Polarimetric SAR application in Oceanography

By

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Polarimetric SAR application in Oceanography

Major Project

Submitted in partial fulfillment of the requirements

For the degree of

Bachelors of Technology in Computer Engineering

By

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Guide
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May 2017

CERTIFICATE

This is to certify that the Major Project entitled "Polarimetric SAR Application in Oceanography" submitted by Mr. Darshan Patel (13BCE071), towards the partial fulfillment of the requirements for the degree of Bachelors of Technology in Computer Engineering of Nirma University of Science and Technology, Ahmedabad is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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I am thankful to all faculty members of Department of Computer Engineering, Nirma University, Ahmedabad for their special attention and suggestions towards the project work.

The blessings of God and my family members makes the way for completion of major project. I am very much grateful to them.

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ABSTRACT

The sole objective of this project is to find novel approaches to use SAR (Synthetic Aperture Radar) data and apply the same in field of oceanography. The simplest application of oceanography is detection of ship by using its characteristics like length and breadth. Other aspects like trying H-Alpha decomposition on compact polarimetric data obtained from ISRO's RISAT-1 satellite data. In this project work, sources of data from satellites other than RISAT-1, viz. ALOS PALSAR and SENTINEL-1 are used. The primary focus of this work is to detect oil spill in ocean which effects marine life most in ocean. Many scenes from different satellites having oil spills and look-alikes are collected and processed using tools like PolSARpro and certain libraries of python. Processing steps involves filtering, decomposition and classification, etc.

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1. INTRODUCTION

1.1 General

Today, there is advancement in tools and technologies to study surface of earth, even we can know what is beneath surface of earth to certain extent using sensors hanging from satellites or by other means like Airborne tools (drones, aircraft). Humans have one important sensor: The eye, but it has limitation of sensing only certain portion of whole electromagnetic spectrum. To cover electromagnetic spectrum as wide as possible, technologies like polarimetry. Interferometry, hyper spectrum, etc have emerged. Now, compacting those varied bands of electromagnetic spectrum into what human can pursue is now becoming emerging field. This project work is discussing and implementing one of these technique called 'SAR Polarimetry'.

1.2 Objective of work

The objective of this work is to explore different tools and techniques to process SAR polarimetry data, create novel approaches which can be applied in oceanography like oil spill detection, ship characteristics, etc. Not only oceanography, the explored tools and techniques can also be applied or tried in varied fields like soil moisture detection, wind speed estimation, glacier motion estimation, types of crop harvested, forest area estimation, urban planning, construction purpose and many other fields. Exploring libraries in python for processing of SAR data, and use it to build tools for feature extraction from available data.

1.3 Scope of work

This project work could help future engineers and researchers in the field of SAR polarimetry. With using new tools and technologies to process SAR data, the so called 'young' filed SAR polarimetry can open doorways to young students willing to work in this field. The optical images that take more data and time to capture the same location images can be more costly than the microwave images that is processed in this work. The microwave images not only take less space but to process it is also efficient. With usefulness of microwave data like its day-night capturing ability, penetration through cloud, etc; it also have certain limitations.

1.4 Organization of Major project

This report is divided into five major chapters which include introduction and literature review as first two chapters. The next three chapters explains details about basics and work carried on during entire coursework. Further, third chapter talks about basics of basics of SAR polarimetry which is essential to understand the remaining portion of the project. It contains details of basic microwave bands to details of present sensors. This chapter give introduction to SAR satellites, Radar geometry, SAR resolution, SAR data contents, RADAR polarization, speckle filtering and SAR data format. The next chapter "SAR data processing" talks about different levels of data available in microwave remote sensing, how matrix generation takes place from complex SAR data, applying filters to remove noise from level 1 data, different decomposition techniques like entropy, h-alpha classification, flow of processing, h-alpha scatter plots etc. Last part of this chapter explains applied classification techniques like estimation of ship characteristics using CLTR (Circular transmit Linear Receive) data, proof of lack of determining difference between oil spill and lookalikes using unsupervised/ decomposition like entropy, alpha and many other. The final chapter discusses about tools and techniques used to generate decomposition, classification, etc. in SAR polarimetry.

Chapter No: 2
Literature Review

2. Literature Review

2.1 Literature Review Table

Author	Year	Topic/Focus	Findings
Michael E. Nord, Thomas L. Ainsworth, Senior Member, IEEE, Jong-Sen Lee, Life Fellow, IEEE, and Nick J. S. Stacy, Member, IEEE	2009	Comparison of Compact Polarimetric Synthetic Aperture Radar Modes	Relation between RH,RV and HH,HV,VH,VV scattering coefficient
R. K. Raney, Life Fellow, IEEE	2016	Comparing Compact and Quadrature Polarimetric SAR Performance	Critically comparing studies of compact polarimetry and suggestion of what may be the right way to go for compact polarimetry.
Kruti Vyas, Pooja Shah, Usha Patel, Tanish Zaveri, Rajkumar Geo-Sciences and Applications Group Space Applications Centre (ISRO)	2015	Oil spill detection from SAR image data for remote monitoring of marine pollution using light weight imageJ implementation	• Biogenic oil: It occurs because of ocean plants and animal growth. It appears as a thin layer of oil over the ocean surface. • Mineral oil: Such kind of oil spills occur because of common oil leaks, discharge of factories, ship leakages etc. They may be spread or evaporate over a particular time span.
S. V. Nghiem, S. H. Yueh, R. Kwok, and F. K. Li	1992	Symmetry properties in polarimetric remote sensing	Assuming certain symmetric properties like reflection symmetry, azimuth symmetry, etc. derivation of its respective covariance matrix using quad pole data.
Jean-Claude Souyris, Member, IEEE, Patrick Imbo, Roger Fjørtoft, Member, IEEE, Sandra Mingot, and Jong-Sen Lee, Life Fellow, IEEE	2005	Compact Polarimetry Based on Symmetry Properties of Geophysical Media: The ∏/4 Mode	The relation between covariance matrix of compact and quad-pole data.
Hanning Wang , Zhimin Zhou , John Turnbull and Qian Song	2015	Explicit Expressions of	Equations which contains two and three component

		Freeman-Durden Decomposition for Compact Polarimetric SAR under CTLR Mode	modes for volume, surface and double bounce scattering
Shane CLOUDE, AEL Consultants, Cupar, Scotland, UK	Jan, 2004	The dual polarization entropy/alpha decomposition : A PALSAR Case Study	The only material which shows H-Alpha scatter plot curve, All other materials are available on quad pole data
P.V. Jayasri*, H.S.V. Usha Sundari, E.V.S. Sita Kumari, AVV Prasad	2014	STUDY OF OIL SPILL IN NORWEGIAN AREA USING DECOMPOSITION TECHNIQUES ON RISAT-1 HYBRID POLARIMETRIC DATA	This is the only research work done using compact polarimetry on oil spill, that is related to our research work.
F.J. Charbonneau, B. Brisco, R.K. Raney, H. McNairn, C. Liu, P.W. Vachon, J. Shang, R. DeAbreu, C. Champagne, A. Merzouki, and T. Geldsetzer	2010	Compact polarimetry overview and applications assessment	Family of polarizatoin diversity and polarimetric imaging radars
S. R. Cloude, Fellow, IEEE, D. G. Goodenough, Fellow, IEEE, and H. Chen	1, JANUARY 2012	Compact Decomposition Theory	Equation for C2 matrix for compact polarimetry

Chapter No: 3
SAR Polarimetry basics

- **Microwave remote sensing**
- **SAR application and its usefulness**

3. SAR POLARIMETRY BASICS

3.1 Microwave Remote Sensing

Electromagnetic Radiation

Electromagnetic radiation contains two vector:

1) Electric Field
2) Magnetic field

The direction of propagation of electromagnetic wave is perpendicular to both the above mentioned field. Both electric field and magnetic field are also perpendicular to each other. Speed of propagation of electromagnetic radiation is speed of light (c).

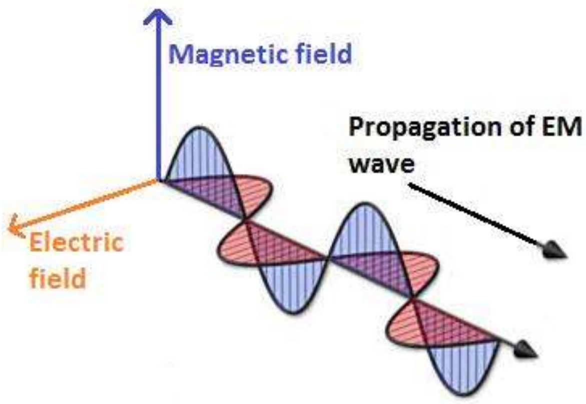

Figure 3.1 Propagation of EM waves [1]

Microwave Bands

This chapter talks about microwave remote sensing. What is remote sensing? Remote sensing is the technique in which one utilizing the concept of electromagnetic scattering, reflection, emission, to know the properties of object without touching or any physical contact of that object. Again, remote sensing is subdivided into different category and one category microwave remote sensing. The remote sensing done in microwave region of electromagnetic spectrum is called microwave remote sensing. The following image shows electromagnetic spectrum

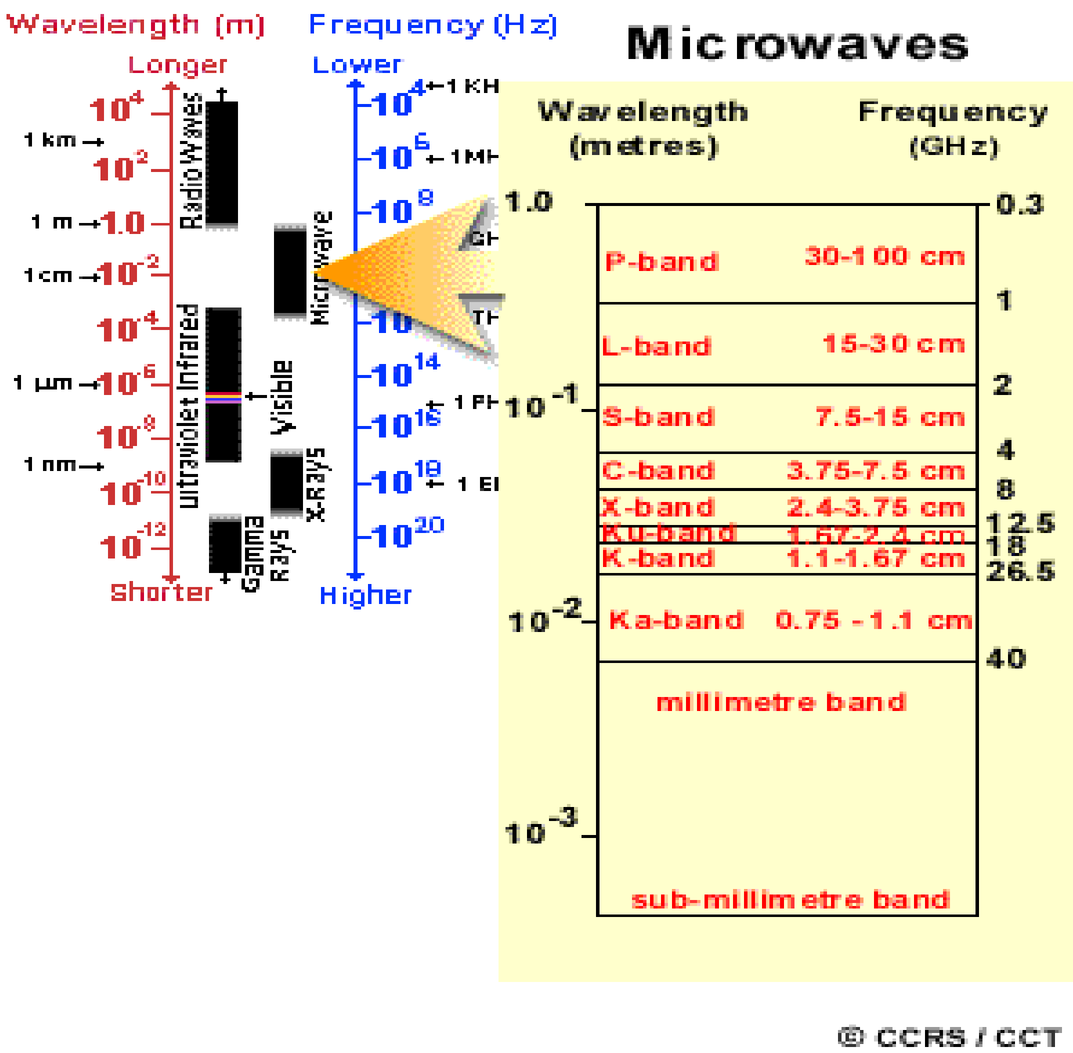

Figure 3.2 Microwave Bands wavelength [2]

In microwave remote sensing, electromagnetic spectrum with wavelength 1 millimeter to 100 centimeter is used. In the following table, microwave region of electromagnetic spectrum is further divided into bands. In microwave remote sensing, excluding millimeter band, bands from Ka-band to P-band are extensively used. Each and every band has its own range of wavelength, like C-band ranges from 3.75-7.5 cm, L-band ranges from 15-30 cm, etc. When we move from K band to P band, there will be increase in wavelength and decrease in frequency. For each and every wavelength there will be separate sensor to operate on. For example, radar sensor is configured to work in C band, then data collected will be limited to C band only, not other band data. There are different advantages and dis-advantages of each band, applied according to different application.

The following table shows the wavelengths of different bands in microwave region:

Band	Wavelength (cm)
Ka	0.75 – 1.1
K	1.1-1.67
Ku	1.67-2.4
X	2.4-3.8
C	3.8-7.5
S	7.5-15
L	15-30
P	30-100

Table 3.1 Wavelength of different bands [3]

Microwave sensors are of two types: Passive microwave sensors and Active microwave sensors. A passive microwave sensors read or detect microwave energy which is naturally available in form of reflected radiation from earth emitted by sun, emission related to temperature and moisture properties of objects on surface of earth, etc. Passive microwave sensors application includes hydrology, meteorology, oceanography, etc. Microwave energy reflected from:

1) Reflected from the surface
2) Emitted from the surface
3) Transmitted from the subsurface

Passive sensor rely on another source of energy, active sensors rely on energy generated on its own. Passive microwave sensors again divided in two distinct category, imaging and non-imaging microwave sensors. Radio detection and ranging (RADAR) is one of non-imaging microwave sensor. Non-imaging take reading in 1D, in which it transmits signal and reading in one dimension, for example for measurement of altitude on air craft, for topography mapping, for sea height estimation, Radar altimetry is used. For the measurement of the amount of energy backscattered from targets, scatterometers are used.

3.2 SAR application and its usefulness

Why to use SAR images:

- All Weather support
- Not dependent on Sunlight

- Pollution or any other atmospheric constituents does not tamper quality of Image
- Sensitive to dielectric properties(water, biomass, etc)

SAR Satellites:

These are some of SAR satellites that are launched by reputed agencies like ISRO, ESA, JAXA, etc.

RISAT-1	2012-2017	C band
Radarsat 1	1995	C band
Radarsat 2	2007	C band (quad pole)
ERS 1	1991-2000	C band
ERS 2	1995	C band
JERS	1992-98	L band
ENVISAT	2002	C band
ALOS	2006	L band (quad pole)
TerraSAR-X	2007-2012	X band (quad pole)

Table 3.2 Operational band of SAR satellites [3]

SAR Versus Optical Multispectral instruments

There are certain advantages and disadvantages if comparison made between optical and SAR instruments:

	Optical Multispectral	*SAR*
Radiation	Reflected Sunlight	Own Radiation
Spectrum	Visible/Infrared	Microwave
Acquisition time	Day only	Day/Night
Polarimetry	N.A	Polarimetric phase
Weather	Blocked by clouds	See through clouds

Table 3.3 SAR versus Optical multispectral instruments [3]

SAR application: Application of SAR data in varied fields includes:

- For Soil Moisture Content
- For biomass estimation
- Crop Estimation

- Flood control
- Oil Spills monitoring

SAR data format: SAR data available in many formats as mentioned here:

- Raw data
- SLC data
- Multilook data
- Geocoded data
- Polarimetric data

<u>Chapter No: 4</u>
SAR data processing

- **Levels of data**
- **Matrix generation from complex SAR data**
- **Applying filter to smoothen data**
- **Different decomposition techniques**
- **Application of classification on SAR data**

4. SAR data processing

4.1 Levels of data

While working with SAR data, certain terms like level 0, level 1, level 1A, etc are encountered. Level 0 data is raw data, which is read from satellite and stored, nothing else! There is no processing involved in this type of data. Level 0 data is generally not used by any researcher or data analyzer. This data is processed for better results for application, which in turns converted to Level 1 data. Further processing applied as per requirement which can be sub level like 1A, 1B, etc or further enhancements like geo referencing in Level 2 data.

Level 0 data contains raw information which is not available in public, level 1 data contains complex numbers if it is SLC data, like: a + ib. Example of level 1 data, scaled from 0 to 1, is as shown here:

0.00252+0.03655i	0.00452+0.09655i	0.00272+0.03654i	0.00052+0.03605i
0.00712+0.03965i	0.00112+0.03115i	0.00200+0.00650i	0.00202+0.00695i
0.00122+0.01255i	0.00922+0.03655i	0.00411+0.00055i	0.00252+0.03485i
0.00411+0.03705i	0.00111+0.03655i	0.00850+0.09652i	0.00961+0.03410i
0.00252+0.03412i	0.00142+0.09654i	0.00128+0.07802i	0.00963+0.03850i
0.00452+0.03696i	0.00740+0.01420i	0.00960+0.07630i	0.00711+0.03950i

Table 4.1 Example of SLC data

This is just a part of whole image, where number of rows and columns depends on swath, resolution, and many other factors of sensors as well as satellite. Converting these complex numbers to power values i.e by taking square root of summation of squares of real part and imaginary part, and plotting it in gray image, we get this type of visualization. Below image is taken from RISAT-1.

Figure 4.1 RISAT-1 plotting in grey scale

Above image contains backscattered information of coastal area near Veraval, Gujarat, India. According to backscattered waves, image will be seen, for example, water will give less backscattering, and so dark spots will be seen wherever there is water like properties. Bright spot seen wherever there will be possibility of high backscattering. Level 2 data is generally geo referenced data, where along with power values of each pixel, location of particular pixel will be available in form of latitude and longitude. Geo referencing data is useful in many ways, all application cannot be discussed here but for an example, if data is geo referenced, then separation of land and water can be done on basis of already known and verified data. For instance, latitude x and longitude y is part of lake, then if one wants to process data of water containing bodies, then that pixel will be part on one's interest. Other application of geo referencing data includes city planning, oil spill monitoring, etc.

4.2 Matrix generation from complex SAR data

Before explanation of matrix generation of complex SAR data, explanation of what is SAR Polarimetry is important. Polarimetric SAR systems show the capacity to separate the different scattering elements available in single SAR resolution cell. Now to extract more features, combination of real and imaginary values of different polarization states is used. As per properties of different sensors, different type of data is acquired. For instance, RISAT-1 is capable of acquiring data as Circular Transmit and Linear Receive, Linear Transmit Linear Receive. PALSAR is capable of acquiring quad pole data which have 4 channels, which are: HH, HV, VH and VV. The convention which is followed here is the first letter describes transmission polarization and the letter next to is received polarization states. Till date, space borne SAR sensors have generally acquired data in single band, for example TerraSAR-X is operating in X band, ISRO's RISAT-1 is operating in C-Band. RISAT-1 can transmitting right circular R polarized channel and receive in linear H and V channels. So two channels: RH and RV is generated. Each channel has complex numbered values depending on resolution and Swath. Channels may differ according to imaging mode of RISAT-1. Stokes Paremeters: Polarization of a plane monochromatic wave can be represented by stokes vector:

$$\begin{bmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \end{bmatrix} = \begin{bmatrix} \langle |E_{RH}|^2 \rangle + \langle |E_{RV}|^2 \rangle \\ \langle |E_{RH}|^2 \rangle - \langle |E_{RV}|^2 \rangle \\ 2Re\langle E_{RH} E_{RV}{}^* \rangle \\ -2Im\langle E_{RH} E_{RV}{}^* \rangle \end{bmatrix}$$ [4]

Where S_0 , S_1 , S_2 , S_3 are four stokes parameters. Re represents real values, Im represents imaginary values, <> represents ensemble averaging, E_{RH} and E_{RV} are received horizontal and vertical components of the electric field vector.

Scattering matrix: The scattering matrix is a 2*2 matrix. All four elements are complex numbers. Co-polarized elements are represented by diagonal elements and off-diagonal represents cross-polarized information.

$$S = \begin{bmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{bmatrix}$$

Lexicographic feature vector: It is obtained from simple lexicographic expansion of scattering matrix [S] using lexicographic basis.

Lexicographic feature vector K_L becomes

$K_L = [\ S_{HH}\ S_{HV}\ S_{VH}\ S_{VV}\ ]^T$

Pauli Feature vector is obtained from renowned complex Pauli Spin matrix basis.

$K_P = [\ S_{HH} + S_{VV} \quad S_{VV} - S_{HH} \quad S_{HV} + S_{VH} \quad j(S_{HV} - S_{VH})]^T$

The 4*4 lexicographic polarimetric covariance matrix is generated using product of feature vector and its conjugate transpose.

4.3 Applying filter to smoothen data

After matrix generation, removing speckles is necessary. Speckles are unwanted noise signals which is removed using certain filters like: An-Yang Filter, Box-car Filter, Box-car Edge Filter, Gaussian Filter, IDAN Filter, Lee Refined Filter, Lee Sigma Filter, Lopex Filter, Mean-Shift Filter, Non-local Means Filter an many more. There is lots of literature available to remove speckles from polarimetric SAR data. Here, results of non-filtered image and filtered image is shown in Figure 4.2 and Figure 4.3

Figure 4.2 Image without speckle filtering

Figure 4.3 Image with speckle filtering

The filter that is applied on Figure 4.2 is LEE refined Filter. It is not bounded that particular filter is best one, different filter applied as per requirement of application. The tools that are used to generate these images is discussed in fifth chapter.

Date of data acquisition	20 February 2014
Number of rows	12974
Number of columns	10097
Incidence angle	42.89 (in degree)
Imaging mode	FRS1
Azimuth resolution	33.3 Km
Range resolution	23.4 Km
Space borne Sensor	RISAT-1
Polarization	RH,RV
Calibration constant RH	73.48
Calibration constant RV	70.44

Table 4.2 Data details

4.4 Different decomposition techniques

Entropy: This is a measure of the dominance of a given scattering mechanism within a resolution cell. Entropy ranges from 0 to 1, where the randomness of a scattering medium from isotropic scattering (H=0) to totally random scattering (H=1). Values in between indicate the degree of dominance of one particular scatterer.

H-alpha classification

Plotting entropy on X axis, and on Y-axis Alpha is plotted. The figure shows scatter plots and its 9 zones. Each zones represent different scattering models through which one can use it to analyze in their relevant fields. For example if scatter plots shows up in zone number 7 then the portion contains double bounce scattering.

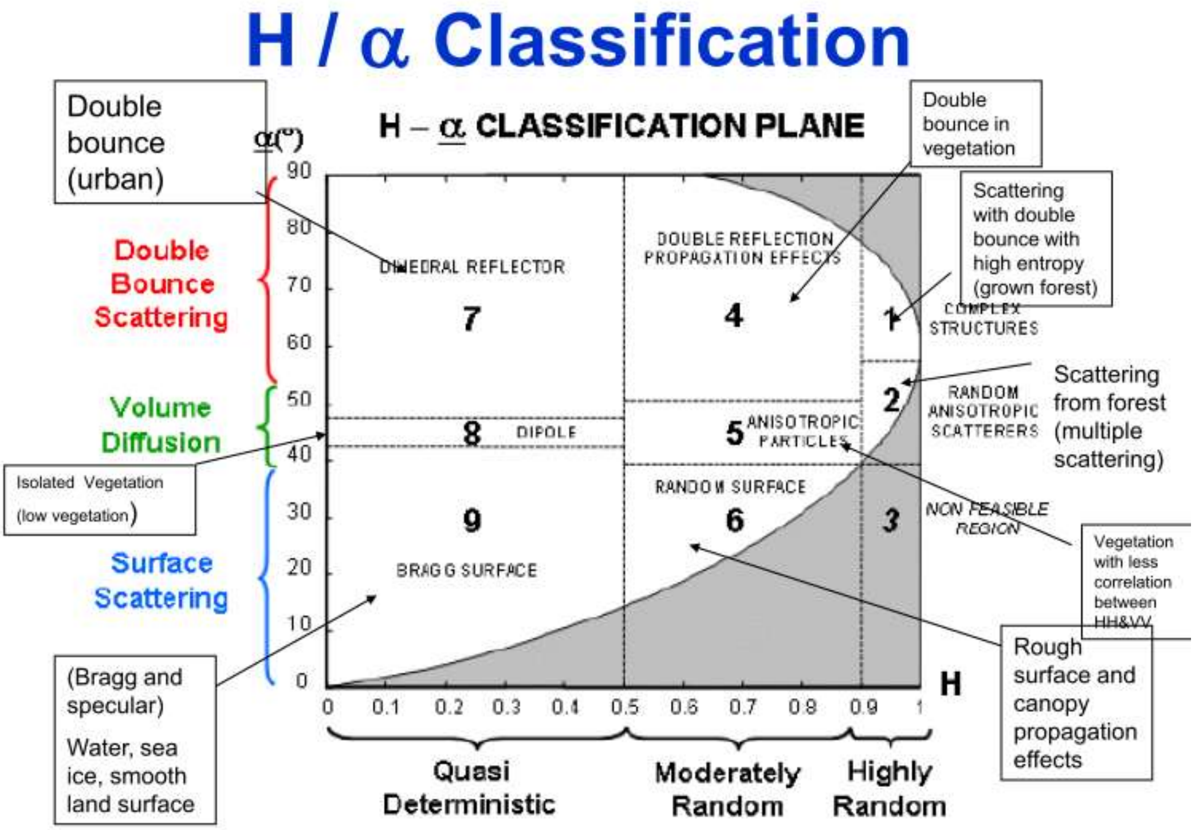

Figure 4.4 H-Alpha plot zones [5]

The following image shows pictorial representation of ROI (Region of interest) which is sea area in this case. First step is to remove noise, so speckled removed using Lee refined filter. After that decomposition algorithms like entropy, anisotropy, alpha is generated. These decompositions further can be used to generate planes of combinations of more than one decomposition. For example, here Entropy-Alpha plane and Anisotropy-Alpha plane is generated. For further analysis of ROI, scatter plots are used as shown in Figure 4.5 (Entropy-Alpha plot and Anisotropy-Alpha plot).

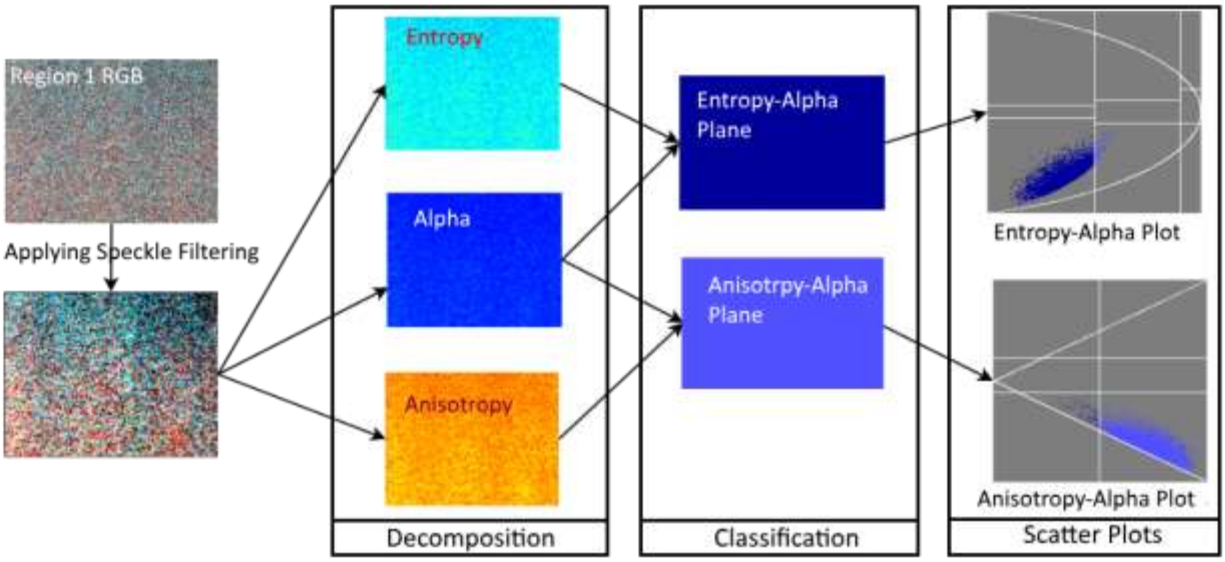

Figure 4.5 Flow of data processing

4.5 Application of classification on SAR data

Ship Characteristics using CTLR (Circular Transmit Linear Receive) data

In detection of ships, if object's length and breadth is known then it will be one more parameter to detect whether it is a ship or something else, which look similar to ships. Using length and breadth, tracking of ship location and its where about on particular day can be estimated. The approach to know ship characteristics is as shown in the Figure 4.6.

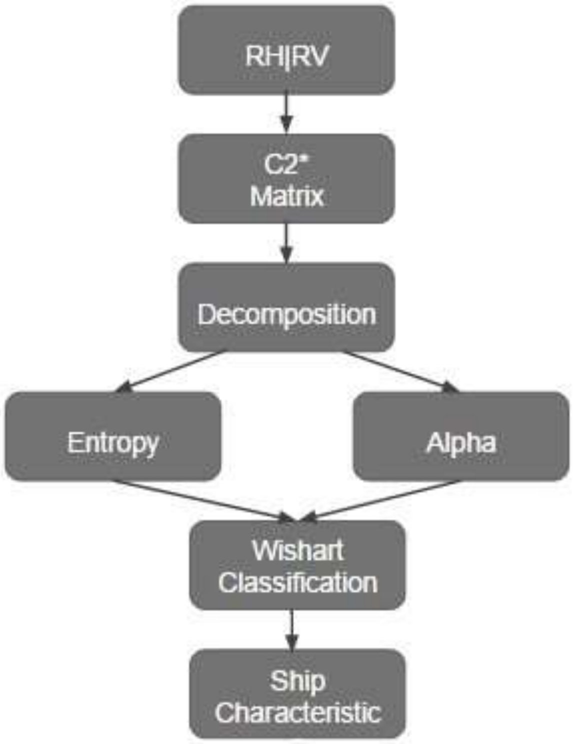

Figure 4.6 Flow chart for ship detection

RISAT-1 FRS-1 data consists of RH and RV image, which consists of complex numbers. Now, using the same complex number image, separating its real and imaginary value, c2 matrix is generated. * indicates it is speckled image. Entropy, Alpha and Anisotropy are calculated. These three comes under decomposition of polarimetric sar images. Other decomposition of compact polarimetry like m-chi, m-delta are available, but after practically working on many SAR images, entropy and alpha works best for target ships. Before this, many ship detection algorithms paper are available, but characteristics of ship is less explored topic.

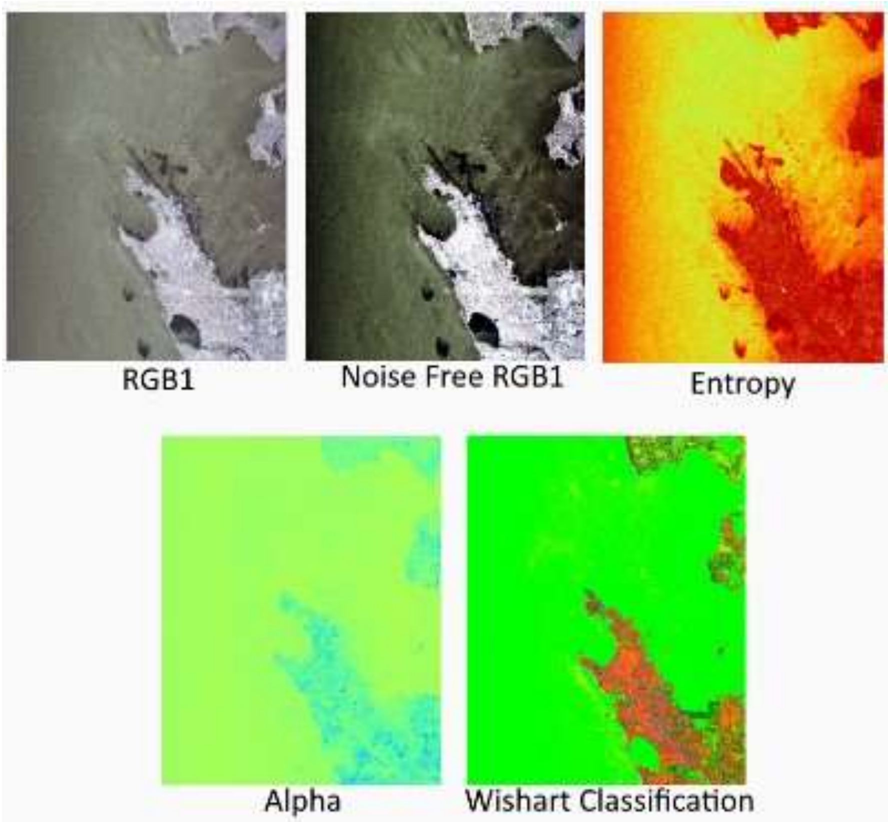

Figure 4.7 Decomposition and classification on Mumbai area

RISAT-1 FRS-1 data with right circular transmit and linear receive of Bombay area. Below image show RGB (with and without speckle filtering) and entropy image. The swath of data taken is 32.13 kilometer along azimuth direction and 23.98 kilometer along range direction. The following image shows different images as per given in flowchart. Different ships are taken into consideration as shown in Figure 4.8.

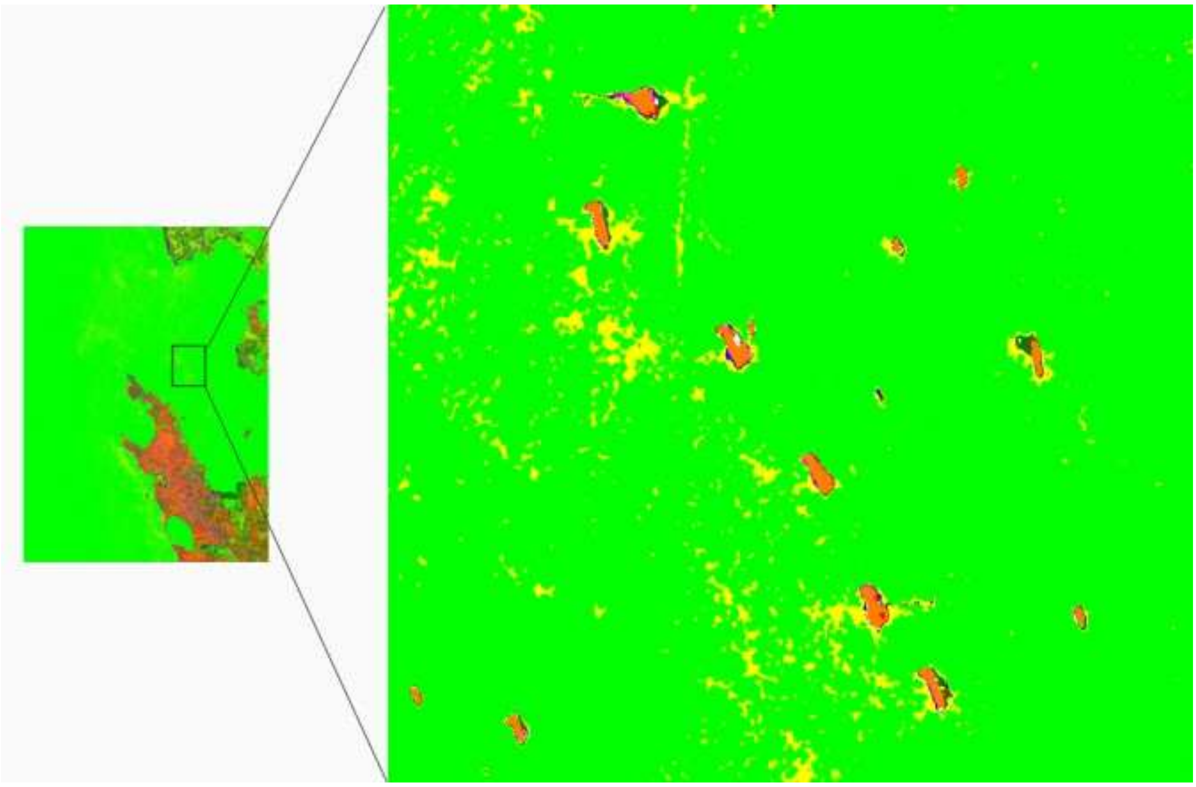

Figure 4.8 Enlarged area of ships presence

As shown in Figure 4.8, wihsart classification separates ships and water, so that by using certain image classification techniques, boundary around ship can be drawn as shown in Figure 4.9.

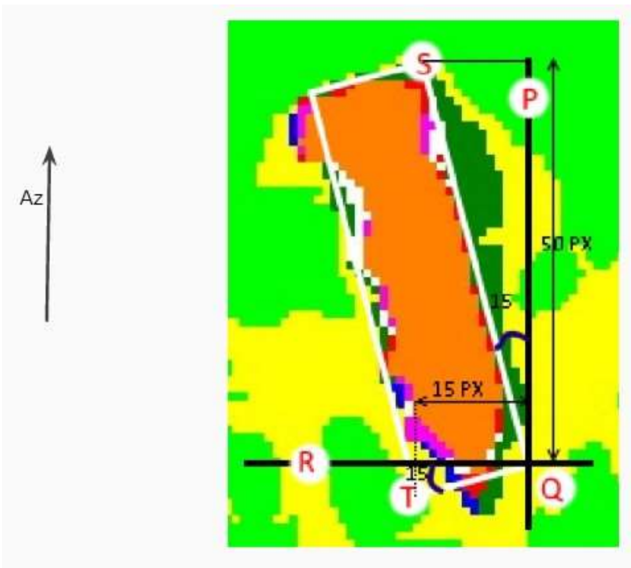

Figure 4.9 Calculation of projection of ship along azimuth and range direction.

In the above figure, the proposed methodology to know length and breadth of ships is figured out. First step is to outline ship with a rectangle. By using this rectangle, its projection along azimuth direction and range direction can be known. Now by calculating the number of pixel along azimuth direction projection and the same along range, its length and breadth can be known. Here is some mathematical equations and calculations for a candidate ship is calculated.

Azimuth Cover: 32.13 Kilometer
Range Cover: 23.98 Kilometer
Number of Pixel Represented along Azimuth direction: 7812
Number of Pixel along Range direction: 5776
Each Pixel along Azimuth is 4.11 meter
Each Pixel along Range is 4.15 meter
Using above calculations, ship length and breadth is calculated.

Length = (Number Of Pixel along Az)*(Azimuth_Sp)/cos(PQS)
= (50*4.11)/cos(15)
= 212m
Breadth = (Number Of Pixel along Rg)*(Range_Sp)/cos(RQT)
= (15*4.15)/cos(15)
= 64m

Height of ships can also be calculated using Shadow of ships, but it comes with certain limitations. Similar type of analyzing can be done on other ships as well. The Figure 4.10. show the ROIs of different shapes.

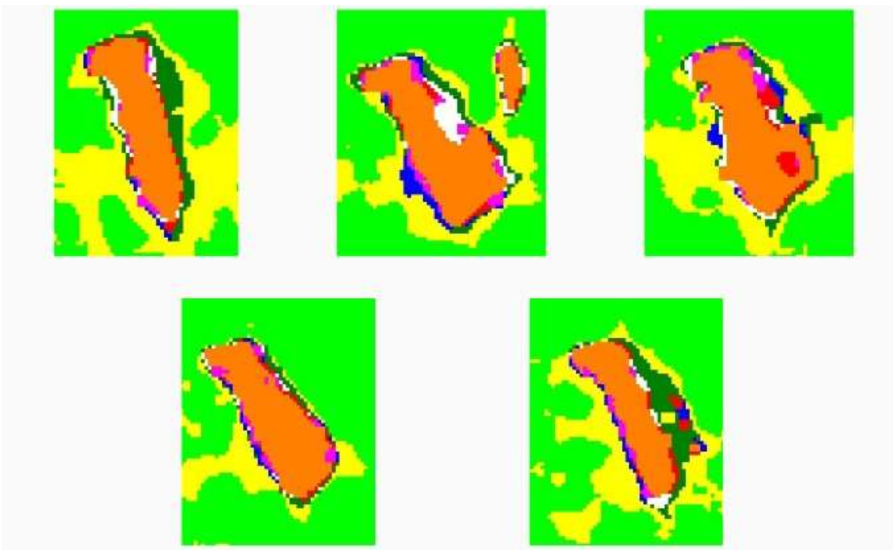

Figure 4.10 ROIs of different shapes

Using above proposed method, ships tracking using SAR polarimetry images can be made easy. RISAT-1 SAR images are less explored, using these type of novelty approaches to track ship and its location. Wishart classification is best tool to detect as well as identify ships, detection can also be made possible by calculating ratio of length to breadth of ships.

Lack of determining difference between oil spill and look alike using unsupervised / decomposition like entropy, alpha and many other:

Risat-1 Level 1 Data Imaging mode: FRS-1

Source: https://www.nrsc.gov.in/Brochures?q=Search_and_Order_Data

Alos Palsar Level-1.1 data

Source: https://vertex.daac.asf.alaska.edu/?

Sentinel 1 SLC data

Source: https://vertex.daac.asf.alaska.edu/?

	Sentinel 1 (Chennai, India)	ALOS Palsar (Deep Horizon, Gulf of Mexico)	ALOS Palsar (Montara, near australia)
Date	29th January,2017	28th May,2010	18th August, 2009
Data Type	Level 1 SLC data	Level 1.1	Level 1.1
Image from Google Earth			

Here are some examples of Oil spill events:

Figure 4.11 Oil Spill near Bombay area from Sentinel 1 RGB1 Composition

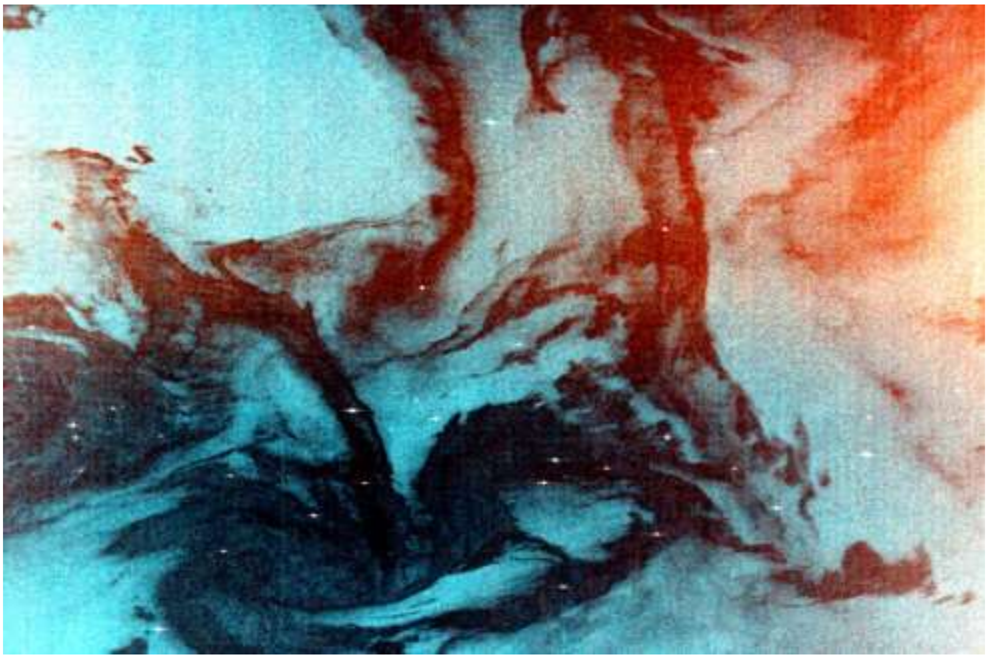

Figure 4.12 Montara Oil Spill, ALOS PALSAR data RGB1 Composition

Now, as dark spots are visible in oil spill images, the same type of dark spots will be seen in lookalike of oil spills. Lookalikes of oil contains algae blooms, sea weeds, fish sperms etc. Data of Victoria Lake is taken where there is no oil spill event take place in history, sensor is ALOS PALSAR. Polarization is HH and HV

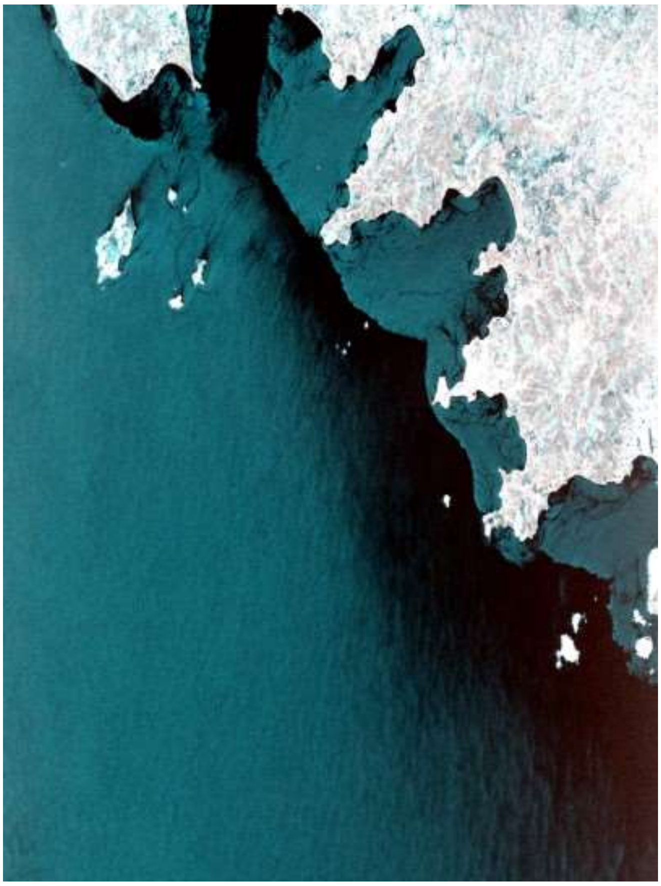

Figure 4.13 Look-alikes near Victoria Lake

Here are some examples of Oil Slick and Look-Alikes, trying different decomposition and classification like H-Alpha.

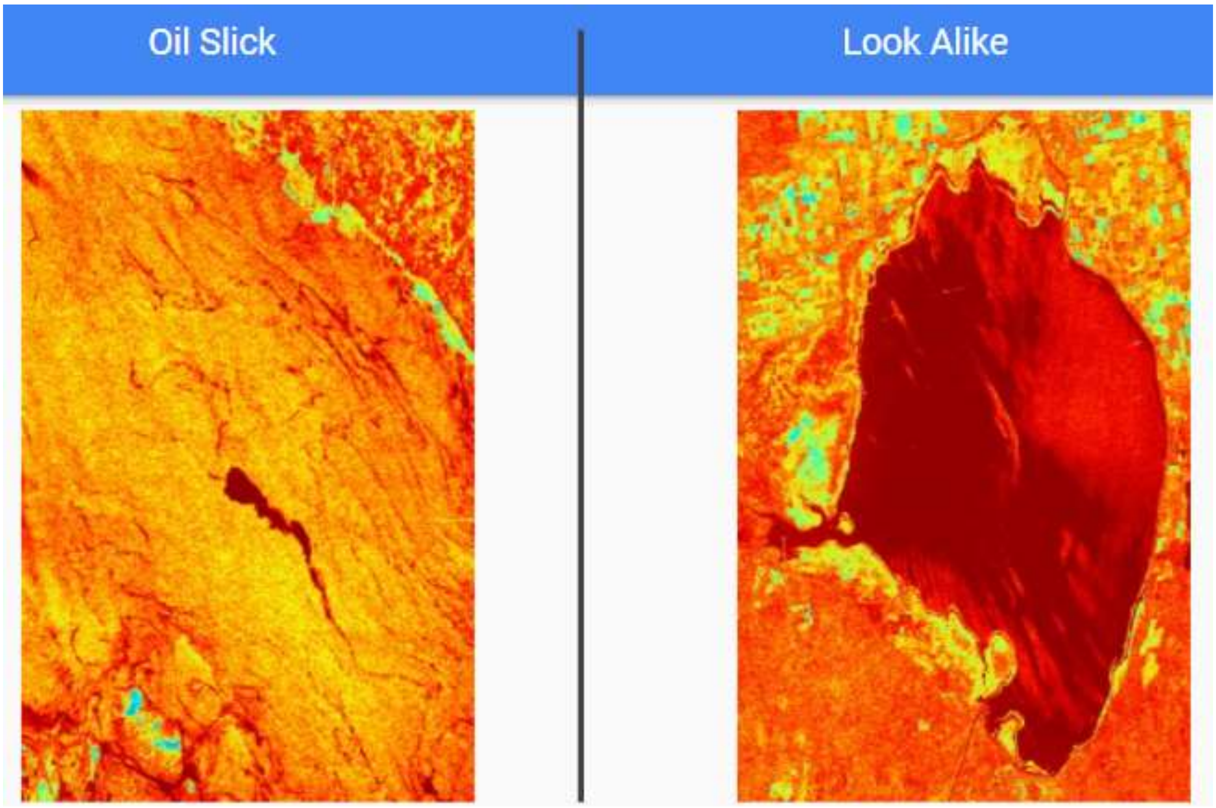

Figure 4.14 Entropy

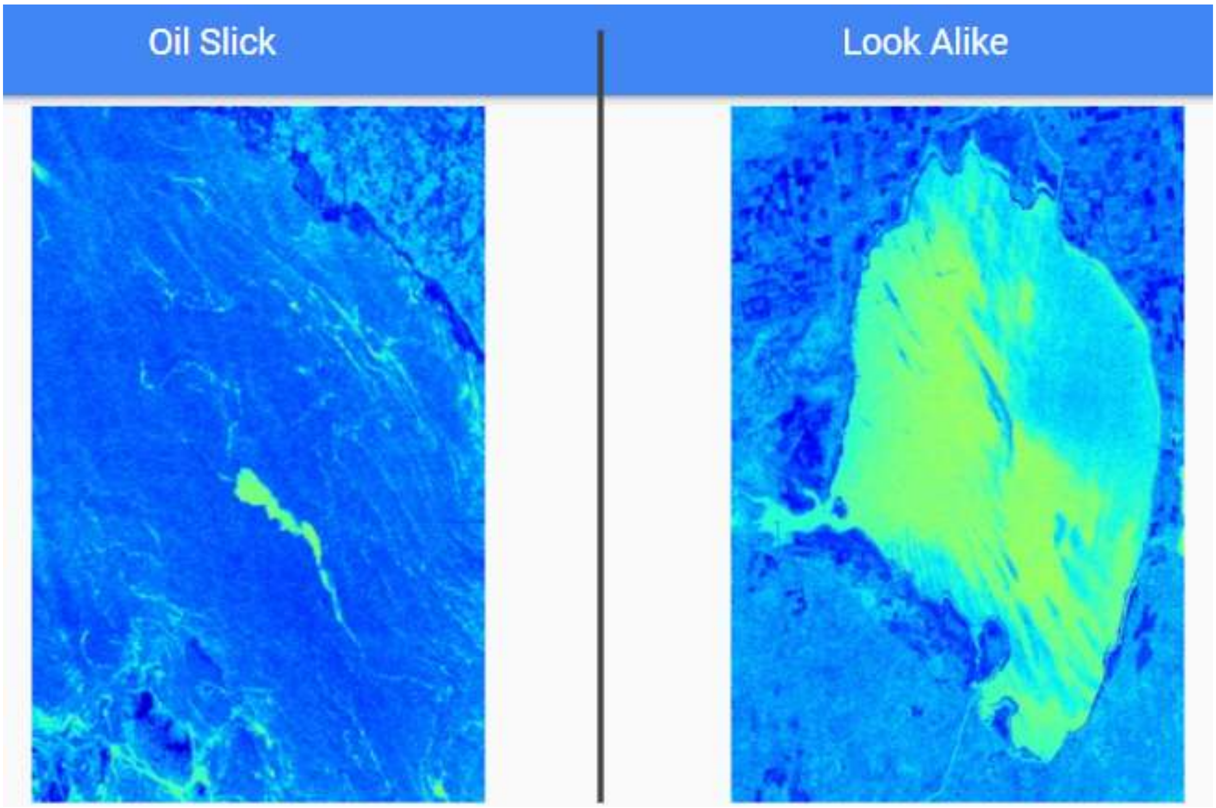

Figure 4.15 Alpha

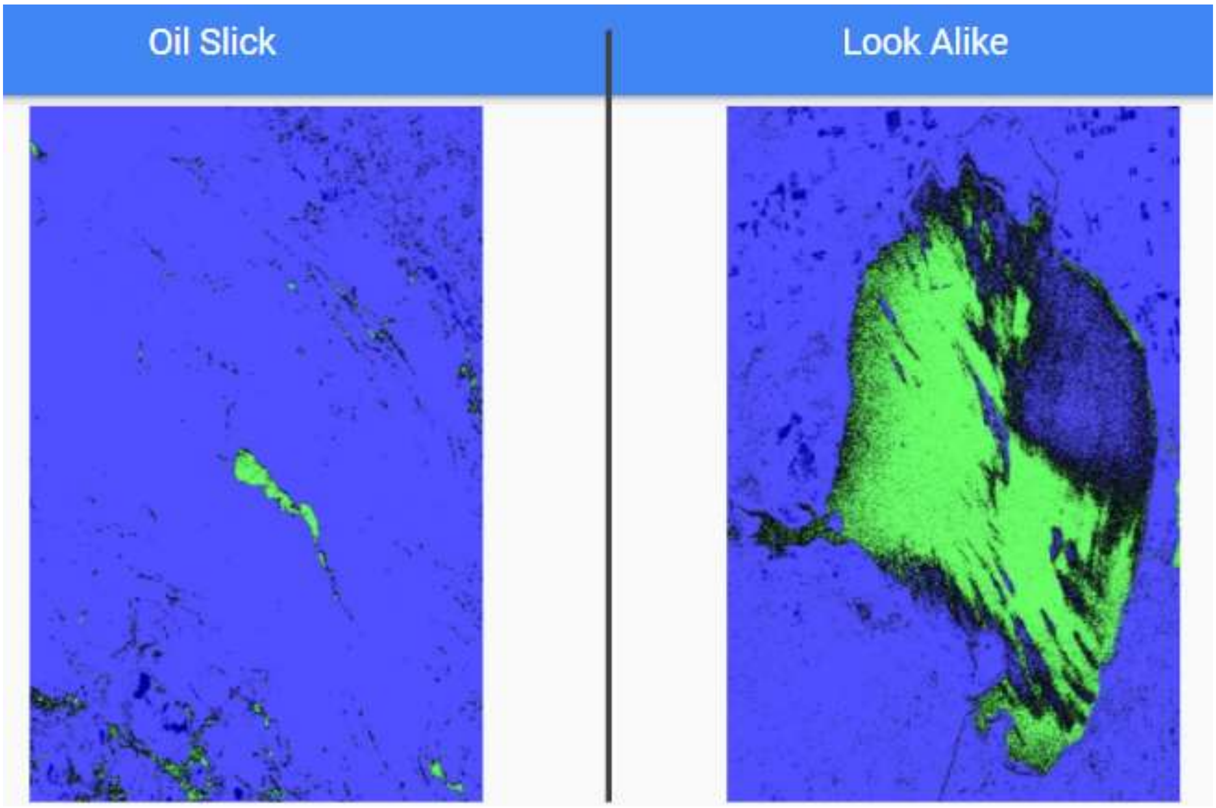

Figure 4.16 H-Alpha Classification

So from above examples, it is clear that using only SAR data, differentiating lookalikes and actual oil spill is hard. But, as a solution to this, adding optical images data and combining it with SAR data, probability of differentiating them will be easier.

Chapter No: 5
Tools and Techniques

- **About PolSARpro**
- **Using python libraries**

5. Tools and Techniques

5.1 About PolSARpro

Developed under contract ESA-ESRIN, PolSARpro-The polarimetric SAR data processing and education tool is a rich FOSS to process SAR (Synthetic Aperture Radar) data. Most of the SAR sensors provide data at two different levels. Level 1 is complex raw data and needs a lot of mathematical and physical understanding of a phenomenon before it can be used. Level 2 is on the other hand, calibrated, georeferenced data and majority of the processing goes as image processing. In this chapter, Level 1 SAR processing through FOSS PolSARpro ver 5.1 is demonstrated.

PolSARpro supports data processing of both airborne and space-borne radars. Below is the list of Airborne and space-borne satellite:

Airborne Satellites	*Space-borne satellites*
· Airsar · Convair · Emisar · E-Sar · F-Sar · Sethi · Uavsar	· Alos-1-Palsar · Alos-2-Palsar · Cosmo-Skymed · Envisat-Asar · Radarsat2 · Risat · Sentinel-1 · SIR-C · TerraSAR X

Table 5.1 Airborne and space-borne satellites in PolSARpro

Among the above mentioned satellites, data of Sentinel-1a, Sentinel-1b, UAVSAR, ALOS PALSAR is freely available and can be found from this link https://vertex.daac.asf.alaska.edu/

The processing capabilities of PolSARpro is as mentioned here:

PolSARpro is bagged with tools for smoothing of images or speckle removal. An-Yang Filter, Box-car Filter, Box-car Edge Filter, Gaussian Filter, IDAN Filter, Lee Refined Filter, Lee Sigma Filter, Lopex Filter, Mean-Shift Filter, Non-local Means Filter and many more popular filters are available at your fingertips while working with this FOSS.

As a visual pleasure you can find Refined Lee filter applied on an SAR image in figure:

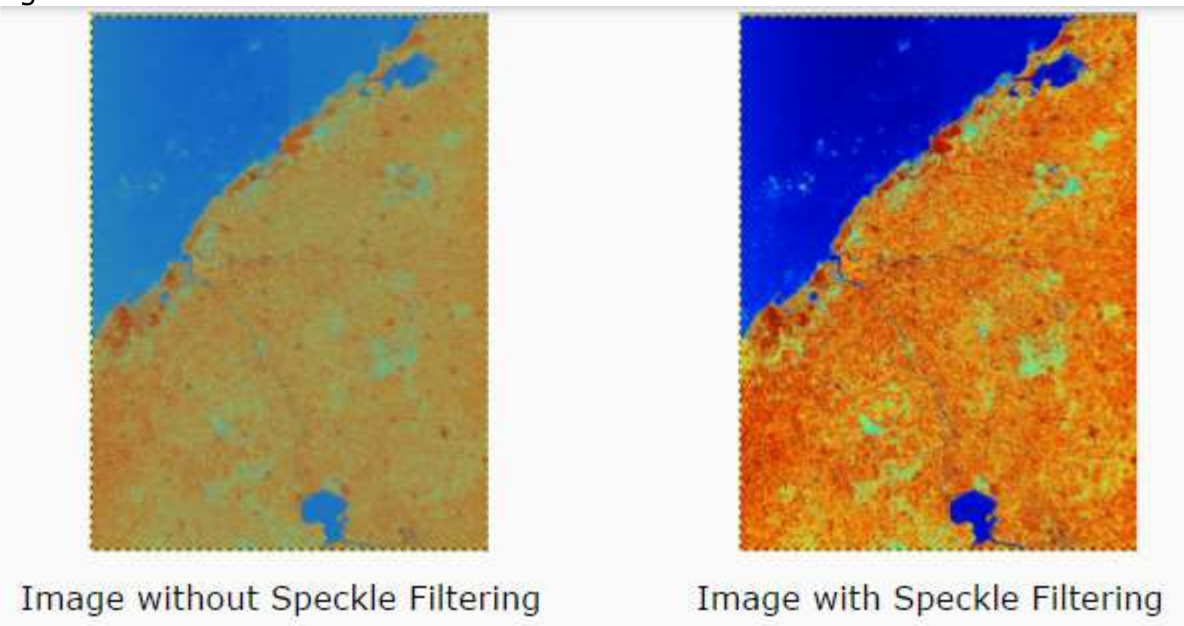

Figure 5.1 Results of Refined Lee filter

There are significant decomposition algorithms available for quadrature polarimetric data, dual polarimetric data as well as compact polarimetric data. These decomposition algorithms help for study on particular features like ship detection, oil spill detection, agricultural applications, etc. The rich set of popular decomposition algorithms available with PolSARpro. A few of them are listed in table:

H / A / Alpha	Huynen	Barnes	Cloude	Holm	An & Yang	Bhattacharya & Ferry
Freeman	Neumann	Arri	Van Zyl	Singh 4	Yamaguchi	L. Zhang
Touzi	RVoG	Raney	Entropy	Anisotropy	EigenValues	Aghababaee

Table 5.2 Available decomposition algorithms in PolSARpro

A step by step decomposition of SAR data through PolSARpro version 5.1 is:

This is home screen of PolSARpro Version 5.1:

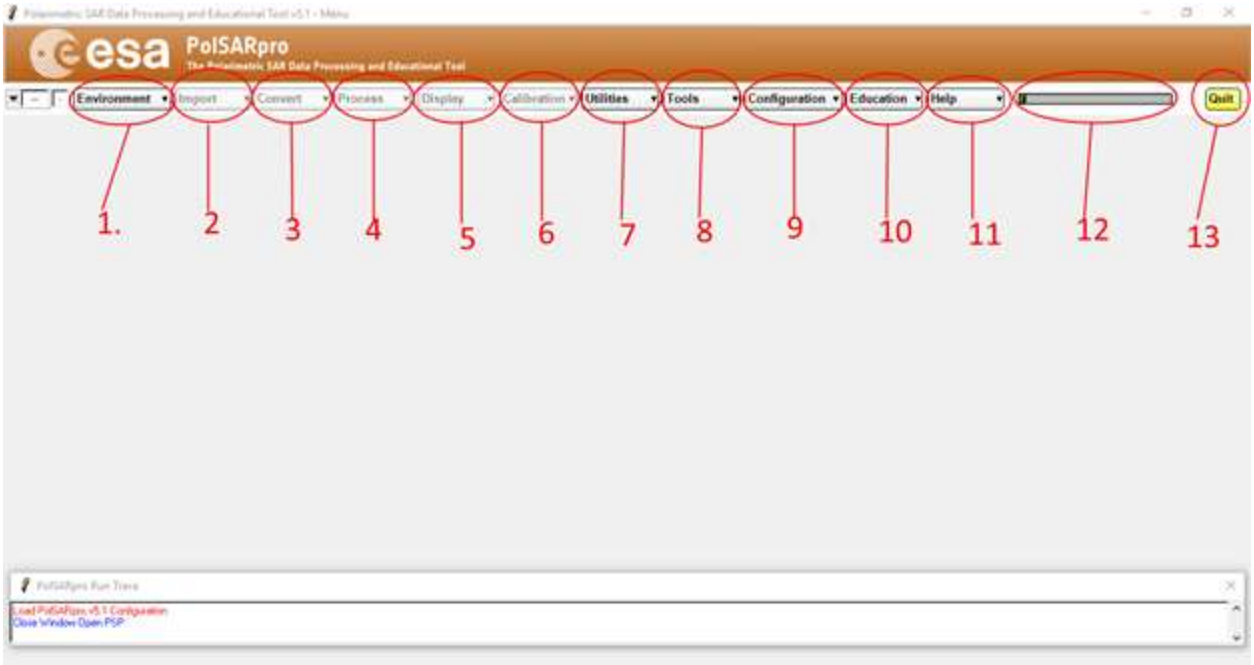

Figure 5.2 Home screen of PolSARpro

First step is to select environment. The first active tab shown above shows to select Single data set,Dual data set or Multi data set. Select single data set if one wants to process only single scene or a single SAR image. Select appropriate folder location. Environment folder selection depends on particular satellite on which one wants to work with. Let's take example of Sentinel-1 SAR SLC level 1 data (Sentinel data available free as discussed before). After selecting Environment, import tab(Number 2 in above figure) will be activated. For Sentinel-1, select Import → Spaceborne Sensors → Sentinel-1 → Unzipped data product.

Figure 5.3 Sentinel Window

Select swath number as Sentinel data contains 3 swath in single data set. This window differs according to different sensors. It will take time to process as per user's hardware and data size. After importing data, select Import → Extract PolSAR images. This will show you option to create covariance matrix. If it is quad pole data, then multiple options like T3, C3, C2, sinclair, etc. will be shown. These matrix are the "BASE" for further processing of the same data. These matrix generated are now key for further processing like decomposition, classification, etc. Now all tabs will be activated including "Process" (Number 4 in Figure 1). Make sure that the matrix on which you are working on is appearing on top left as shown here. Whatever process one select will be applied to the mentioned matrix in the box (C2 in this example)

Figure 5.4 Showing C2 matrix

When you press "Process" tab, all possible speckle filtering algorithms, decomposition algorithms, classification algorithms, etc. will be visible. Now from here it's up to you! You can try as many decompositions, filters, classification which is relevant to your field.

One of the feature of PolSARpro is that it creates KML file which can be seen on Google Earth application. Google Earth Application can also be linked with PolSARpro software during installation. This KML file shows highlighted location of SAR image on Google Earth. Sample of highlighted image is shown here:

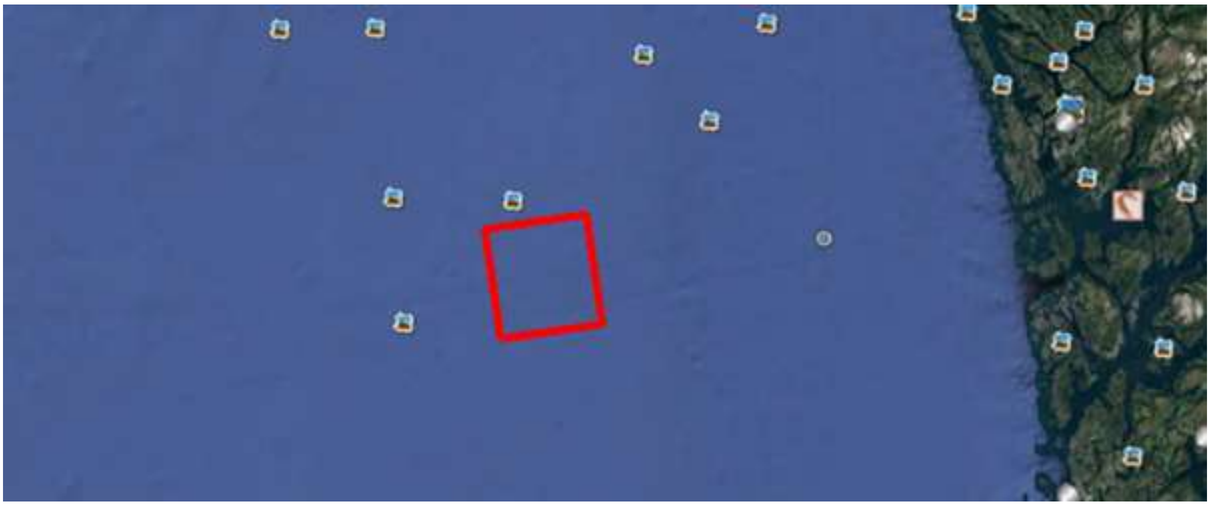

Figure 5.5 KML File

This snap is taken from Google Earth software developed by Google Inc.

Some segmentation algorithms are as shown here:

H / A / Alpha Classification	H / u / v Classification	H / A / Alpha - Wishart Classification	Unified Huynen Classification
G.P.F Supervised Classification	Fuzzy - H / Alpha Classification	Rule-based Hierarchical Classification	SVM Supervised Classification

Table 5.3 Available classification techniques in PolSARpro

Wishart Classification, H-Alpha classification, H-A-Alpha classification and many more. Scatter plots can also be generated using any two entities as X-axis and Y-axis.

5.2 Using Python Libraries

For validation of output images, programming in python was required using rich libraries like GDAL – Geospatial Data Abstraction Library. Using this library, reading files with varied formats become easy. For example, in our case reading data file: RH and RV, it is done using simple array reading available in GDAL library as shown here:

```
import gdal
import numpy as np
import matplotlib.pyplot as plt
x=gdal.Open("rh16161.001").ReadAsArray()
y=gdal.Open("rv16161.001").ReadAsArray()
```

The above line shows usability of GDAL, this will give matrix in form of complex number. To separate real and imaginary part, following code is used:

```
rh_real=np.real(x)
rv_real=np.real(y)
rh_imag=np.imag(x)
rv_imag=np.imag(y)
```

rh_real contains real values of RH file, rv_real contains real values of RV file and like wise rh_imag and rv_real. To get power values of complex number containing file of RH and RV file, using following code will help:

```
mode_rh = np.absolute(x)
mode_rv = np.absolute(y)
```

Simple stokes parameters can be calculated using simple calculations between obtained values using GDAL library.

```
g0 = new_rh*new_rh + new_rv*new_rv

g1 = new_rh*new_rh - new_rv*new_rv

g2 = 2*(rh_real*rv_real + rh_imag*rv_imag)

g3 = -2*(rh_imag*rv_real - rh_real*rv_imag)
```

where g0, g1, g2, g3 are four stokes parameters.

Conclusion

- After experiments on given data (Level 1/SLC), it is observed that oil slicks can be identified using multiple parameters like entropy, anisotropy, alpha, lambda etc. but not differentiate with look-alikes.
- SAR polarimetry features has more potential than optical images, from which we can have all day-night observations and classify according to need in specified field of interest.
- Look alikes are main threat to identify oil slicks, these look alikes have same scattering characteristic. But decomposition parameters like Shannon entropy may differentiate some of look alikes.

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