COMPARATIVE DETECTIONS OF OIL SPILL USING MULTIMODE RADARSAT-1 SYNTHETIC APERTURE RADAR SATELLITE DATA

AHMED A MEHDAWI

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Universiti Teknologi Malaysia

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To Colonel Muammar Abu Minyar Al Gaddafi

The brotherly leader of of the Socialist People's Libyan Arab Jamahiriya

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ABSTRACT

Oil spill or leakage into waterways and ocean spreads very rapidly due to the action of wind and currents. The study of the behavior and movement of these oil spills in sea had become imperative in describing a suitable management plan for mitigating the adverse impacts arising from such accidents. But the inherent difficulty of discriminating between oil spills and look-alikes is a main challenge with Synthetic Aperture Radar (SAR) satellite data and this is a drawback, which makes it difficult to develop a fully automated algorithm for detection of oil spill. As such, an automatic algorithm with a reliable confidence estimator of oil spill would be highly desirable. The main objective of this work is to develop comparative automatic detection procedures for oil spill pixels in multimode (Standard beam S2, Wide beam W1 and fine beam F1) RADARSAT-1 SAR satellite data that were acquired in the Malacca Straits using three algorithms namely, textures using co-occurrence matrix, post supervised classification, and neural network (NN) for oil spill detection with window size 7 x 7. The results show that the mean textures from co-occurrence matrix is the best indicator for oil spill detection as it can discriminate oil spill from its surrounding such as look-alikes, sea surface and land. The entropy and contrast textures can be mainly used for look-like detections. The receiver operator characteristic (ROC) was used to determine the accuracy of oil spill detection from RADARSAT-1 SAR data. The results show that oil spills, look-alikes, and sea surface roughness are perfectly discriminated with an area difference of 20% for oil spill, 35% look–alikes, 15% land and 30% for the sea roughness. The NN shows higher performance in automatic detection of oil spill in RADARSAT-1 SAR data as compared to other algorithms with standard deviation of 0.12. It can therefore be concluded that NN algorithm is an appropriate algorithm for oil spill automatic detection and W1 beam mode is appropriate for oil spill and look-alikes discrimination and detection.

ABSTRAK

Tumpahan atau kebocoran minyak di saluran air dan lautan kebiasaanya merebak dengan cepat disebabkan oleh tindakan angin dan arus. Kajian tentang perilaku dan pergerakan tumpahan minyak adalah penting untuk mengurangkan kesan negatif kemalangan tumpahan minyak melalui rancangan pengurusan yang sesuai. Namun, kesulitan dalam membezakan antara tumpahan minyak dan tampak kesamaan sering menjadi cabaran dan kekurangan apabila berurusan dengan data Radar Bukaan Sintetik (SAR), ia menyukarkan pembinaan pengesanan tumpahan minyak secara automatik. Algoritma pengesanan tumpahan minyak secara automatik yang dilengkapkan dengan tahap keyakinan anggaran yang tinggi amat diperlukan. Tujuan utama kajian adalah untuk membina prosedur pengesanan automatik piksel tumpahan minyak dalam pelbagai mod (alur piawai *S2,* alur lebar *W1* dan alur halusF1) data satelit RADARSAT-1 dengan menggunakan tiga algoritma pengesanan tumpahan minyak iaitu tekstur mengunakan matrik saling keberulangan, pasca pengkelasan berpenyelia dan jaringan neural (NN) bagi kawasan Selat Melaka dengan saiz tetingkap 7x7. Keputusan kajian menunjukkan tekstur menggunakan purata dari matrik saling keberulangan adalah penunjuk yang paling bagus untuk pengesanan tumpahan minyak kerana ia dapat membezakan tumpahan minyak daripada tampak kesamaan, permukaan laut dan darat. Tekstur entropi dan kontra adalah sesuai untuk pengesanan tampak kesamaan. Ciri penerimaan operator (ROC) digunakan untuk menentukan ketepatan pengesanan tumpahan minyak untuk data satelit RADARSAT-1. Keputusan kajian juga menunjukkan bahawa tumpahan minyak, tampak kesamaan dan kekasaran permukaan laut dapat dibezakan 20% untuk tumpahan minyak, 35% untuk tampak kesamaan, 15% untuk darat dan 30% untuk kekasaran permukaan laut. NN menunjukkan prestasi yang lebih baik dengan sisihan piawai 0.12 untuk pengesanan tumpahan minyak secara automatik. Pada kesimpulannya, NN adalah satu algoritma yang sesuai untuk pengesanan tumpahan minyak secara automatik dan mod W1 adalah paling sesuai untuk membezakan dan mengesan tumpahan minyak serta tampak kesamaan.

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LIST OF ABBREVIATIONS

AVHRR	-	Advanced Very High Resolution Radiometer
HH	-	Refers to horizontally transmitted
VV	-	Refers to vertically transmitted
MODIS	-	Moderate- Resolution Imaging Spectro radiometer
ANN	-	Artificial Neural Network
SSA	-	Static Security Assessment
NN	-	Neural Network
MLP	-	Multilayered Perception
SOM	-	Self Organizing Map
NASA	-	The National Aeronautics and Space Administration
NOAA	-	National Ocean and Atmospheric Administration
MWR	-	Microwave Radiometer
OSTM	-	Ocean Surface Topography Mission
SAR	-	Synthetic Aperture Radar
SLAR	-	Side-Looking Airborne Radar
SeaWiFS	-	Sea-viewing Wide Field-of-view Sensor

ERS	-	European Remote Sensing Satellite
HMC	-	Hidden Markov Chain
NRCS	-	Normalized Radar Cross Section
APC	-	Antenna Pattern Correction
SNR	-	Single to Noise Ratio
GLDM	-	Grey Level Dependency Matrix
GLDV	-	Grey Level Difference Vector
Ref	-	Reference Pixel
Nbr	-	Neighbor Pixel
HOM	-	Homogeneity
CON	-	Contrast
Dis	-	Dissimilarity
Ent	-	Entropy
ASM	-	Angular Second Moment
Cor	-	Correlation
BP	-	Back-propagation
SSA	-	Static Security Assessment
ANFIS	-	Adaptive Neuro-Fuzzy Inference System
IEEE	-	Institute of Electrical and Electronic Engineering
IR		Infrared radiation
UV		Ultraviolet radiation

LIST OF SYMBOLS

C	-	Velocity of light
f	-	Frequency
λ	-	Wavelength
Θ	-	Incident angle
$\sigma°$	-	The backscatter coefficient
dB	-	Decibel unit of measurement frequency
λ_B	-	Wavelength of the ocean wave
λ_r	-	SAR wavelength
δ_{Ocean}	-	reflection of the signal occurs over the ocean
SCN	-	Scan SAR Narrow
WSM	-	Wide Swath Mode
SCW	-	Scan SAR Wide
μ	-	Mean
Σ	-	Standard deviation
LoG	-	Laplace of Gaussian
DoG	-	Difference of Gaussian
D	-	The fractal dimension

C-OCC	-	Co-occurrence matrix
M1	-	Class 1
M2	-	Class 2
w_{jk}	-	The weight connected between node j^{th} and k^{th}
θ_j	-	The bias of node j^{th}
θ_k	-	The bias of node k^{th}
$_j$, i,k	-	Nodes at input, hidden and output layers(nodes)
O_j	-	The output of node j^{th}
O_i	-	The output of node i^{th}
O_k	-	The output of node k^{th}
w_{ij}	-	The weight connected between node i^{th} and j^{th}
w_{jk}	-	The weight connected between node j^{th} and k^{th}
θ_j	-	The bias of node j^{th}
θ_k	-	The bias of node k^{th}
d_{ij}	-	The j^{th} desired output for the i^{th} training pattern
y_{ij}	-	The corresponding actual output
$x_i^{(2)}$	-	The input of neuron i^{th} in Layer2
$y_i^{(2)}$	-	The output of neuron i^{th} in Layer2

a_i, b_i and c_i	-	Parameters that control, respectively, the centre, width and slope of the bell activation function of neuron i^{th}.

CHAPTER 1

INTRODUCTION

1.1 Background

Oil spill pollution has a substantial role in damaging marine ecosystem. Oil spill that floats on top of water, as well as decreasing the fauna populations, affects the food chain in the marine ecosystem (Dunnet et al., 1982). In fact, oil spill is reducing the sunlight penetrates the water, limiting the photosynthesis of marine plants and phytoplankton. Moreover, marine mammals for instance, disclosed to oil spills their insulating capacities are reducing, and so making them more vulnerable to temperature variations and much less buoyant in the seawater. Dunnet et al. (1982) stated that oil coats the fur of sea otters and seals, reducing its insulation abilities and leading to body temperature fluctuations where the body temperature is much lower than normal (hypothermia). Ingestion of the oil causes dehydration and impaired digestions (Fingas, 2001 and Zeynalova et al., 2009).

Oil spill pollution causes political and scientific concerns because they have serious effects on feeble maritime and coastal ecologies. Significant parameters in evaluating seawater quality are the amounts of pollutant discharges and associated effects on the marine environment (Topouzelis, 2008). There are many sources of oil pollution and spillage, which may be as a result of exploitation, extraction, transportation, and/or disposal activities. In the case oil pollution occurrence in marine environment, the first undertaken task is determination of priorities for protection against pollution (Shattri and Pourvakhshouri, 2003). According to Roslinah and Shattri (2000); Fingas (2001), more than 75 % of sea pollution is manmade (Roslinah and Shattri, 2000; Fingas, 2001; Brekke and Solberg, 2005). Each year, around 48 % of oil pollution in the oceans is from fuels, 29 % is from crude oil, while tanker accidents contribute only 5 % (Zeynalova et al., 2009).

Remote sensing technology is a valuable source of environmental marine pollution detection and surveying that improves oil spill detection by various approaches. The different tools to detect and observe oil spills are vessels, airplanes, and satellites (Brekke and Solberg, 2005). Vessels can detect oil spills at sea, covering restricted areas, say for example, (2500 m x 2500 m), when they are equipped with navigation radars. On the other hand, airplanes and satellites are the main tools that are used to record sea-based oil pollution (Topouzelis, 2008).

Recently, scientists and researchers have reported the fluorescent Lidar as a promising technique for oil spill detection, because of its high capability to perform actively and can positively distinguish oil from biological substances and surrounding sea environment. According to Holt (2004), most organic multi-party compounds have individuality of the fluorescence production spectrum. Hence, fluorescence emission is a strong indication of the presence of oil. On the other hand, most huge systems installed on large airplanes are seldom use as tool for oil pollution cleanup (Hengsterman and Reuter, 1990; Balick et al., 1997; Brown et al., 2000).

Further Brekke and Solberg, (2005) reported that the most applicable space-borne sensor for oil spill detection is synthetic-aperture radar (SAR). SAR sensors perform in all-weather conditions and provide all-day detection coverage. Again, SAR satellite data can penetrate the cloud covers because of its independence on sun radiation (Trivero et al., 2001), and also can operate at wind speeds of up to 12–14 m/s depending on oil type and age. Sensors operating in wide strip modes with a resolution of 50–150 m are found to be satisfactory and efficient in covering large ocean areas (Topouzelis et al., 2008).

Most scientists have shown great interest in the huge maritime environmental damage due to oil slicks, which have increase pollution effects greatly. Space-borne RADARSAT-1 SAR images are used to monitor and control oil slicks, however, the main challenges lies in the difficulties inherent in discriminating between oil spills and look–alikes. According to Maged and Hashim (2005) both appears as a dark spot in SAR data. Also according to Alpers and Hühnerfuss (1988); Trivero et al., (1998), the existence of an oil layer on the sea surface damps the small waves which increase the thickness of the top film and this significantly decreases the measured backscattering energy resulting in darker areas in SAR imagery. The European remote sensing satellite (ERS) task is an example of SAR.

However, Frate et al., (2000), argued that careful analysis is required since the dark areas might also be generated by local low winds or by normal sea slicks. Researchers such as Solberg et al., (1999); Brekke and Solberg, (2005); Topouzelis, (2008), agreed that well tuned classification algorithms can be employed to avoid false alarms. Oil spills show a larger discontinuity effect on the environment, mainly because of its thickness. A possible procedure could be formulated based on the selection of an area in an image containing dark pixels; computation of physical and geometrical features characterizing an object; classification of the object into oil spill or look-alike, based on the dark spot texture (Brekke and Solberg, 2005;Topouzelis et al., 2008).

1.2 Significance of the Study

Standard procedures are required for oil spill detection from multi SAR data to ensure the coastal zone clean up. These procedures can be of benefit to international oil companies like Brega Marketing Company in Libya (Middle East) and Petronas (Malaysia). Rapid information on pollutant substances that exist on the sea is necessary for coastal management to avoid damage to marine ecosystem. In addition, the improvement of coastal tourism requires the involvement of many parties such as local inhabitants, policy makers, and the scientific community (Siry, 2007). Policy makers play an important role by issuing regulations and policies that guide the design of sites for tourist and support facilities like hotels and recreational areas. In designing such sites, designers need accurate information which could be supplied by microwave radar data (Assilzadeh and Shattri, 2001). According to Marghany (2004), policy makers are required to make the decision more comprehensible by involving scientists.

Furthermore, the role played by the scientific community becomes more crucial due to its potential in contributing to logical ideas through research and developmental activities. Environmentalists and Engineers, as part of the scientific communities are responsible for finding new applications that could improve the quality of human life within coastal areas that are prone to pollutions from oil spills, industrial and household wastes problems encountered by many different countries, including Malaysia, which causes great damages along these coastal zones. In this context, these problems can influence the tourist sector, as it is one of the main sources of income (Carlo et al., 2008).

As humans are one of the agents causing environmental problems, more concerns need to be focused on human activities. Mohamed et al., (2006) stated that the destruction of an island’s ecological environment could also be as a result of unregulated development of extensive infrastructure such as jetties, resorts, and airports. The Malaysian authorities are required to embark on educating inhabitants of the coastal area by providing them with enabling regulations that may enhance clean environmental policies that could promote tourism, since tourism is one of the main sources of Malaysian income (Mohamed et al., 1999; Assilzadeh and Shattri, 2001; Hashim et al., 2006).

1.3 Research Objectives

The main objective of this work is to develop comparative detection procedure of oil spills using multimode RADARSAT-1 SAR satellite data. This objective is divided into the following sub-objectives:

i. To examine various algorithms such as co-occurrence texture, Mahalanobis classifier, and artificial intelligence techniques for oil spill automatic detection in multimode RADRASAT-1 SAR data.

ii. To determine an appropriate algorithm for oil spill automatic detection in multimode RADRASAT-1 SAR data that is based on algorithm's accuracy (Solberg et al., 1999).

iii. To develop detection techniques for oil spill based on pixel classifier tools (Neural Network, Mahalanobis Distance, and Texture Algorithm).

iv. To determine the detectability of Radarsat-1 SAR scale image (mode) for oil spill detection from surroundings pixel.

1.4 Problem Statement

Oil spill or leakage into waterways and ocean spreads very rapidly due to the action of wind and currents. There is really no part of a marine and coastal environment that is not in some way greatly affected by an oil spill incidence. The closer this spill occurs to the shoreline, the more devastated the damage will be because of the fact that coastal zones are home to a great number of diverse populations of marine, bird and animal life than far into the sea. It is worthy of note that a single gallon of oil can create an oil slick up quite a number of acres in size. The study of the behavior and movement of these oil spills in sea had become imperative in describing a suitable management plan for mitigating the adverse impacts arising from such accidents. But the inherent difficulty of discriminating between oil spills and look-alikes is a main challenge with SAR satellite data and this is a drawback, which makes it difficult to develop a fully automated detection of oil spill. As such, an automatic algorithm with a reliable confidence estimator of oil spill would be highly desirable. The needs for automatic algorithms rely mostly on the number of images to be analyzed, but, for monitoring large ocean areas, it is a cost-effective alternative when compared to manual inspection. Automatic detection algorithms of oil spill are normally divided into three steps: dark spot detection; dark spot feature extraction; and dark spot classification (Brekke and Solberg, 2005; Topouzelis, 2008; Marghany et al., 2009a).

One of the main problems faced in combating and managing oil slick is in forecasting the behavior (i.e. movement and spreading) of oil slicks. Generally, the main idea of predicting the behavior of oil slicks is to determine the time-evolving shape of the slick under different weather patterns in water, where currents exist (Marghany et al., 2009a). Wind direction and speed are the most important climate parameters that can impact the oil spill imagery in SAR data. Models for oil slick behavior are important in environmental engineering and are used as a decision support tool in environmental emergency responses. These models are used to help ships avoid oil slicks (Adam, 1995). Although great progress had been made in detecting and surveying oil slicks, a general model for oil slick movement and spreading has not yet been devised (Marghany et al., 2009a). They also reported that past progresses in modeling the extent of oil in the ocean are not always tested against authentic spills neither does the models are regularly developed with real databases, but rely instead on theoretical scenarios.

According to Verma et al., (2008), some spill-threat scenarios have not been based on real oil movement data at all yet there are frequent demands to provide just such models with credible precision. Consequently, it is important to study the behavior and movement of spilled oil in the sea in order to describe a suitable management plan for mitigating adverse impacts arising from such accidents. Simulation of oil spills using mathematical models form an important basis for subsequent studies collectively, with the information on position of weak resources in time and space (Reed et al., 2004). The simulation outcome may develop a basis for evaluating the damage potential from an eventual oil spills. This may help the regulatory authorities to take direct preventive measures (Marghany, 2004).

In addition, most of the studies that have been conducted in the coastal waters of Malaysia using single radar image, which is inadequate to ensure accurate detection of oil spills. Some of the work involved the implementation of non-appropriate techniques for oil spill automatic detection. For instance, Mohamed et al., (2006) have used data fusion techniques in a single RADARSAT-1 SAR image, with different co-occurrence texture algorithms. However, the data fusion techniques apply to two or more different sensors for example, ERS-1 and LANDSAT. According to Solberg and Solberg (1996), using principal component analysis (PCA) analysis is not considered an appropriate method for data fusion. Data fusion technique involves several methods such as high pass filtering technique, IHS intensity–hue–saturation transformation method, Brovey method, and à Trous wavelet method (Brekke and Solberg, 2005).

1.5 Research Questions

In line with exploring the different issues and aspects of this research study, the following research questions are presented. These questions were answered in the process of the research methodology:

i. How can we discriminate between oil spills and look-alikes?

ii. Are the achieved SAR algorithms used in oil spill detection applied to real situations?

iii. Is the oil spill detection on the Malaysian coast using single SAR data per day adequate?

1.6 Research Scopes

In order to achieve the research objectives, the scope of the study is focused on the following aspects:

i. Examining Multimode-SAR data of for oil spill detection.

ii. Comparing the results of different algorithms namely- the co-occurrence texture, Mahalanobis classifier, and artificial intelligence techniques, to determine among the three the appropriate detection algorithm for oil spill.

iii. Using Back Propagation Algorithm an Artificial Intelligence technique as a classification tool for oil spill detection.

1.7 Contributions of the Research

The contributions of the research are as follows:

(i) The study utilizes multimode RADRASAT-1 SAR data and compare them with previous studies conducted by Mohamed et al., (1999); Roslinah and Shattri (2000); Assilzadeh and Shattri (2001); Marghany (2001); Marghany and Hashim (2005).

(ii) To develop an automatic detection tool based on Artificial Neural Network (ANN), previous studies according to Mohamed et al., (1999); Assilzadeh and Shattri, (2001); Roslinah and Shattri, (2001); Mohamed, (2006), imposed semi automatic tools for single SAR data.

References

Adam, J.A. (1995). Specialties: Solar Wings, Oil Spill Avoidance, *On-Line Patterns. IEEE, Spectrum,* 32, 87-95.

Aggoune, M.E., Atlas, L.E., Cohn, D.A., El-Sharkawi, M.A and Marks, R. J. (1989). Artificial Neural Networks for Power System Static Security Assessment.IEEE International Symposium on Circuits and Systems, Portland, Oregon, May 9 -11, 1989, pp. 490-494

Aiazzi, B., Alparone, L., Baronti, S. and Garzelli, A. (2001). Multiresolution Estimation of Fractal Dimension from Noisy Images. *SPIE-IS&T Journal of Electronic Imaging*. 10, 339-348.

Alpers, W. and Hühnerfuss, H. (1988). Radar Signatures of Oil Films Floating on the Sea Surface and the Marangoni Effect. *J. Geophys. Res.* 93, 3642-648.

Anne, S. (2002). World Oil Pollution: Causes, Prevention and Clean Up. http://oceanlink.island.net/oceanmatters/oil%20pollution.

Anys, H., Bannari, A., He, D.C. and Morin, D. (1994). Texture Analysis for the Mapping of Urban Areas using Airborne MEIS-II Images. Proceedings of the First International Airborne Remote Sensing Conference and Exhibition, Strasbourg, France, Vol. 3, Pp. 231-245.

Arivazhagan, S., Ganesan, L. and Subash, K. (2006). Texture Classification using Curvelet Statistical and Co-occurrence Features [C]. In: *Proceedings of the* 18*th International Conference on Pattern Recognition*. Hong Kong, China, *2006.938-941*.

.Assilzadeh, H. and Mansor, S. B. (2001). Early Warning System for Oil Spill Using SAR Images. Proc. ACRS 2001—22nd Asian Conference on Remote Sensing, 5–9 November 2001, Singapore. 1, 460-465.

Australian Communications Authority, (2008). http://www.ic.gc.ca/eic/site.

Balick, L., Dibenedetto, J.A. and Lutz, S.S. (1997). Fluorescence Emission Spectral Measurements for the Detection of Oil on Shore. Environmental Research Institute of Michigan, *Ann Arbor, Michigan, Vol. I, pp. 13- 20.*

Baltzer, H. (2001). Forest Mapping and Monitoring with Interferometric Synthetic Aperture Radar (InSAR). *Progress in Physical Geography.* 25(2), 159 -177.

Barni, M., Betti, M. and Mecocci, A. (1995). A Fuzzy Approach to Oil Spill Detection on SAR Images. *Proc. IGARSS '95*. 1, 157– 159.

Benelli, G. and Garzelli, A. (1999a). A Multi-Resolution Approach to Oil-Spills Detection in ERS-1 SAR Images. *Image and Signal Processing for Remote Sensing*. 4, 145-156.

Benelli, G. and Garzelli, A. (1999b). Oil-Spill Detection in SAR Images by Fractal Dimension Estimation. In: Proceedings of Geoscience and Remote Sensing Symposium, 1999, IGARSS'99. Hamburg, Germany, 28 June–2 July 1999. IEEE Geoscience and Remote Sensing Society, USA. 2, 1123-1126.

Bern, T., Moen, S., Wahl, T., Anderssen, T., Olsen, R. and Johannessen, J. A. (1992). Oil Spill Detection Using Satellite Based SAR. Completion Report for Phase 0 and 1. Tech. Rep., OCEANOR Report No. *OCNR92071, Trondheim.*

Brekke, C. and Solberg, A. (2005). Oil Spill Detection by Satellite Remote Sensing. *Remote Sensing of Environment*. Elsevier Inc. 95, 1-13.

Brown, C.E., M.F. Fingas, R.H., Goodman, J.V., Mullin, M.C. and Monchalin, J-P. (2000). Airborne Oil Slick Thickness Measurement in *Proceedings of the Fifth InternationalConference on Remote Sensing for Marine and Coastal Environments.* Environmental Research Institute of Michigan, Ann Arbor, Michigan, Pp. I219-224.

Canada Centre for Remote Sensing, Natural Resources Canada. (2010). http://www.ccrs.nrcan.gc.ca/resource/index_e.phpv

Canny, J. (1986). A Computational Approach to Edge Detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence, PAMI*. 8(6), 679- 698.

Carletta, J. (1996). Assessing Agreement on Classification Taks: the Kappa Statistic, Computational Linguistics, V. 22(2), Pp. 249-254.

Carlo, B., Johanna, B., Wesnigk, W., Michael, U., Susanne, A. and Ulrich, C. (2008). Oil Pollution in Marine Ecosystems – Policy, Fate, Effects and Response. GKSS, Max-Planck-Straße 1, 21502 Geesthacht.

Change, L.Y., Chen, K., Chen, C. and Chen, A. (1996). A Multi -Resolution Approach to Detection of Oil Slicks using ERS SAR Image. Proc. ACRS 1996—17th Asian Conference of Remote Sensing, Sri Lanka.

Chen, C. F., Chen, K. S., Chang, L. Y. and Chen, A. J. (1997). The Use of Satellite Imagery for Monitoring Coastal Environment in Taiwan. *Proc. IGARSS'97*. l(3), 1424-1426.

Congalton, R. G. (1991). A Review of Assessing the Accuracy of Classifications of Remotely Sensed Data, Remote Sensing Environment, *V*.37, Pp. 35-46.

Dokken, S. T. (1995). Optimal Bruk Av Avanserte Radarsatellitter. Master's Thesis, Institutt for Tekniske Fag, Norges Landbrukshbgskole.

Dunnet, G., Crisp, D., Conan, G. and Bourne, W. (1982). Oil Pollution and Seabird Populations. Philosophical Transactions of the Royal Society of London. *B 297(1087): 413–427.*

Espedal, H. (1999). Detection of Oil Spill and Natural Film in the Marine Environment by Spaceborne SAR. *Proc. IGARSS'99*. 3, 1478-1480.

Espedal, H. A. and Johannessen, O. M. (2000). Detection of Oil Spills near Offshore Installations using Synthetic Aperture Radar (SAR). *International Journal of Remote Sensing*. 21(11), 2141–2144.

Espedal, H.A. (1998). Detection of Oil Spill and Natural Film in the Marine Environment by Spaceborne Synthetic Aperture Radar. Ph.D. Thesis. Department of Physics, University of Bergen and Nansen Environment and Remote Sensing Center, Norway.

Falconer, K. (1990). *Fractal Geometry*. New York: John Wiley & Sons.

Fingas, M. (2001). *The basics of oil spill cleanup.* Lewis Publishers.

Fingas, M. F. and Brown, C. E. (1997). Review of Oil Spill Remote Sensing. Spill Science and Technology Bulletin, 4, 199– 208.

Fiscella, B., Giancaspro, A., Nirchio, F., Pavese, P. and Trivero, P. (2000). Oil Spill Detection using Marine SAR Images. *International Journal of Remote Sensing*. 21(18), 3561–3566.

Fortuny-Guasch, J. (2003). Improved Oil Spill Detection and Classification with Polarimetric SAR. Proc. Workshop on Application of SAR Polarimery and Polarimetric Interferometry, ESA-ESRIN Frascati, Italy, January 14–16 2004, available at http://earth.esa.int/polinsar/ pr.html, accessed 1 September 2004.

Frate, F. D., Petrocchi, A., Lichtenegger, J. and Calabresi, G. (2000). Neural Networks for Oil Spill Detection using ERS-SAR data. *IEEE Transactions on Geoscience and Remote Sensing*. 38(5), 2282– 2287.

Friedman, K. S., Pichel, W. G., Clemente-Colo´n, P. and Li, X. (2002). GoMEx—an Experimental GIS System for the Gulf of Mexico Region using SAR and Additional Satellite and Ancillary Data. *Proc. IGARSS'02*. 6. 3343– 3346.

Gade, M. and Redondo, J. (1999). Marine Pollution in European Coastal Waters Monitored by the ERS-2 SAR: a Comprehensive Statistical Analysis. OCEANS ’99 MTS/IEEERiding the Crest into the 21st century. 3, 1239– 1243.

Gade, M., Alpers, W. and Bao, M. (1996). Measurements of the Radar Backscattering over Different Oceanic Surface Films during the SIR-C/XSAR Campaigns. *Proc. IGARSS’96*. 860–862.

Gade, M., Scholz, J. and von Viebahn, C. (2000). On the Detectability of Marine Oil Pollution in European Marginal Waters byMeans of ERS SAR Imagery. *Proc. IGARSS 2000*. 6, 2510– 2512.

Gasull, A., Fabregas, X., Jimenez, J., Marques, F., Moreno, V. and Herrero, M. (2002). Oil Spills Detection in SAR Images using Mathematical Morphology. Proc. EUSIPCO’2002, Toulouse, France. 1, 25–28.

Girard-Ardhuin, F., Mercier, G. and Garello, R. (2003). Oil Slick Detection by SAR Imagery: Potential and Limitation. Proc. OCEANS 2003. 1, 164–169.

Grüner, K.; Reuter, R.; Smid, H. (1991**).** A New Sensor System for Airborne Measurements of Maritime Pollution and of Hydrographic Parameters. *Geojournal, 24.1* 103-117.

Hamzah A. (1988). *Malaysia’s Exclusive Economic Zone: A Study in Legal Aspects*, Pelanduk Publications, Petaling Jaya, Pp. 100.

Haralick, R.M. (1979). Statistical and Structural Approaches to Texture. Proc. IEEE 67 (5), 786-804.

Hashim, M., Ibrahim, A.L. and Ahmad, S. (2006). Mapping and Identifying Oil Spill Occurrences in Malaysian Water (Straits of Malacca and South China Sea) using 2000–2005 Archived Radarsat-1 SAR. In: Evaluation Report. Department of Remote Sensing, Universiti Teknologi Malaysia, Skudai, Malaysia, Pp.20, Unpublished.

Hect-Nielsen, R. (1989). Theory of the Back Propagation Neural Network. Proceeding of the International Joint Conference on Neural Network June 1989, NewYork: IEEE Press, vol. I , 593 611.

Henderson, F. M. And Lewis, A. J. (1998). *Principles and Application of Imaging Radar*.Volume1. New York: John Wiley & Sons Inc.

Hengstermann, T. and Reuter, R. (1990). Lidar Fluorosensing of Mineral Oil Spills on the Sea Surface, *Applied Optics*, *Vol. 29*, Pp. 3218-3227.

Hodgins, D.O., Goodman, R.H. and Fingas, M.F. (1994). Remote Sensing of Surface Currats in the Fraser River Plume with the SeaSonde HF Radar. Proceedings of the 17th Arctic and Marine Oilspill Program (AMOP) Technical Seminar, Vancouver, Canada, 1994.

Holt, B. (2004). SAR Imaging of the Ocean Surface. In Jackson, C. R. and Apel, J. R. (Eds.) Synthetic Aperture Radar Marine User's Manual, Pp. 25– 81. Washington, DC7 NOAA NESDIS Office of Research and Applications.

Hovland, H. A. and Johannessen, J. A. (1994). Norwegian Surface Slick Report, Final Report to Norwegian Defence Research Establishment and Norwegian Space Centre. Tech. Rep., Nansen Environmental and Remote Sensing Center.

Hovland, H. A., Johannessen, J.A. and Digranes, G. (1994). Slick Detection in SAR Images. Proc. IGARSS'94. 4, 2038–2040.

Hu, C., Mqller-Krager, F.E., Taylor, C. J., Myhre, D., Murch, B. and Odriozola, A.L. (2003). MODIS Detects Oil Spills in Lake Maracaibo, Venezuela. EOS, Transactions, American Geophysical Union, 84(33), 313-319.

Huang, B., Li, H. and Huang, X. (2005). A Level Set Method for Oil Slick Segmentation in SAR Images. *International Journal of Remote Sensing*. 26, 1145–1156.

Ibrahem, S. (2009). Static Security Assessment in Deregulated Power System using Artificial Intelligence. Masters Thesis Faculty of Electrical Engineering Universiti Teknologi Malaysia.

Indregard, M., Solberg, A. and Clayton, P. (2004). D2-Report on Benchmarking Oil Spill Recognition Approaches and Best Practice. Tech. Rep., Oceanides Project, European Commission, Archive No. 04-10225-A-Doc, Contract *No: EVK2-CT-2003-00177.*

Ivanov, A., He, M-X. and Fang, M-Q. (2002). Oil Spill Detection with the RADARSAT SAR in the Waters of the Yellow and East China Sea: A Case Study.

Jensen, A., Loog, M. and Solberg, A. (2010). Using Multiscale Spectra in Regularizing Covariance Matrices for Hyperspectral Image Classification. *IEEE Transactions On Geoscience and Remote Sensing, VOL. 48, NO. 4,*

Jensen, J.R. (2000). Remote Sensing of the Environment – an Earth Resource Perspective. New Jersey: Prentice Hall.

Johannessen, J., Shuchman, R., Johannessen, O., Davidson, K. and Lyzenga, D. (1991). Synthetic Aperture Radar Imaging of Upper Ocean circulation and wind fronts, *J.Geophysjcal* Res., 96, *C6, P*p. 1041 1 - 10422,1991.

Jones, B. (2001). A Comparison of Visual Observations of Surface Oil with Synthetic Aperture Radar Imagery of the Sea Empress Oil Spill. *International Journal of Remote Sensing*. 22(9), 1619– 1638.

Keller, J. M., Chen, S. and Crownover, R.M. (1989). Texture Description and Segmentation through Fractal Geometry. *Computer Vision, Graphics, and Image Processing*. 45, 150– 166.

King, R. L. (1998). Artificial Neural Networks and Computation Intelligence. *IEEE Computer Applications in Power*. 11(4), 14 - 16, 18-25.

Kingsley, S. and Quegan, S. (1992). *Understanding Radar Systems*. London: McGraw–Hill.

Kotova, L.A., Espedal, H.A. and Johannessen, O. M. (1998). Oil Spill Detection using Spaceborne SAR; a Brief Review. Proc. 27th ISRSE, Tromsb, Norway.

Kubat, M., Holte, R.C. and Matwin, S. (1998). Machine Learning for the Detection of Oil Spills in Satellite Radar Images. *Machine Learning*. 30, 195–215.

Lakide, V. **(**2009**)** Classification of Synthetic Aperture Radar Images Using Particle Swarm Optimization Technique. Master Thesis, National Institute of Technology Rourkela-769008 Pp.29.

Leber, F.W. (1990). Radargrammetric Image Processing. Artech House.

Lee, J. -S. (1981). Speckle Analysis and Smoothing of Synthetic Aperture Radar Images. *Computer Graphics and Image Processing*. 17, 24– 32.

Leopold, J. and Cantafio, (1989). *Space-based Radar Handbook*, Norwood, MA: Artech House.

Litovchenko, K., Ivanov, A. and Ermakov, S. (1999). Detection of Oil Slicks Parameters from ALMAZ-1 and ERS-1 SAR imagery. Proc. IGARSS'99. 3, 1484–1486.

Liu, A.K., Peng, C.Y. and Chang, S. Y-S. (1997). Wavelet Analysis of Satellite Images for Coastal Watch. *IEEE Journal of Oceanic Engineering*. 22(1), 9– 17.

Liu, J. (2003). Marine Oil Spill Detection, Statistics and Mapping with ERS SAR Imagery in South-East Asia. *International Journal of Remote Sensing*, 24(15), 3013–3032.

Lu, J., Lim, H., Liew, S. C., Bao, M. and Kwoh, L.K. (1999). Ocean Oil Pollution Mapping with ERS Synthetic Aperture Radar Imagery. *Proc. IGARSS'99*. 1, 212–214.

Maged, M. and Mazlan, H. (2005). Simulation of Oil Slick Trajectory Movements from the RADARSAT-1 SAR. *Asian Journal of Geoinformatics*. 5, 17–27.

Maged, M., and van Genderen, J. (2001). Texture Algorithms for Oil Pollution Detection and Tidal Current Effects on Oil Spill Spreading. *Asian Journal of Geoinformatics*. 1, 33–44.

Maio, A.D., Ricci, G. and Tesauro, M. (2001). On CFAR Detection of Oil Slicks on the Ocean Surface by Multifrequency and/or Multipolarization SAR. In Radar Conference, 2001. Proceedings of the 2001 IEEE, Pp. 351– 356.

Manjunath, B.S. and Ma, W.Y. (1996). Texture features for browsing and retrieval of image data, *IEEE Trans. Pattern Anal. Machine Intell.*, Vol. 18, Pp. 837–842.

Manore, M. J., Vachon, P.W., Bjerkelund, C., Edel, H.R. and Ramsay, B. (1998). Operational use of RADARSAT SAR in the Coastal Zone: The Canadian Experience. 27th International Symposium on Remote Sensing of the Environment, Tromsø, Norway, June 8–12. pp. 115– 118.

Marghany, M. (2001). RADARSAT Automatic Algorithms for Detecting Coastal Oil Spill Pollution. *International Journal of Applied Earth Observation and Geoinformation*. 3, 191–196.

Marghany, M. (2004). RADARSAT for Oil Spill Trajectory Model. Environmental Modelling & Software 19 (2004) 473–483.

Marghany, M., Cracknell, A. and Hashim, M. (2009a). Modification of Fractal Algorithm for Oil Spill Detection from RADARSAT-1 SAR Data. International Journal of Applied Earth Observation and Geoinformation.Vol 11, pp.96-102.

Marghany, M., Cracknell, A. and Hashim, M. (2009b). Comparison between Radarsat-1 SAR Different Data Modes for Oil Spill Detection by a Fractal Box Counting Algorithm. International Journal of Digital Earth. Vol. (2) (3), pp. 237-256.

Marghany, M., Hashim, M. and Cracknell, A.P. (2007). Fractal Dimension Algorithm for Detecting Oil Spills using RADARSAT-1 SAR. O. Gervasi and M. Gavrilova (Eds.): ICCSA, Part I. 1054–1062. Springer-Verlag Berlin Heidelberg.

Marghany, M.M. (1994). Coastal Water Circulation Off Kuala Terengganu. M.Sc. Thesis, Universiti Pertanian Malaysia

Measurements Using Wavelets. *IEEE Transactions Signal Processing*. 40, 611– 623.

Mercier, G., Derrode, S., Pieczynski, W., Caillec, J-M. L. and Garello, R. (2003). Multiscale Oil Slick Segmentation with Markov Chain Model. *Proc. IGARSS’03*. 6, 3501– 3503.

Metz, C. (1978). Basic principles of ROC Analysis. *Seminars in Nuclear Medicine*, 3(4).

Michael, N. (2005). Artificial Intelligence: A Guide to Intelligent Systems. 2nd editon, Harlow, England: Addison Wesley.

Migliaccio M., Gambardella A. and Tranfaglia M. (2007). SAR Polarimetry to observe Oil Spills. IEEE Transaction on Geoscience and Remote Sensing, 45,2, 506-511.

Mohamed, B., Mat, S.A.P., Jamil, J. and Yew, W.K. (2006). Island Tourism in Malaysia: The Not So Good News**.**

Mohamed, I.S., Salleh, A.M. and Tze, L.C. (1999). Detection of Oil Spills in Malaysian Waters from RADARSAT Synthetic Aperture Radar Data and Prediction of Oil Spill Movement. In: Proceeding of 19th Asian Conference on Remote Sensing. Hong Kong, China, 23–27 November. Asian Remote Sensing Society, Japan, vol. 2, Pp. 980–987.

Mohamed, SM (2006). Utilization of Texture Analysis and Fusion Technique for Oil Spill Detection Using SAR Data. Thesis Master of Science (Remote Sensing), Universiti Teknologi Malaysia (UTM), Johor, Malaysia.

Napolitano, D. J., Vesecky, J. F., Gonzalez, F. and Peteherych, S. **(**1991). SAR Measurements of Ocean Waves and Other Phenomena during the OASEX *IGARSS'89*. 4, 2331-2334.

Nasser, M.S. (2004). Automated Oil Spill Detection with Ship Borne Radar. Master Thesis from International Institute for Geo-Information Science and Earth Observation Holland.

Patin, S. (2004). Crude Oil Spills, Environmental Impact of, In: Cutler J. Cleveland (Editor), *the Encyclopedia of Energy*. Elsevier Science, Oxford,Pp. 737-748.

Patin, S. and Elena C. (1999). Environmental Impact of the Offshore Oil and Gas Industry. EcoMonitor Pub, East North Port, N.Y. ISBN: 0-9671836-0-X.

Pavlakis, P., Sieber, A. and Alexandry, S. (1996). Monitoring Oil-Spill Pollution in the Mediterranean with ERS SAR ESA Earth Observation Quarterly (52).

Pentland, A.P. (1984). Fractal-Based Description of Natural Scenes. *IEEE Transactions on Pattern Analysis and Machine Intelligence, PAMI*. 6(6), 661–674.

Perez-Marrodan, M. (1998). ENVISYS—Environmental Monitoring Warning and Emergency Management System. Proc. of the AFCEA Kiev Seminar, 28–29 May, Pp. 122–132.

Perna, S. (2005). Airborne Synthetic Aperture Radar *Models, Focusing and Experiments* Anno Accademico 2004–2005. Pp. 11 Proc. ACRS 2002—23rd Asian Conference on Remote Sensing, November *25–29, 2002, Kathmandu, Nepal.*

Plant, W. J. (1990). Bragg Scattering of Electromagnetic Waves from the Air/ Sea Interface, in Surface Waves and Fluxes. vol. II, Remote Sensing, edited by G. Raney, R.K., 1998.

Provost, F. and Fawcett, T. (2001). Robust Classification for Imprecise Environments. *Machine Learning*, 42:203.231.

Raney, R.K. (1998). Radar Fundamentals: Technical Perspective. Chapter 2 in Principles and Applications of Imaging Radar, Manual of Remote Sensing, Third Edition, Volume 2, ASPRS, John Wiley and Sons Inc., Toronto.

Redondo, J.M. (1996). Fractal Description of Density Interfaces. *Journal of mathematics and its Applications*. 5, 210–218.

Reed, M., Daling, P., Lewis, A., Ditlevsen, M.K., Brors, B., Clark, J. and Aurand, D. (2004). Modeling of Dispersant Application to Oil Spills in Shallow Coastal Waters. *Environmental Modeling & Software*. 19, 681–690.

Robinson, I.S. (1994). *Satellite Oceanography : An Introduction for Oceanographers and Remote-Sensing Scientists*. Wiley–Praxis series in remote sensing.

Rosen, P., Hensley, S., Joughin, I., Li, F., Madsen, S., Rodriguez, E. and Goldstein, R. (2000). Synthetic Aperture RADAR Interferometry. *Proceedings of the IEEE,* Vol. 88, No. 3.

Roslinah, S. and Shattri, M. (2000). Detection of Oil Spill Pollution using RADARSAT SAR Imagery. Departement of Civil Engineering, Universiti Putra Malaysia, Serdang, Malaysia.

Salem, F. and Kafatos, P. M. (2001). Hyperspectral Image Analysis for Oil Spill Mitigation. Proc. ACRS 2001—22nd Asian Conference on Remote Sensing, 5–9 November 2001, Singapore, Vol. 1 Pp. 748– 753.

Salvatori, L., Bouchaib, S., Frate, F.D., Lichtenneger, J. and Samara, Y. (2003). Estimating the Wind Vector from Radar SAR Images when Applied to the Detection of Oil Spill Pollution. Fifth International Symposium on GIS and Computer Catography for Coastal Zone Management, CoastGIS'03.

Samad, R. and Mansor, S.B. (2002). Detection of Oil spill Pollution using RADARSAT SAR Imagery. *Proceedings of 23rd Asian Conference on Remote Sensing, Birendra International Convention Centre in Kathmandu, Nepal*, November 25 - 29, 2002, Asian Remote Sensing.

Shattri, M. and Pourvakhshouri, S.Z. (2003). Oil Spill Management via Decision Support System. *2nd FIG Regional Conference*. December 2-5, 2003. Marrakech, Morocco

Shaw, K.E. and Thomson G.G. (1973). *The Straits of Malacca in Relation to Problems of the Indian and Pacific Ocean*, University Education Press, Singapore, Pp. 174.

Shepherd, I. (2004). Developing an Operational Oil-Spill Service in GMES. Version 2, OCEANIDES workshop, 25 May, 2004, EEA, Copenhagen.

Shepherd, I., Bauna, T., Chesworth, J., Kourti, N., Lemoine, G. and Indregard, M. (2004). Use of ENVISAT at JRC for Marine Monitoring in 2003. JRC Technical Note.

Siry, H .Y. (2007). Decentralized Coastal Zone Management in Malaysia and Indonesia: A Comparative Perspective1. *Taylor & Francis Group.*

Skoelv, Z. and Wahl, T. (1993). Oil Spill Detection using Satellite Based SAR, Phase 1B Competition Report. Tech. Rep., Norwegian Defence Research Establishment.

Sletten, M.A. and Mc Laughlin, D.J. (1999). Radar Polarimetry 10.1002 /047134608X .W2032

Solberg, A.H.S and Volden, E. (1997). Incorporation of Prior Knowledge in Automatic Classification of Oil Spills in ERS SAR Images. *Proc. IGARSS'97*. 1, 157– 159.

Solberg, A.H.S. and Solberg, R. (1996). A Large-Scale Evaluation of Features for Automatic Detection of Oil Spills in ERS SAR Images. *Proc. IGARSS'96*. 3, 1484–1486.

Solberg, A.H.S., Dokken, S.T. and Solberg, R. (2003). Automatic Detection of Oil Spills in Envisat, Radarsat and ERS SAR Images. Proc. IGARSS'03, vol. 4 Pp. 2747–2749.

Solberg, A.H.S., Storvik, G., Solberg, R. and Volden, E. (1999). Automatic Detection of Oil Spills in ERS SAR Images. *IEEE Transactions on Geoscience and Remote Sensing*. 37(4), 1916– 1924.

Stolzenbach, K. D., Madsen, O. S., Adams, E. E., Pollack, A. M. and Cooper, C. K. (1977). A Review and Evaluation of Basic Techniques for Predicting the Behavior of Surface Oil Slicks. *Dept. of Civil Engineering. Cambridge, MA: MIT Sea Grant Program, MIT.*

Topouzelis, K., Karathanassi, V., Pavlakis, P.2 and Rokos, D. (2009). Potentiality of Feed-Forward Neural Networks for Classifying Dark Formations to Oil Spills and Look-alikes. *Geocarto International Vol.24, No. 3, June 2009, 179–191.*

Topouzelis, K.; Karathanassi, V.; Pavlakis, P. and Rokos, D. (2007). Detection and Discrimination between Oil Spills and Look-alike Phenomena through Neural Networks. *ISPRS J. Photogramm. Remote Sens.* 2007, *62*, 264-270.

Topouzelis, K.N. (2008). Oil Spill Detection by SAR Images: Dark Formation Detection, Feature Extraction and Classification Algorithms. *Sensors.* 8, 6642-6659.

Toutin, T. (1992). ROS and SEASAT Image Geometric Correction IEEE-IGARS, Vol. 30, No. 3, Pp. 603-609.

Touzi, R. (2002). A review of Speckle Filtering in the Context of Estimation Theory. IEEE Trans. On Geoscience and Remote Sensing, *40(11), pp. 2392-2404.*

Trevett, J.W. (1986). *Imaging Radar for Resource Surveys*. London-NewYork: Chapman and Hall.

Tricot, C. (1993). Curves and Fractal Dimension. Springer Verlag.

Trieschmann, O., Hunsnger, T., Tufte, L. and Barjenbruch, U. (2003). Data Assimilation of an Airborne Multiple Remote Sensor System and of Satellite Images for the North- and Baltic Sea. Proceedings of the SPIE 10th int. Symposium on Remote Sensing, Conference Remote Sensing of the Ocean and Sea ice 2003Q Pp. 51–60.

Trivero P., Fiscella B. and Pavese P. (2001). Sea surface Slicks Measured by SAR, *Nuovo Cimento,* 24 C, 99-111.

Trivero, P., Fiscella, B., Gomez, F. and Pavese, P. (1998). SAR Detection and Characterization of Sea Surface Slicks. *Int. J. Remote Sensing*. 19, 543–548.

Tseng, W.Y., and Chiu, L.S. (1994). AVHRR Observations of Persian Gulf Oil Spills. *Proc. IGARSS'94*. 2, 779– 782.

Vachon, P.W., Thomas, S.J., Cranton, J.A., Bjerkelund, C., Dobson, F.W. and Olsen, R.B. (1998). Monitoring the Coastal Zone with the RADARSAT Satellite. Oceanology International 98, UK, March 10–13, Pp.10-12.

Van Zyl, J. (2010). Radar and Synthetic Aperture Radar Basics. Jet Propulsion Laboratory California Institute of Technology 4800 Oak Grove Drive Pasadena, Ca 91109.

Verma, P., Wate, S. and Devotta, S. (2008). Simulation of Impact of Oil Spill in the Ocean– a Case Study of Arabian Gulf Environ Monit. Assess 146, Pp.191–201.

Wahl, T., Anderssen, T. and Skbelv, Z. (1994a). Oil Spill Detection using Satellite Based SAR, Pilot Operation Phase, final report. Tech. rep. Norwegian Defense Research Establishment.

Wahl, T., Skbelv, Z. and Andersen, J.H.S. (1994b). Practical Use of ERS-1 SAR Images in Pollution Monitoring. *Proc. IGARSS'94*. 4, 1954– 1956.

Waring, R.H., Way, J., Hunt, E., Morrissey, R.L., Ranson, K.J., Weishampel, J.F., Oren, R. and Franklin, S.E. (1995). Imaging Radar for Ecosystem Studies. *BioScience*. 45(10), 715-723.

Wikipedia (2009). *Image Fusion*. Retrieved on April 16, 2009 from: http://en.wikipedia.org/wiki/Image_fusion.

Wornell, G.W. and Oppenheim, A. (1992). Estimation of Fractal Signals from Noisy

Wu, S.Y. and Liu, A.K. (2003). Towards an Automated Ocean Feature Detection, Extraction and Classification Scheme for SAR Imagery. *International Journal of Remote Sensing*. 24(5), 935–951.

Zeynalova, M., Rustamov, R . and Salahova, S. (2009) . Advanced Space Technology for Oil Spill Detection . *DOI 10.1007/978-1-4020-9573-3 5, Springer Science+Business Media B.V*. 2009.

Zhifu, S., Kai, Z., Baojiang, L. and Futao, L. (2002). Oil-Spill Monitoring using Microwave Radiometer. *Proc. IGARSS'02*. 5, 2980– 2982.

Zou, K.H., O'Malley, A.J., Mauri, L. (2007). Receiver-Operating Characteristic Analysis for Evaluating Diagnostic Tests and Predictive Models. *Circulation*, 6;115(5):654–7.