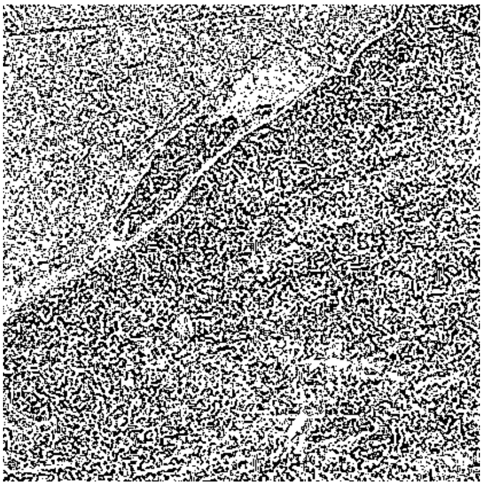


Fig. 8. Adaptive Thresholding

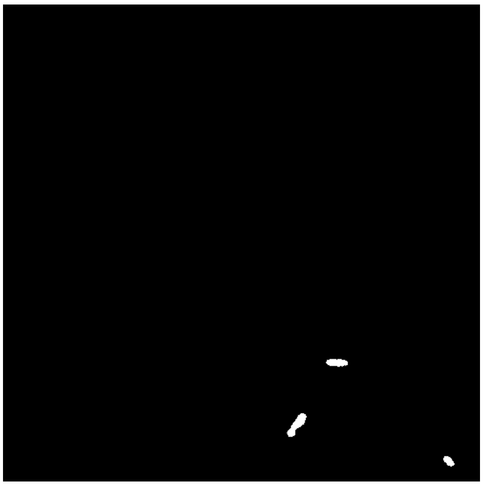


Fig. 9. After applying Morphological operations to remove noise

After subjecting the input test image to the above-mentioned pre-processing steps, the image is subjected to an AI model which detects as well as classifies the objects in the given image.

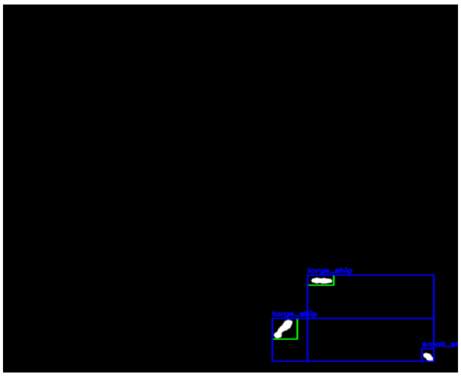
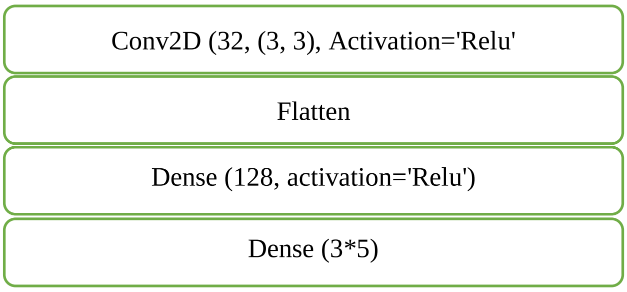


Fig. 10. Detection & Classification of ships by AI model

## V. AI MODEL

The model architecture that is used Sequential CNN. It consists of a convolutional layer with input shape 32 and activation function “Relu” with 3 x 3 filter along with input shape of image 256x256. This is followed by Flatten layer. This is further followed by Dense layer with activation function “Relu”. Dense layer (3*5) is the last layer. The model gives a good prediction accuracy of approx. 80%.




## VI. CONCLUSION & FUTURE SCOPE

The developed model is capable of analysing the SAR image and intelligently detecting the ships and classifying them based on their length. As of now, only two classes have been considered, the number of classes can be increased as per requirement.

Also, there is a scope to go for Data Fusion. The analysis data can be fused with AIS and VMS data to get more accurate and reliable information about the Dark Vessels.
Although some of false predictions were also there because of some disturbed and noisy images which can lead to detection of false objects. In further work, the model can be trained using more sophisticated images to reduce false prediction.

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