

Oil Spill Detection and Classification by ALOS PALSAR at Vietnam East Sea

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Key words: oil spill, ALOS PALSAR, detection, classification

SUMMARY

Oil pollution is getting gradually serious in Vietnam East Sea. Remote sensing technique is the most appropriate for oil pollution management. Microwave remote sensing data are commonly used for ocean pollution monitoring and earlier detection of oil spill. This practice is due to that the microwave sensor precedes optical sensors in all weather and all-day observation capabilities. Oil slick at sea is detected by appearance of dark patterns on the sea surface caused by decreasing of roughness affected by the oil film. The oil film causes lower microwave backscattering that leads to development of dark pattern on microwave image which is used as the first signature for oil slick detection. There are different approaches for oil slick detection such as visual interpretation, semi or fully automated recognition. This paper provides a review on oil spill detection and classification techniques in SAR images. The authors present preliminary results of oil spill detection in the East Sea using the ALOS PALSAR data.

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1. INTRODUCTION

Oil spills are getting more and more frequently on the sea surface. Annually, 48% of the oil pollution in the seas is caused by fuels and 29% by crude oil. Tanker accidents contribute with only 5% of the all pollution entering into the sea. According to the European Space Agency (1998), 45% of the oil pollution comes from operative discharges from ships. When taking into account how frequent such spillages occur, controlled regular oil spills can be a much than larger oil spill accidents.

In Vietnam, oil pollution becomes more and more seriously because the shipment traffic and oil exploitation are getting quickly increased in the East Sea. From 1986 to 2000, the oil production of Vietnam was enlarged from 40.000 tons to 16.500.000 tons. The oil exploitation of Vietnam is set the forth of Asian countries, after Malaysia, Indonesia and the Philippines and the forty-fourth in the list of Petroleum Exporting Countries in the world. According to the National reports on sea pollution in Vietnamese East Sea, 12 oil spills (from 2-3m³ to 15m³) were recorded from 1990 – 1995. From 1995 to 2000, 31 accidents causing oil pollution have occurred in the sea. The most serious oil pollution in Vietnam East Sea has occurred in the early months in 2007. However, response of Vietnam was completely passived and reasons and sources of the oil spills are still unknown. It was unable to define exactly the time oil spills occurs due to lack of proper equipments for inquiring, surveying and detecting the oil spills in early stage at sea.

Therefore, there is strong need of development of solutions and effective scientific methodology for oil pollution monitoring and surveying which are suitable and useable in condition of Vietnam.

2. OIL SPILL DETECTION AT SEA BY MICROWAVE REMOTE SENSING

Nowadays, technologies of early detecting and monitoring oil pollution in the sea are classified according to sensors on the satellites, planes or ships. The most popular sensors are visible, infrared, ultraviolet, fluorescent laser and microwave. Active microwaves sensor like Synthetic Aperture Radar (SAR) play an important part in the monitoring oil pollution systems due to its wide area coverage and day and night weather capabilities. The optical sensor have no these capabilities as microwaves sensors. In SAR images, the brightness of the sea surface is a measure of the sea surface roughness. Smooth sea surface appears dark while the brightness increase as the sea surface becomes rougher.

The presence of an oil film on the sea surface damps the waves due to the increased viscosity of the top layer and drastically reduces the measured backscattering energy, resulting in

darker areas in SAR image. The detectability of oil spills in a SAR image depends on the ocean surface wind speed. If the wind speed is too low (below 2 – 3m/s), the sea surface background does not have roughness to contrast with that of the oil spill. On the other hand, if the wind speed is too high (about 15m/s), the oil can be dispersed by the surface waves and the slick can disappear below the sea surface. However, careful interpretation is required because dark areas might also be caused by locally low winds or by natural sea slicks. Nature dark patches are termed oil slick look – alike. To avoid false alarm, operators or classification algorithms have to take into account texture, position, temperature and other information from GIS database during oil spill analysis.

The methods oil spill detection and classification have been developed for RADARSAT (Francesco, 2005) – Band C, ERS-1,2 SAR (Massimo, 2005) – Band C, ENVISAT ASAR (Stéphane, 2007) – Band C and few ALOS PALSAR – Band L. ALOS is a new generation satellite designed for precise land observation over the optical and microwave portion of the spectrum. The Advanced Land Observing Satellite ALOS was launched into a sun-synchronous orbit on January 24, 2006. Its payload comprises three sensors, the Panchromatic Remote Sensing Instrument for Stereo Mapping (PRISM), the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2), and the Phased Array type L-band Synthetic Aperture Radar (PALSAR) (Table 1).

Table 1

Sensor	PRISM	AVNIR-2	High Resolution	ScanSar
<i>Wavelength(μm)/ Frequency (GHz)</i>	0.52 – 0.77	0.42-0.50	1.27 GHz (L band)	
		0.52-0.60		
		0.61-0.69		
		0.76-0.89		
<i>Spatial resolution (m)</i>	2.5	10	10	100
<i>Swath width (km)</i>	35-70	70	70	250-350
<i>Point angle (°)</i>	+/-24	+/-44	10-51	
<i>Number of looks</i>	3	Flexible	2	8
<i>Polarization</i>			HH,VV,HH & HV,VV & VH	HH, VV
<i>Data transmission rate (Mbps)</i>	960	160	240	

(Source: JAXA, 2004).

3. OIL SPILL DETECTION IN SAR IMAGE

Generally detection of oil spills in SAR images is composed of two main steps:

- Detection of dark spot in SAR images.
- Classification of the slicks (oil or look – alike).

Oil spill can be detected and classified by visual interpretation, semi or fully automatic methods.

3.1 Manual detection

Manual detection is the method when oil spill is visually interpreted by operator. All dark slicks are detected in SAR images manually. Auxiliary information about wind speed and direction, location of oilrigs and pipelines, national territory borders and coast-lines are used to support interpretation. The assignment is based on the following features: the contrast level to the surroundings, homogeneity of the slicks nearby and edge and shape characteristics of the spot. Manual oil spill detection has been conducted by KSAT (Kongsberg Satellite Services) in Norway since 1994 (*Camilla, 2005*).

During manual detection, contextual information is an important factor in classifying oil spills and look – alike. However, it is time consuming and slow processing. For this reason, it is necessary combine expert knowledge with automatic detection algorithms. QinetiQ has used semi-automatic algorithm for oil spills detection and classification of oil spill at sea. Firstly dark spots in SAR images are detected by automatic methods and then the output targets are classified and checked visually by an operator.

3.2 Automatic techniques for oil spill detection in SAR images

Flowchart of automatic oil spill detection is shown on figure 1.

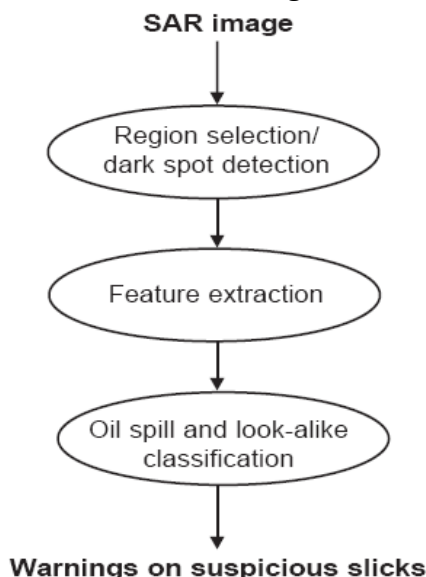


Figure 1: A framework for oil spill detection algorithms

3.2.1 Dark spot detection

As oil spills are characterized by low backscattering levels, dark spot extraction is done by adaptive thresholding. Besides, several automatic algorithms are applied for example Hidden Markov Chain algorithm (HMC) (*Stéphane, 2007*), Constant False Alarm Rate algorithms (CFAR) (*Francesco, 2005*). QinetiQ's dark spot detection algorithm uses a CFAR algorithm to locate dark regions. The common goal this method is to detect all suspicious slicks and to preserve the slick shapes. The result of dark spot segmentation is important for the subsequence discriminating oil spills from look-alikes in the next steps.

3.2.2 Feature extraction

From the thresholded dark spot in SAR images, feature extraction is used to compute features for each slick. The features are used for classification. The most commonly used features are:

- Geometry and shape features of the segmented regions: perimeter, area, complexity, shape factor. These features are used in all methods. To detect pollution from sailing tanker cleaning their tanks, an important feature is shape factor which can be expressed as a ratio between the length and width of the slick (*Fabio Del Fratel, 2000*).
- Feature based on physical characteristics of the backscatter level of the spot and surrounding: object standard deviation (Osd), Standard deviation (indB), Background standard deviation (BSd), Standard deviation (in dB), Max contrast (ConMax), Mean contrast (ConMe), Max gradient (GMax), Mean gradient (GMe), Gradient standard deviation (GSd), mean Harlick texture (THm) (*Fabio Del Frate, 2000; K.Topouzelis, 2007*).
- Spot contextual features: slick location relative to the shore and distance to ships and oilridgs can be used to improve classification results. For examples, if the position of dark slick in SAR image is nearby the land, there's may be look-alike. Besides, a bright spot closes to oil spill, could be a ship or an oil platform causing the slick.
- Fractal texture description can be used to describe natural surfaces. The use of fractal dimension D as a feature for classify observed ocean radar signature is suggested in the paper of Maged Marghany in 2008. A difference in D of oil spill compared to other oceanic phenomena is reported. As a result, oil spill and look-alike are discriminated. (*Maged Marghany, 2008*)

3.2.3 Classification methods

Dark spots in SAR image can be created by a number of phenomena. The purpose of the classification process is to distinguish oil spills and look-alikes. An artificial neural network is regularly used for automatic classification algorithms. Neural network is a mathematical model composed of many neurons operating in parallel. The input to the net are also feature of vectors which extracted from dark spot segmentation. The accuracy of oil spill classification by neural network is 82%.

These automatic methods for oil spill detection are of accuracy between 82% and 94%. This result has been achieved using different dataset and algorithms. However, for new ALOS PALSAR sensor it is challenging to try new algorithm which is suitable for early oil spill warning purpose.

4. EXPERIMENTS AND RESULT

a. Visual Interpretation

The ALOS PALSAR used for this study are given on the table 2.

Table 2

No	ALOS PALSAR image name	Observation time	Scene position	
			Latitude	Longitude
1	PASL4200703080307230811070003	08/03/2007	17°.92	109°.63
2	PASL4200704180301400811070006	18/04/2007	15°.45	110°.73
3	PASL1500803291519540811070001	29/03/2007	17°.56	108°.99

Oil spills detected by visual interpretation in ALOS PALSAR images.

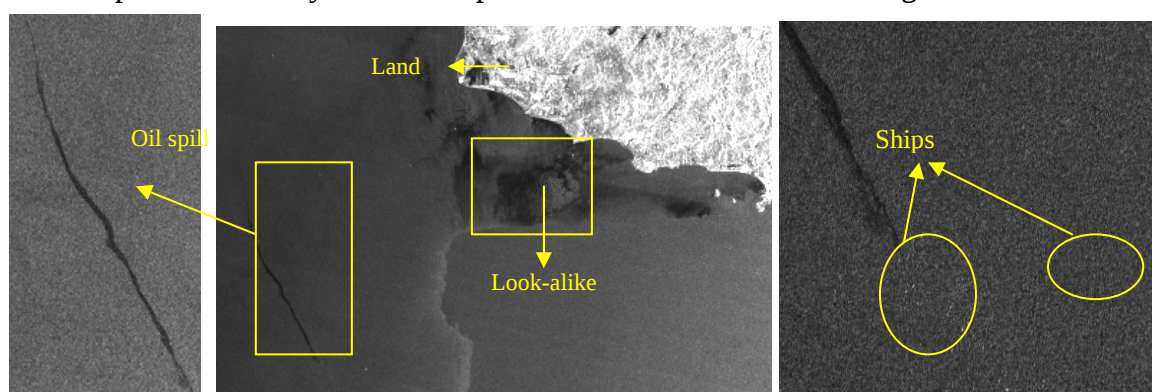


Figure 2: Detection of oil spill in image of 08/03/2007 image

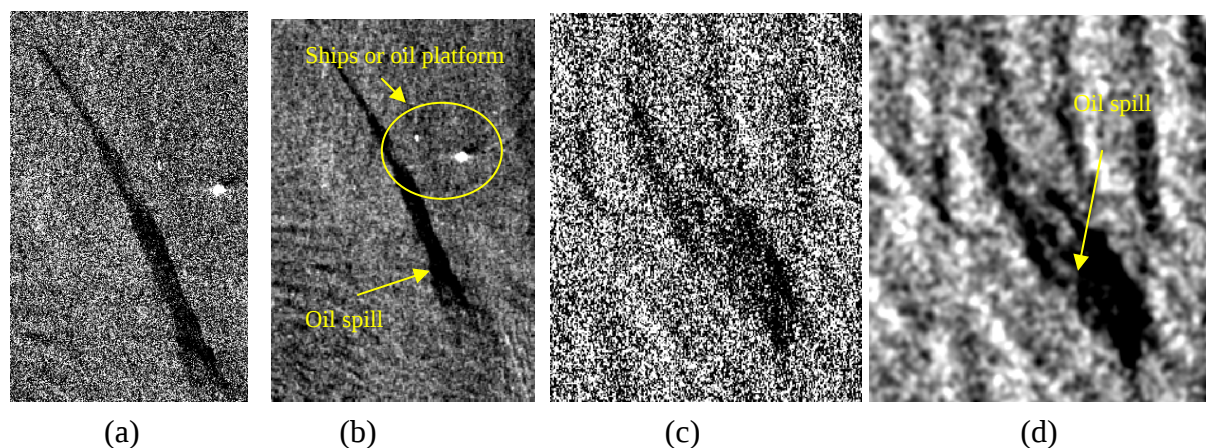


Figure 3: Detection of two oil spills on 29/03/2007 image. (a) and (c) original data. (b) and (d) filtered by LEE algorithm (window 7x7)

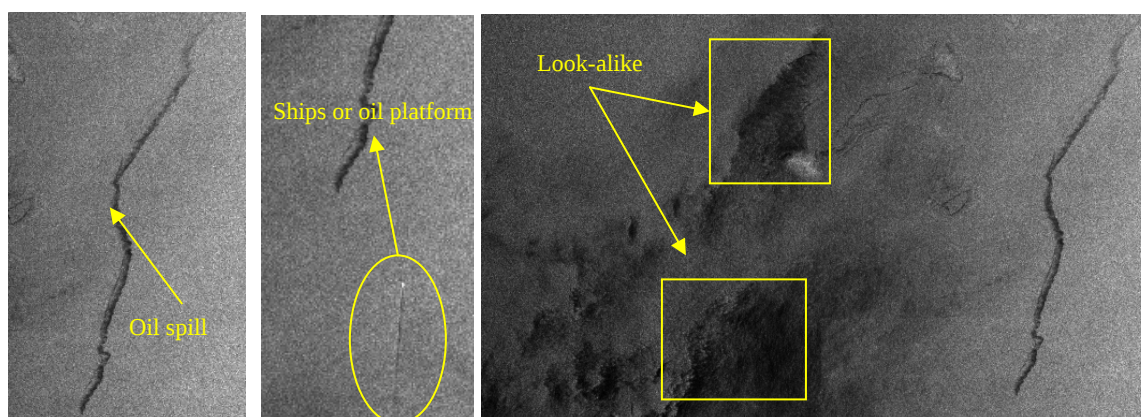


Figure 4: Detection of oil spill on 18/04/2007 image

b. The results by semi-automatic technique

We assume that wind speed is about 10m/s and oil spill can be detected in images.

Firstly the ALOS PALSAR data is smoothed by Lee and Median filter with kernel size of 7x7. After filtering, dark slicks are detected and segmented by level slicing. All dark spots are latter converted to vector (with polygons). Geometrical features as follows are calculated:

1. Area (A). Area (in m²) of the object.
2. Perimeter (P). Length (in m) of the border of the object.
3. Complexity (C). Complexity is defined as follows:

$$C = \frac{P}{2\sqrt{\pi A}}$$

This feature will generally take a small numerical value for regions with simple geometry and larger values for complex geometrical regions (*Del Frate, 2000; K.Topouzelis, 2007*).

4. Shape factor (SP): Describes the general shape of the object. It is the ratio of the lengths of major and minor axes of an ellipse describing the object shape. Linear oil spills are elongated segments characterized by high shape factor (*Iphigenia Keramitsoglou., 2005*).

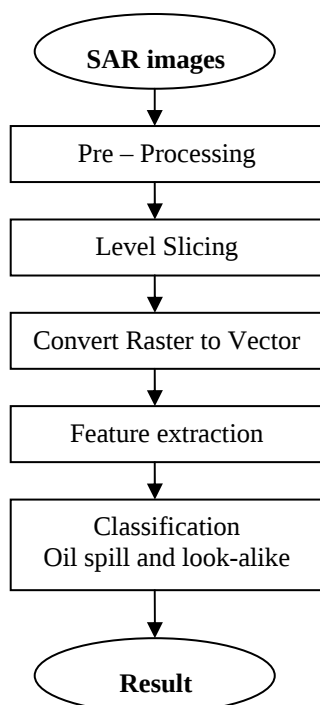


Table 3

Oil spills detection and classification in ALOS PALSAR images

Images	No	Area (m ²)	P (m)	Complex (C)	Shape factor	Result
8/3/07	1	25095000	111800	6.30	36.62	Oil spill
8/3/07	2	119965000	357400	9.21	1.36	Look - alike
29/3/07	3	58694	6144	7.16	12.57	Oil spill
29/3/07	4	7310	986	3.25	1.23	Look-alike
18/4/07	5	25492	4726	8.35	41.43	Oil spill

Figure 5: Flowchart of oil slick detection and values of geometrical features of detected oil slicks

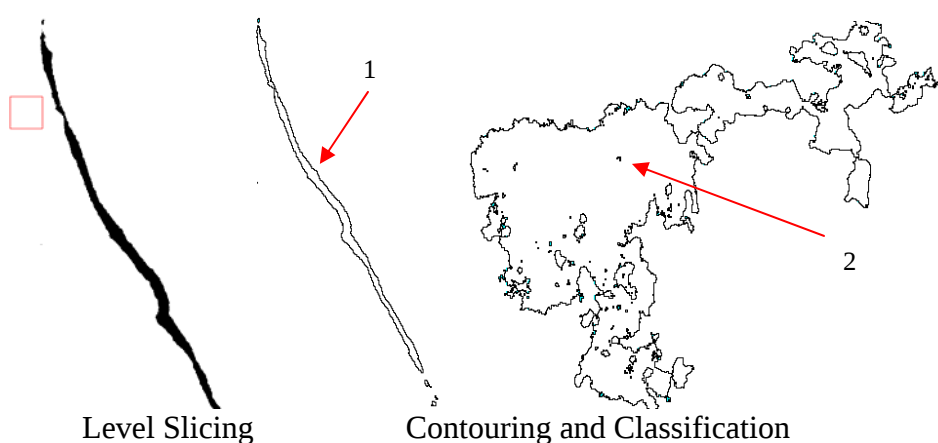


Figure 6: Detection and classification of oil spills on 8/3/2007 image

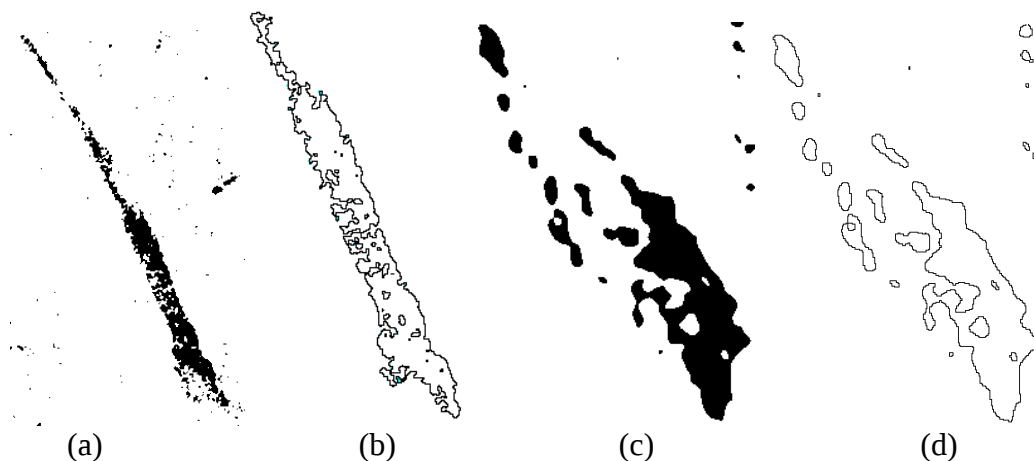


Figure 7: Detection and classification of oil spills on 29/3/07 image. (a) and (c) level slicing. (b) and (d) contouring and classification. (c) and (d) an oil spill has not been detected.

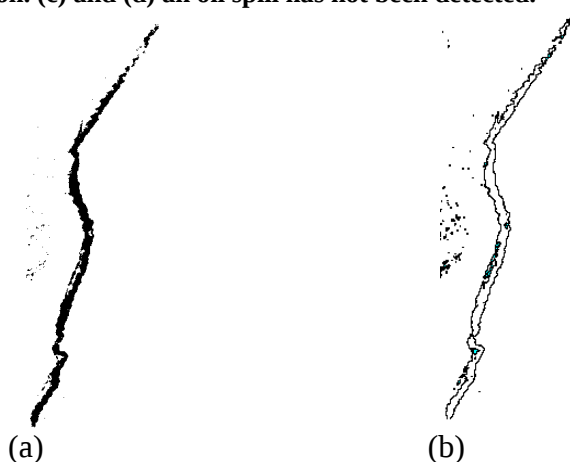


Figure 8: Detection and classification on 18/04/2007 image. (a) level slicing, (b) contouring and classification.

After conversion to vector, dark spots have been classified by area, complexity and shape factor index. These results are arranged from maximum to minimum. All of dark spots with small area and low complexity features are removed. The results given on the table 3 include only dark slicks with maximum complexity factor. After that linear dark slicks are further classified by shape factor index. According to the research, oil spills discharged from tankers are mainly linear features of high shape factor value. Extracted vector boundary of oil slick has been overlaid back over the original image and checked again by operators.

5. CONCLUSION

ALOS PALSAR data of level 4.2 provided by ERSDAC with spatial resolution of 100m resolution can be used for detection and classification of large size oil spill at sea.

Level slicing which is quite simple method can be used and demonstrate quite good results. However, threshold value for dark object was set by trial and error approach. It is necessary to develop an algorithm on automatic computation of threshold values for different SAR image types and different image characteristics.

The largest challenge in detection of oil spills in SAR images is accuracy of discrimination between oil spills and look-alikes. To improve the accuracies, there is a need to find out geometry, shape features and backscattering levels to distinguish oil spills and look-alikes. On the other hand, integration of GIS databases, wind speed, position of lands to detect oil spills to the oil spill detection process could be another direction to achieve better oil spill detection result.

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