



UNIVERSITI PUTRA MALAYSIA

**JANAM
OIL SPILL DETECTION AND CONTINGENCY PLANNING
USING RADAR IMAGERY AND GIS**

HAMID ASSILZADEH

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OIL SPILL DETECTION AND CONTINGENCY PLANNING
USING RADAR IMAGERY AND GIS**

By

HAMID ASSILZADEH

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirement for the Degree of Doctor of Philosophy**

April 2002



DEDICATION

To my dear family, my parents, brothers and sisters who have been my source of inspiration, wisdom and strength through the most difficult times of my life. I dedicate also this thesis to my lovely country mates who are the symbol of resistance.



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment
of the requirement for the degree of Doctor of Philosophy

**OIL SPILL DETECTION AND CONTINGENCY PLANNING
USING RADAR IMAGERY AND GIS**

By

HAMID ASSILZADEH

March 2002

Chairman: Associate Professor Shattri Bin Mansor, Ph.D.

Faculty: Engineering

Shipping casualties often resulted in serious accidental spills as experienced in the Straits of Malacca in the past decade. Operational remote sensing and geographic information system (GIS) are important tools for oil spill research and development activities. The use of remote sensing and GIS has been making important contributions to environmental monitoring, modeling and management. The combined use of remotely sensed images and GIS data has received considerable interest in recent years to protect human life, and reduce the environmental consequences of both spills and cleanup efforts. It is necessary to identify vulnerable coastal locations before a spill happens, and promptly perform removal actions when an oil spill occurs, so that the protection priorities can be established and clean-up strategies recognized. In this project an oil spill contingency plan has been created for the Straits of Malacca in three steps as follow: (a) SAR data such as RADARSAT has been used to detect and map oil spills pattern on the Malaysian coastal waters. Information on detection, exact position and size of the oil spill can be identified by



remote sensing in SAR images and then plotted on maps in GIS and a priority of the combat efforts and means according to the identified coastal sensitive areas can be carried out; (b) environmental sensitivity index (ESI) map; suggested to provide spill response teams with information about shoreline sensitivity and ranking based on vulnerability of the spill area. This map can show resources at risk in the event of an oil or hazardous substance spill; (c) Prediction of oil spill trajectory, using main seasonal surface currents and surface drift produced by winds. Hypothetical spill trajectories have been simulated for each of the potential launch areas across the entrance of the straits of Malacca. These simulations assumed more than hundred spills occurring in each seasons of the year from each launched area. A successful combating operation to a marine oil spill is dependent on a rapid response from the time the oil spill is reported until it has been fully combated. In order to optimize the decision support capability of the surveillance system for oil spill contingency planning, GIS database have been integrated with the detection tool. An automatic oil spill detection tool was established and information on the exact position and size of the oil spill is then visualized in GIS environment. The system offer opportunities for integration of oil drift forecast models by prediction of wind and current influence on the oil spill for risk assessment using EASI program in PCI software.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PENGESAN TUMPAHAN MINYAK DAN PERANCANGAN KONTIGENSI
MENGUNAKAN IMEJ RADAR DAN GIS**

Oleh

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March 2002

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Sektor perkapalan sering menyebabkan kemalangan yang serius sebagaimana yang dialami di Selat Melaka dalam dekad yang lepas. Sistem Penderian Jauh dan GIS merupakan alat yang penting dalam aktiviti penyelidikan dan pembangunan untuk kajian tumpahan minyak. Penggunaan sistem penderian jauh dan GIS telah memberikan sumbangan yang besar dalam pemantauan, pengurusan dan permodelan alam sekitar. Kombinasi penggunaan data dari imej penderian jauh dan GIS telah mendapat perhatian sejak kebelakangan ini dalam melindungi kehidupan manusia dan juga dalam mengurangkan kesan alam sekitar akibat daripada tumpahan minyak dan langkah pembersihan. Untuk tujuan ini, adalah perlu untuk mengenalpasti kawasan pinggir pantai yang terdedah kepada tumpahan minyak dan dengan ini usaha yang serta merta dapat dilakukan untuk mengatasi hal ini apabila ianya berlaku. Dengan ini strategi perlindungan dan langkah pembersihan dapat dikenalpasti. Untuk memenuhi keperluan di Selat Melaka, pelan kontigensi tumpahan minyak telah direkacipta di dalam tiga langkah seperti berikut: (a) Data

SAR contohnya RADARSAT telah digunakan untuk mengesan dan memetakan corak tumpahan minyak di perairan Malaysia. Maklumat tentang pengesanan, posisi yang sebenar dan saiz tumpahan minyak boleh dikenalpasti dengan menggunakan teknik penderian jauh dalam imej SAR dan kemudiannya diplotkan ke dalam peta menggunakan GIS. Dengan ini langkah pencegahan bagi kawasan pinggir pantai yang terdedah dapat dikenalpasti; (b) Peta indeks kepekaan Persekitaran (ESI) dicadangkan bagi memberikan maklumat tentang kepekaan dan tahap garis pinggir pantai berdasarkan kepada kawasan yang terdedah kepada tumpahan minyak kepada pasukan yang bertindakbalas . Peta ini boleh menunjukkan sumber yang berisiko semasa kejadian tumpahan minyak atau bencana yang berkaitan dengannya; (c) Jangkaan trajektori tumpahan minyak menggunakan keadaan permukaan musim utama dan pergerakan di atas permukaan yang dihasilkan oleh angin; Hipotesis trajektori tumpahan minyak telah disimulasikan untuk setiap kawasan perlanggaran yang berpotensi merentasi Selat Melaka. Di dalam mengoptimalkan keupayaan sokongan membuat keputusan bagi sistem pemantauan untuk perancangan kontigensi tumpahan minyak, pangkalan data GIS telah diintegrasikan dengan peralatan pengesanan. Simulasi ini mengandaikan lebih daripada ratusan tumpahan yang wujud bagi setiap musim untuk setiap tahun bagi kawasan yang dilancarkan. Operasi yang berjaya bagi tumpahan di lautan ini bergantung kepada tindak balas yang kerap dari masa tumpahan minyak dilaporkan sehinggalah ianya diatasi sepenuhnya. Untuk tujuan mengoptimalkan keupayaan sokongan keputusan untuk sistem pengesanan bagi pelan kontigensi tumpahan minyak, pangkalan data GIS telah diintegrasikan dengan alat pengesan. Alat pengesan automatik tumpahan

minyak telah dikenal pasti dan maklumat posisi sebenar dan saiz tumpahan minyak kemudiannya divisualkan dalam persekitaran GIS. Sistem ini menawarkan satu keupayaan untuk mengintegrasikan model ramalan hanyutan minyak dengan membuat jangkaan pengaruh angin dan semasa ke atas tumpahan minyak untuk penilaian risiko dengan menggunakan program EASI yang terdapat dalam perisian PCI.

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I certify that an Examination Committee on 26th April 2002 to conduct the final examination of Hamid Assilzadeh on his Doctor of Philosophy thesis entitled "Application of remote sensing and geographic information system for oil spill contingency planning in the Straits of Malacca" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Putra Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citation, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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TABLE OF CONTENTS

DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	viii
APPROVAL	ix
DECLARATION	xi
TABLE OF CONTENTS	xii
LIST OF TABLES	xv
LIST OF FIGURES	xii
LIST OF ABBREVIATIONS	xii
CHAPTER	
1. INTRODUCTION	1
1.1 Background of Study	1
1.2 Problem Statement	3
1.3 Significance of Study	4
1.4 Purpose of Study	5
1.5 Study Objectives	5
2. LITERATURE REVIEW	7
2.1 Oil Spill	7
2.2 Oil Spill in the Straits of Malacca	11
2.3 Oil Spill Contingency Plan	14
2.3.1 An Evaluation of Previous Contingency Planning	17
2.3.2 Remote Sensing and GIS Support Oil Spill Contingency	23
2.3.3 Oil Spill Contingency Planning in Malaysia	27



2.5	Remote Sensing and Oil Spill Evaluation	30
	2.5.1 The Problems of Oil Spill Remote Sensing	41
3.	MATERIALS AND METHODS	45
3.1	Radar Imagery	46
3.1.1	Pre-Processing of Radar Image	50
	3.1.1.1 Radiometric Correction	50
	3.1.1.2 Geometric Correction	53
3.1.2	Post-Processing of Radar Image	55
	3.1.2.1 Generate Radar Brightness	56
	3.1.2.2 Texture Analysis	57
	3.1.2.3 SCALING Radar Image	60
	3.1.2.4 GAMMA Distribution for Reduce Speckles	62
	3.1.2.5 Feature Extraction	63
3.1.3	Oil Spill Image Classification	64
3.1.4	Automatic Spill Detection Using Visual Modeler in PCI	66
3.2	GIS Application	68
3.2.1	Creating Data in GIS	68
3.2.2	Creating Attribute Data	73
3.2.3	Data Output from GIS	74
	3.2.3.1 ESI Map	74
	3.2.3.2 Bathymetric Map	76
3.3	Oil Spill Trajectory Simulation	76
3.3.1	Mathematical Model	76
3.3.2	Programing the Mathematical Model Using EASI	80
3.3.3	Evaluation of the Simulation Model (Accuracy Analysis)	88



4.	RESULTS AND DISCUSSIONS	90
4.1	Pre-processing Results of Radar Image	90
4.1.1	Geometric and Radiometric Correction	90
4.2	Post-processing Results of Radar Image	93
4.2.1	Image Enhancement	93
4.2.2	Derivation of Brightness Value	93
4.2.3	Texture Analysis Results	95
4.2.4	Image Gray Level Scaling and Quantization Results	99
4.2.5	Image Gamma Map Filtering Results	100
4.3	Oil Spill Image Classification Results	101
4.4	Automatic Spill Detection Results by Visual Modeler	104
4.5	GIS Application Results	109
4.5.1	Mapping Oil Spill	109
4.5.2	Other Maps Created with Database in GIS	112
4.5.3	Automatic Trajectory Simulation	119
4.6	Accuracy Analysis of the Model	121
5.	CONCLUSION AND RECOMMENDATIONS	135
	REFERENCES	142
	APPENDICES	158
	VITA	201



LIST OF TABLES

Table		Page
2.1	Oil pollution incidents in the Straits of Malacca (BOI. 2002)	12
2.2	Oil spill contingency planning procedures (EPA. 1990)	15
2.3	Spill evaluation criteria (Environmental Law Report, 1991)	16
2.4	Thickness of thin oil layer based on its color and appearance (Environmental Law Report, 1991)	30
4.1	Comparison of oil spills trajectory based on simulated model and real images	134
4.2	Comparison of oil spills trajectory based on angle simulated in model and real images	134



LIST OF FIGURES

Figure		Page
2.1	Transport of crude oil and distribution of resource areas sensitive and vulnerable to oil pollution in East Asia (Chua, 1997).	13
3.1	Schematic of an oil spill contingency plan for the Straits of Malacca based on remotely sensed data and GIS.	46
3.2	Raw image database on PIX format presented in PCI's image processing software.	47
3.3	The expansions of oil spill detection and oil spill classification algorithm.	48
3.4	<i>Picture Analysis, Correction, and Enhancement</i> (PACE) provides extensive digital image processing functions.	51
3.5	<i>Antenna Pattern Compensation</i> (APC) performs a radiometric balancing on synthetic aperture radar.	51
3.6	Geometric Correction based on GCPWorks main panel.	54
3.7	SARBETA generates a radar brightness channel from the input scaled radar channel using the gain offset and scaling.	56
3.8	Texture analysis calculates a set of texture measures for all pixels in an input image.	56
3.9	Scaling radar standardized the texture values. Scaling performs a linear or nonlinear mapping of image gray levels to a desired output range.	61
3.10	<i>Gamma function</i> in PCI performs spatial filtering on each individual pixel in an image using the gray-level values in a square window surrounding each pixel.	63
3. 11	Classification methods and session configuration for the image in PCI allows configuring the type of classification.	65

3.12	<i>Model Librarian</i> can serve all commands needed for processing radar image to detect oil spill automatically.	67
3.13	Vectorised topographic map of coastal area of Tanjung Tohor region in the Straits of Malacca.	71
3.14	Vectorised topographic map of Batu Pahat area in the Straits of Malacca.	71
3.15	Vectorised topographic map of Malacca area in the Straits of Malacca.	72
3.16	Vectorised topographic map of Johor area in the Straits of Malacca.	72
3.17	Schematic of oil spill trajectory modeling in sea environment based on wind induced current and net current.	79
3.18	Simulation model for oil spill trajectory converted to SPANS functions by EASI programming.	82
3.19	<i>Compute New Column</i> creates a column containing new attributes by applying a user defined mathematical equation to existing attributes in the data layer.	83
3.20	The grid for the study area (with 10000 m resolution cells).	84
3.21	Monthly wind direction, speed and sea conditions reported by ground stations in the Straits of Malacca (October 1997) (Malaysian Meteorological Service, 1997).	85
3.22	Oceanographic and atmospheric chart data over the Straits of Malacca (26 Oct. 1997) (Malaysian Meteorological Service, 1997).	86
3.23	Figure 3.23: Oceanographic and Sea condition data in the Straits of Malacca, point data format and its attribute data in SPANS.	87
3.24	Thirty oil spill samples collected in the Straits of Malacca from the 26 Oct. 1997 oil spill accident. Real directions of the spills based on their centerline are determined.	89

4.1	Raw image on PIX format before geometric and radiometric correction presented in PCI image processing software.	91
4.2	The image after pre-processing (geometric and radiometric correction).	92
4.3	Enhancing radar image using FSPEC--SAR Speckle Filters command in PACE.	94
4.4	Brightness values of the image in 32-bit pixel size referring to pixel brightness.	95
4.5	Effects of the <i>Homogeneity</i> function of texture analysis on the image.	97
4.6	Effects of the <i>Angular Second Moment</i> function of texture analysis on the image.	98
4.7	Scaling performs a linear mapping of image gray levels to a desired output range.	100
4.8	Classification result of the processed image.	102
4.9	SAR image classification and attribute DN values of the image pixels showing three different classes for oil spill.	103
4.10	Automatic detection of oil spill using <i>Visual Modeler</i> was designed to detect any spilled oil in a short time.	104
4.11	Input is a sample of oil spill in radar image.	106
4.12	Two different actions on image by <i>Visual Modeler</i> to identify Spill area (ii) and Pollution area (i).	106
4.13	Classified oil spill image by <i>Visual Modeler</i> in two regions: oil spills area in red and polluted area in black color.	107
4.14	Grey values of original image (channel 1) and attribute values after <i>Homogeneity</i> (Channel 2) and <i>Angular Second Moment</i> (Channel 3) texture analysis. Channel 2 specified the all polluted area and channel 3 rectified only very high-polluted area (spilled area).	108

4.15:	Oil spill mapping in GIS system giving information about area, and thickness of spilled oil.	110
4.16	Spill area extracted from classified image using GIS.	111
4.17	High and low pollution area extracted from classified image using GIS.	111
4.18	Malacca Straits: Bathymetric data extracted and overlaid with radar image.	113
4.19	Malacca Straits ESI map in North-West of Johor state extracted and overlaid from topographic map and radar image. See legends in Figure 4.22.	114
4.20	Malacca Straits ESI map in Johor region extracted and overlaid from topographic map and radar image. See legends in Figure 4.22.	115
4.21	Malacca Straits ESI map of the whole study area extracted and overlaid from topographic map and radar image. See legends in Figure 4.22.	116
4.22	Legends display some features on the ESI map in SPANS engine.	117
4.23	Oil spills history in the Straits of Malacca, (DOE, 1998) in point data format and its attribute data in SPANS.	118
4.24	Oil spill trajectory simulated based on oceanographic and meteorological information extracted from the charts and records on 26 Oct 1997.	120
4.25	Hypothetical oil spill trajectory simulated for an appropriate point in the Straits of Malacca.	121
4.26	Regression line is showing the relationship between the model and the real image.	122
4.27	Oil spill from radar images at two different times (ERS-1997-03-19 and ERS- 1997-05-12).	124
4.28	Oil spill from radar image at two different times (ERS-1997-05-28 and ERS- 1997-07-18).	124



4.29	Oil spill from radar image at two different times (ERS-1997-09-10 and ERS-1997-11-19).	125
4.30	Oil spill from radar image at two different times (ERS-1998-03-04 and ERS-1998-04-08).	125
4.31	Oil spill from radar image at two different times (ERS-1997-10-15 and ERS-1997-10-14).	126
4.32	Oil spill from radar image at two different times (ERS-2000-02-21 and ERS-2000-02-20).	127
4.33	Oil spill from radar image at two different times (ERS-2000-03-08 and ERS-2000-03-07).	128
4.34	Initial position of oil spill on 7 March 2000 (ii) and the position of the same spill after 24 hours on 8 March 2000 (i).	129
4.35	Trajectory simulation of oil spill in the Straits of Malacca, using two reference point (A; the initial point of center mass coordination is $X = 553962.1$ m, $Y = 166125.4$ m B; initial point of center mass coordination is $X = 534392.5$ m, $Y = 181877.5$ m). A and B are initial points of oil spills on 7 March 2000 and A' and B' are destination points of oil spills on 8 March 2000.	130
4.36	Schematic of angular difference on movement of oil spill based on final location of oil spill simulated by model and the real location of oil spill extracted by radar image.	132



LIST OF ABBREVIATIONS

APC:	Antenna Pattern Correction
ASA:	Applied Science Associates
ASEAN:	Association of South East Asian Nations
CASI:	Compact Airborne spectrographic Imager sensor
CCRS:	Canada Center for Remote Sensing
CCRS:	Canadian Center for Remote Sensing
DBIC:	Database Input Channel
DBOC:	Database Output Channel
DN:	Digital Number
DOE:	Department of Environment
DSS:	Decision Support System
EASI:	Engineering Analysis and Scientific Interface
ESI:	Environmental Sensitivity Index
FLI:	Flourescence Line Imager
GCP:	Ground Control Point
GEMS:	Marine Department of Environmental Management System in USA
GIS:	Geographical information system
GLCM:	Gray level co-occurrence matrix
IAS:	Image Analysis System
LDIAS:	Landsat Digital Image Analysis System
LEAF:	Laser Environmental airborne fluorosensor
MEIS II:	Multi-spectral Electro-optical Imaging Scanner sensor



MOSIS:	Marine Oil Spill Information System
Nbr:	Neighbor pixel
NLOOK:	Number of Looks
NOCC:	National Oil Spill Control Committee
NRDA:	Natural Resource Damage Assessment Model
Oil SCAN:	Oil Spill Contingency and Navigation System
OSC:	On Scene Commander
OSPAR:	Oil Spill Preparedness and Response in Asia
PACE:	Picture Analysis, Correction, and Enhancement
PMI:	Programmable Multi-spectral Imager
PMR:	Power-to-mean ratio
Ref:	Reference pixel
RPI	Research Planning Institute
SAR:	Synthetic Aperture Radar
SARBETA:	PCI function generates a radar brightness
SARGEO:	PCI function creates a geocoded SAR image
SCAL:	Gray Level Scaling program in PCI
SI:	Spill Impact
SIS:	Spatial Information System
SLAR:	Side-looking Airborne Radar
TEX:	PCI function produces several output based on texture analysis
WQ:	Water Quality



CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysian coastal and marine environment contain many species, habitats and other resources that could be severely affected by oil pollution. The most sensitive areas are coastal areas where oil can strand on the foreshore. The Straits of Malacca is located west of Peninsular Malaysia and it is an important and unique water body. A unique, tropical estuarine environment, rich in renewable and non-renewable natural resources characterizes the Malacca Strait. For the local communities, the Straits host a large marine fishery sector and numerous aquaculture and mariculture ventures. At a national level, the three littoral states rely greatly either on the production of rich natural resources or on trades/shipping business associated with the Straits. Finally, the importance of the Straits to international users is reflected in the high tonnage of goods carried through the Straits.

The Malacca Straits is considered highly vulnerable to pollution risk due to increased maritime activities and rapid industrial developments along the coastal areas causing deterioration of the marine and coastal ecosystems. The most important risk is that associated with possible oil spills from tankers crossing the Straits of Malacca. There are several reports since 1975 on the number and extent of these oil spills in the Straits of

Malacca (Calow, 1997). According to these records the southwestern coast of Johor state up to Melaka are areas at highest risk. This area is vulnerable due to presence of different kinds of environmental reservoirs, natural resources and anthropogenic activities. Managing and reducing pollution risks in the Straits will require concerted efforts among users and bordering littoral states. Such efforts were initiated by GEF/UNDP/IMO Regional Program for the Prevention and Management of Marine Pollution in the East Asian Seas, including Environmental Profile (1997) and Initial Risk Assessment (1997), prepared by Professor Peter Calow and Dr. Valery E. Forbes.

On the other hand, development of space technology in Malaysia was driven initially by its effort to use space remote sensing technology for natural resources and environmental management in 1990s. Despite having a short history in space technology, Malaysia has already made significant impacts towards achieving selected capabilities in this technology - through the launching of MEASAT-1 communication satellite in 1997. In the ground segment, Malaysia is currently implementing a project to acquire a satellite remote sensing ground receiving station to facilitate real-time reception of high-resolution data to meet the national need for a more effective environmental monitoring and natural resources management. These include monitoring of forest fires that lead to recent serious haze problem, illegal forest logging, and oil spill in the surrounding waters. In the field of oil spill detection, and environmental impact assessment, this technology has already been widely utilized.