Ship detection and size estimation

Problem statement

SAR satellites provide useful information for **object detection**. A methodology needs to be developed to detect ships at ocean area using SAR data and **estimate size** of the detected ships (size invariant). The methodology should be applicable for **different resolution SAR data of same bands**.

Develop **software** with following two features-

1. Land water **discrimination** using **SAR imagery**,
2. Output detected ships as a **vector file**, with an estimate of the size of ship

Things to determine

Object detection - Detect the object in the ocean, based on data we will see the number of classes to determine but for now its Ship, Container ship, Boat, Oil extraction stations.

Estimate size - Estimating the LOA and WOA of the ship which is the length and width of the ship.

Software - A simple API on a web app / GUI for local machine which takes in SAR images and outputs

a)Types of objects in the image

b)Vector line in the direction of head , LOA and WOA as integer values.

c)A picture output of these Vector lines in a boundary box overlaying the areas where the ships are detected with labels on them for a better visualization of output.

Discrimination - Classification of sea water and land in the input image as a binary output (black for sea and white for land). This discrimination is simultaneously done along side for every picture.

SAR imagery - Since raw SAR data cannot be visualized we have to use SNAP a desktop app specially designed for SAR imagery pre-processing. Since we are automating a task i.e as input is given we need to give an output quickly we can't open

SNAP every time in our VM as its CPU expensive and slow. But we need the tools of SNAP we need to access these within our object detection & size estimation script. So we can use this python library which is an API for SNAP called pyroSAR which has most of the tools we need from SNAP. We can see the images and use tools to process it.

Vector file - Vector images allow for more flexibility. Constructed using mathematical formulas rather than individual colored blocks. A few examples of a vector file types are EPS, AI and PDF. Therefore, in vector images the resizing of the image should not affect it's clarity. So it has readjust it's clarity based on the scale of zoom in or zoom out. Like a company's logo format.

Data

The dataset they have provided us has 2 images of size 1GB each containing 25663 x 19287 pixels. They have also provided the annotated data for the two images in xml files. These pictures have been taken from the Sentinel-1 IW satellite which captures ground level (GRD) ,ocean level (OCN) and raw level 0 data. Since the size and dimensions are huge we need to chop it up linearly and go by it one grid cell at a time. Considering a 400x400 dimension picture we have around 3024 of these pictures at one whole SAR image given. Although, I'm not completely sure if the 25663 x 19287 directly account to a picture in that size, it might also have an extra layer of information which can account to a lesser dimensions which is easier to work with.

Understanding SAR

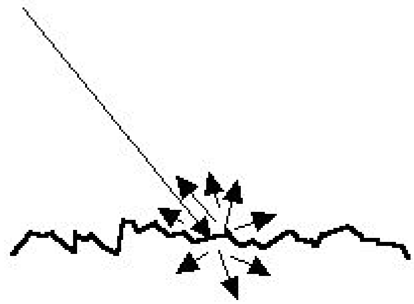
Processed SAR images are often grayscale and they do not contain any color information.

SAR or Synthetic Aperture Radar images are formed by coherent interaction of the transmitted microwave with the targets. Hence, it suffers from the effects of speckle noise which arises from coherent summation of the signals scattered from ground scatterers distributed randomly within each pixel. A radar image appears more noisy than an optical image due to this scattered energy.

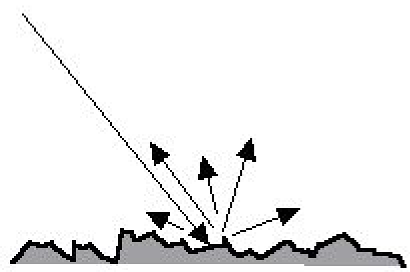
So for less energy emission there must exist smooth surfaces because they are reflective and when that happens the incident ray is at the same angle of reflected ray and there will be no continuous scattering of these microwaves coming from the satellite leading to no emission of energy forming a nice dark spot. Where as in rough surfaces there is more scatter so more speckles are formed, wet soil is such a case (terrain).

A Speckle is caused by the constructive and destructive interference of the coherent returns scattered by small reflectors within each resolution cell.

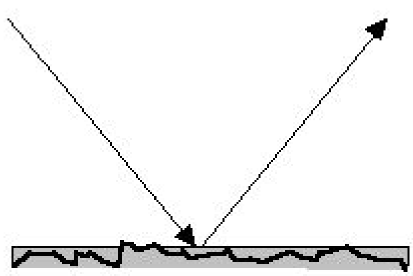
Dry Soil: Some of the incident radar energy is able to penetrate into the soil surface, resulting in less backscattered intensity.



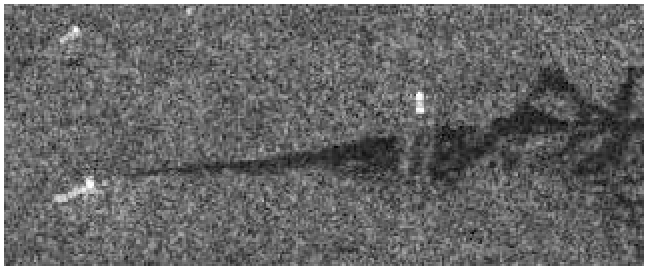
Wet Soil: The large difference in electrical properties between water and air results in higher backscattered radar intensity.



Flooded Soil: Radar is specularly reflected off the water surface, resulting in low backscattered intensity. The flooded area appears dark in the SAR image.



Calm sea surfaces appear dark in SAR images. However, rough sea surfaces may appear bright especially when the incidence angle is small. The presence of oil films smoothen out the sea surface.



A ship (bright target near the bottom left corner) is seen discharging oil into the sea in this ERS SAR image.

Here we can see the white noise (caused by speckles) in the picture, the dark spots are caused by oil as it smoothens the areas of the sea causing the water to act calm.

We can take away a point here that ships can be easily detected at calm waters or oil rich water because the ships are against the dark background, it gives nice sharp edges compared with the distorted ships due to noise like notice the bottom left ship.

Objectives for and End to End solution

1.Creating GUI or a Web App

- To accept a SAR image
- Backend request to run it on our script
- Get and Show the predicted output in frontend
    - A vector image of detected ships enclosed in a box labeled with index along with its LOA and WOA when hovered upon.
    - A table with indexed objects containing the Class of object, LOA, WOA, direction of head and other features which can be thought of.
    - A binary masked image of land and water classification.

2.Preprocess Data

- To view SAR image and crop into multiple (not sure yet if required).
- Pre processing of SAR image using PyroSAR.
- Instantly create a binary mask of land and water and pass it on to the frontend.

3.CNN

- Pass the pre-processed data of images into the YOLOv2 CNN with around 9 million weights meaning way faster than VGG-16 or Google Le-Net. Being very fast it is proved to have 90% ~ accuracy.
- This CNN is only for detecting the class of ship and put a bounding box around it.

4.Calculating the Size

- Using the outputs from the CNN we get our bounding box images (images are cropped from those boxes making a very zoomed in picture of only the ship) which we pass through a few **vector algebra calculations** and determine the Head(direction of heading), LOA, WOA.
- As this is done we need to label(class,loa,woa,head) each of these zoomed in pictures of the ships and pass all of them to our frontend.

Approach

GUI or Web App?

Tkinter or MERN stack

Software

Pre processing of SAR?

1) **Calibrate the image**

“To properly work with the SAR data, the data should first be calibrated. This is especially true when preparing data where we could have several data products at different incidence angles and relative levels of brightness. Calibration radiometrically corrects a SAR image so that the pixel values truly represent the radar backscatter of the reflecting surface causing the different and relative levels of brightness.”

The corrections that get applied during calibration are mission-specific, therefore the software will automatically determine what kind of input product you have and what corrections need to be applied based on the product’s metadata. Calibration is essential for quantitative use of SAR data.

Since it will automatically detect our input being OCN (ocean) it will be simple for us as it's just one line of code.

2) **Multilook**

“Multilook processing can be used to produce a product with nominal image pixel size.Multiple looks may be generated by averaging over range and or azimuth resolution cells improving radiometric resolution but degrading spatial resolution. “

This is done to create less speckles and a less noisy image but we won't be using it since our objective is not only to reduce the speckles but also to determine the size and dimensions of the ship later. We can not have spatial resolution degrade either by convolution or average pool of the pixels as it doesn't keep our ship sharp.

3) **Reduction of speckels**

SAR Imagery

Different resolution SAR data of same bands

Binary masks ?

In order to avoid detection of false targets (ships) on land the SNAP Ocean Object detection includes a land masking function. By default the SRTM 3sec digital elevation model is used to identify and mask out areas with positive elevation.
A simple solution by an API call to this will give us a binary mask. A better way might exist need to be looked at.

Discrimination

Boundary boxes?

First, YOLO uses a single neural network to directly predict the bounding box and class probability. The SAR image is divided into an S × S grid of cells. Each grid cell predicts only one object. Once a ship is predicted that particular grid is stored in memory for it to be accessed later for its dimension detection.

Dimensions ?

After obtaining the enlarged pictures all we have left to do is define a finer boundary layer rectangle in the shape of that ship and get its angle of head from the normal. This is done in multiple ways by using a few numerical methods and vector algebra using rms distances with inertial vectors. Referring to the particular research paper mentioned below.

Vector file

Sources

- PyroSAR - https://readthedocs.org/projects/pyrosar/downloads/pdf/latest/
- SNAP- https://rus-copernicus.eu/portal/wp-content/uploads/library/education/training/OCEA01_ShipDetection_Trieste_Tutorial.pdf
- Understanding SAR - https://crisp.nus.edu.sg/~research/tutorial/sar_int.htm
- Math for dimension estimation - https://www.researchgate.net/publication/322336908_Size_and_Heading_of_SAR-Detected_Ships_through_the_Inertia_Tensor
- Class of ship and boundary box - https://www.mdpi.com/2072-4292/11/7/786/htm#remotesensing-11-00786-f005

Other related research papers

This one is really good as well (uses other CNN architectures)- https://www.researchgate.net/publication/332078787_A_SAR_Dataset_of_Ship_Detection_for_Deep_Learning_under_Complex_Backgrounds

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5855538/

Ps - There are 4 types of polarizations (VV,VH,HH,HV) occurring which can cause distortions on the ship and might alter the dimensions when we calculate. Need to look on this more.