CHAPTER 3

AN AUTOMATIC PATTERN MATCHING APPROACH FOR OIL SPILL DETECTION IN SAR IMAGES

The research work is aimed to use the pattern matching method for oil spill detection in the SAR images. Each day numerous thousand tonnes of oil are spilled or unlawfully derelict into the marine. It spoils the ocean living things and non-living things. Since, to provide protection or to know the location, it is necessary to find the location of the oil spill in the ocean. From the literature survey it is noticed that most of the research works detect and segment various kind of images using pattern matching methods.

3.1 Proposed Method

In the initial stage a pattern matching approach is applied for oil spill detection on the SAR images. Pattern matching can effectively detect an odd pattern or known pattern present in the input image. An automatic system is required to give early information where it leads to cleaned up getting more damages in the ocean. This problem is taken into account and it is aimed to create a detection system to know the oil spill location using SAR images. In this initial stage, it is aimed to design and develop an automated approach for applying pattern recognition for oil spill detection in SAR images. This stage is also motivated to increase the detection accuracy. Petroleum products are occupying an essential place in present society, specifically in the journeys, Plastics, and fertilizer industries. It is a fact that ten to fifteen changes are there for the spillage of oil from the route source to the end consumer. Oil spills can occur while oil transportation or storage and spillage can happen in water, ice or on land. Ocean oil spills can be highly dangerous since the wind, waves and currents can spread a huge oil spillage among the area, in the range of few hours in the open sea, Fingas (2001). From 1988 to 2000 there were

2,475 spills which released over 800,000 liters of oil in Toronto and nearby regions, Li, J (2002).An oil spill is also due to the transportation accidents. Heavy oils are less toxic but persist in the environment for a long time. Heavy oils can get mixed with pebbles and sandy beaches where they may remain for years Worldwide, fuels account for 48% of the total oil spilt into the sea worldwide, while crude oil spills account for 29% of the total, Brekke et al. (2005).

The environmental impacts of oil spills can be considerable. Oil spills in water may severely affect the marine environment causing a decline in phytoplankton and other aquatic organisms. Phytoplankton remains at the bottom of the food chain and can pass absorbed oil on to higher levels in the food chain. Oiled birds suffer from behavioral changes and this may result in the loss of eggs or even death. The livelihood of many coastal people are be impacted by oil spills, particularly those who are based on fishing and tourism. The movement of oil on ground it depends on various factors such as oil type, soil type and moisture content of the soil. Oil Spill on agricultural land, impact soil fertility and pollute ground water resources, Fingas (2001).

The many oil spill accidents in the past decades as a consequence of our massive oil consumption have raised global awareness. However, accidents and illegal discharges of oily mixtures and bilge waters by vessels pose an equal threat to our aquatic environment. Although international rules introduced norms and standards in this area as well, illegal operational discharges remain common. To reduce the number of illegal discharges, governments organize sea and air patrols to monitor marine areas. In addition to sea patrols, a new monitoring tool was introduced during the last decade through the technique of remote sensing.

Remote sensing data, commonly known as satellite pictures, are a way to retrieve valuable data about objects and processes from the Earth’s surface. Although remote sensing is already around for over 50 years and is a considerable enhancement to the ability of governments to patrol the seas, this technique still presents many difficulties. Used intensively by the military during the Cold War, the scope of remote sensing applications has extended far beyond its original purpose. Today applications range from ordinary phone calls to highly sophisticated research projects. However, the use of remote sensing in criminal proceedings is a highly debated issue and there is no general clear-cut answer.

Every country has its rules and standards regarding evidence and its value. On the one hand, this hinders effective prosecution of offenders in some economies because of a high evidentiary burden. Otherwise, this prevents an effective exchange of information between flag states, coastal states and port states when it comes to initiating criminal proceedings. The entire contribution of this stage is:

- Read the SAR image under various constraints; enhance the image after noise removal.
- Calculate the Super-Pixels in the image
- Divide the image into number of partitions using super-pixel values
- Detect oil spills using super-pixels over partitions.
- Performance Evaluation

To do the process, initially the input image is divided into sub-regions. After division, the input image gives a number of small sized grids. The partitioned grid image is applied for image segmentation method using watershed segmentation. From the segmented image, the set of features is extracted using GLCM method. From the extracted features like entropy and energy, the oil spill portion is detected. In order to increase the performance the partition images of the trained image and test image are also compared using various statistical parameters. This statistical comparison decreases the false positive comparison. Initially, the input image is preprocessed to increase the eminence of the image in terms of pixel values (threshold, intensity, brightness, contrast). Preprocessing is supports to enhance the features of the image required for accurate image processing. Since RGB of the input image depends on the image color and skin texture color, it is necessary to normalize the RGB, which decreases the RGB permeation in the edge. Here the preprocessed image is converted into LAB color and it is mathematically represented as given in equation 3.1, 3.2 and 3.3.

$$L^* = 116 f\left(\frac{Y}{Y_n}\right) - 16 \tag{3.1}$$

$$a^* = 500\left[f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right)\right] \tag{3.2}$$

$$b^* = 200\left[f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right)\right] \tag{3.3}$$

Where, $X_n, Y_n\ and\ Z_n$ are the CIE XYZ tristimulus values from the brightest regions in the image. By using CLAHE, the contrast of the image is enhanced which helps to facilitate later segmentation, due to those non-exudates regions on the image is differentiated. After preprocessing the real contribution of the stage is applied. Here it is assumed that the images used in this experiment are SAR images. In the proposed model initially read the input image and divided it into a number of partitioned images where it reduces the computational and comparison complexity. Then the image is segmented using watershed segmentation method based on the super-pixel available within the boundary as shown in Figure 3.1.

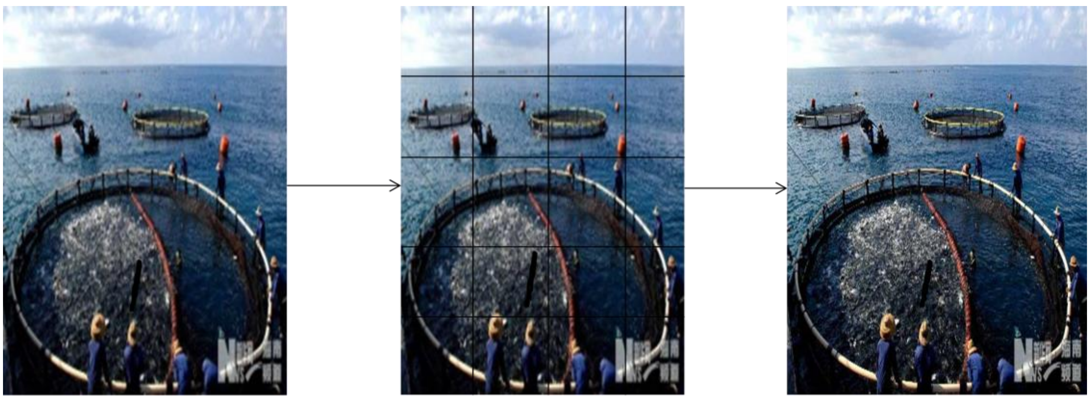


Figure 3.1 Proposed Models- Using Watershed Segmentation method based on the Super-pixel available within the boundary

Segmenting the image can be obtained by watershed segmentation within the image boundary. Segmentation is carried out based on the super-pixel value calculated and selected within the image region. The super-pixel procedure is accomplished as the main contribution of this segmentation task. Here the super-pixel value is calculated in terms of highest threshold values in the image while image binarization. Then the computed super-pixels are clustered using ANN in order to eliminate the false positive super-pixel calculation. False positive values include intensity or threshold deviation, distance in space and image size. The initial stage of super-pixel calculation is dividing the image into equal partition as grids. Then the center threshold values and center values in the spatial domain of the image are calculated. Partitioning and super-pixel generation based segmentation are applied to provide a uniform verification on the entire image to check for oil spill detection. For each pixel *Pi*, the probability $Prob_i$ is calculated in terms of a threshold value in each partition. Finally, the missing super-pixels are calculated using image processing methods.

In a given image partition Pt=$\{Pt\}_{i=1}^{L}$ taken from image I=$\{g(P)\}_{p\epsilon I}$ where *g(P)*is the intensity of the pixel *P*. The center-intensity of every partition Pt_i is represented as equation 3.4 as shown below.

$$GP_i = \frac{1}{|P_i|}\sum_{p\epsilon p_i} g(P) \tag{3.4}$$

Where $|P_i|$ denotes the total number of pixels belonging toP_i. The center spatial is calculated using below equations 3.5 and 3.7.

$$CS_{P_i}(x,y) = \left(\sum_{P\in P_i} W_P \cdot P_x, \sum_{P\in P_i} W_P \cdot P_y\right) \tag{3.5}$$

$$\widehat{W}_P = \frac{G_{P_i}}{\left|g(P) - G_{P_i}\right|} \tag{3.6}$$

$$W_P = \frac{\widehat{W}_P}{\sum_{P\in P_i} \widehat{W}_P} \tag{3.7}$$

Where, W_P represents the pixel weight,(x, y) represents the coordinate of the pixel P. The probabilities of one pixel are calculated with the super-pixels available in the neighbor location and it can be expressed by using equations 3.8 and 3.9 as shown below.

$$Pro(P, P_i) = \frac{\sqrt{\left(\hat{g}(P) - G_{P_i}\right)^2}}{I} \cdot \frac{\sqrt{\left(x - x_{P_i}\right)^2 + \left(y - y_{P_i}\right)^2}}{II} \cdot \frac{N_{P_i}}{8} \quad (3.8)$$

$$\hat{g}(P) = \frac{\sum_{i=1}^{L} \sum_{j=1}^{L} g(P_{x+i,\ \ y+j})}{9} \quad (3.9)$$

where, I represent the intensity threshold constant value, II represents the threshold constant of space distance, $\boldsymbol{x_{P_i}}$, $\boldsymbol{y_{P_i}}$ are the center coordinates of the super-pixel Pi.

Algorithm_OilSpill_Detection(I image)

```
{
Input: I is the input image, k number of partition
For j=1 to k
divide I in to partition image
for i = 1 to P
   {
   P -> Q
check for Pi as visited
If  (Pi = unvisited) then
visit each Pi until Q is empty
end
collect all 3 x 3 neighbors for Pi
end
for i=1 to P
check for Super-Pixel
     Pi -> Q
If  (Pi = unvisited) then
visit each Pi until Q is empty
end
collect all 3 x 3 neighbors for Pi
```

end i

end j

output= {P_ik}

}

N_{P_i} is a k x k (k=3) neighbor pixels. Once the super-pixels are calculated, then the missing super-pixels are verified.

The entire process of the proposed approach is written in the form of the algorithm, where it can be coded and the performance is verified in any computer programming language. After detecting un-visited super-pixels, all the partitioned images are joined together to the using the gray distance. Finally, the joined image is reconstructed into the real image back.

3.2 Extracting the Oil Spills in the segmented image

After segmenting the super-pixels, watershed segmentation is applied over the Binarized image. Watershed segmentation method processes on the super-pixel values. Watershed is more efficient and it can separate the super-pixel images into negatives and the remaining into ones. After negative and positive conversion, only positives are filtered using distance, deviation of intensity and size of the image. In order to obtain the accurate information about the super-pixels all, the super-pixels are clustered. This clustering process detects and eliminates missed super-pixels in the image. Whenever finds the parts bigger than the highest threshold T is taken as the centers CSPof the confirmed oil spills. Now the distance is calculated among the center portion and super-pixel portion is calculated as equation 3.10.

$$DoS(C_c, C_i) = \min\left\{\sqrt{\left(X_{Pc} - X_{Psp}\right)^2 + \left(Y_{Pc} - Y_{Psp}\right)^2}, \quad P_c \in C_c, P_{sp} \in C_i\right\} \quad (3.10)$$

Where, P_c and P_{sp} denotes the center portion and super-pixel portions of the C_c, C_i respectively. If the distance is larger, then N_{P_i} is rejected as negatives. The intensity deviation is defined as equation 3.11.

$$\text{Intensity-Distance } (C_c, C_i) = \sqrt{\left(I_{C_i} - I_{C_c}\right)^2} \qquad (3.11)$$

Where, I_{C_i} and I_{C_c} denotes the intensity portion of C_i and center portion C_c respectively. According to the size of the clustered portion and intensity distance value the negative portions are confirmed and eliminated and the other portions are extracted.

3.3 Experimental Results and Discussion

The experiment is carried out using MATLAB software and the results are presented. The performance of proposed approach is evaluated by comparing the results with the existing system results. The Oil Spill Detection algorithm is programmed in MATLAB software and the efficiency of the algorithm is verified. The dataset is taken from internet sources and they are benchmark dataset experimented and proved. The images available in this dataset have various intensities and the performance of the proposed approach gives better results. The corresponding parameters and the values of the parameters used in the experiment are given in Table 3.1.

Table 3.1 Parameters and the values of the parameters used in the experiment.

Parameters	Assigned Values
I	10
II	60
X, Y	Size of the Image
Spatial Resolution	50m
Oil Spill Pixels	200 to 500

In order to evaluate the proposed approach, there are three different criteria are used here. These criteria are used to determine the Accuracy, Commission area (Commission error) NC, and Elimination area (Elimination error) NE. Commission area is the point at which a pixel reports the nearness of an oil, in all actuality, is missing (no oil are really present). Ground truthing guarantees that the blunder networks have a higher exactness rate than would be the situation if no pixels were ground truthed. This esteem is the reverse of the client's exactness. A sample Commission area and Elimination area are shown in Figure 3.2.

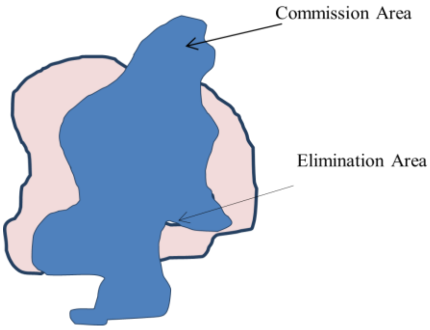


Figure 3.2 A sample of Commission Area and Elimination Area

Ground truth uses a set of measurements that is known to be more accurate as compared to the measurements from the testing system. It is applied to various areas, such as satellite imagery. Ground truth image cross check with the real picture, within the segmentation technique the base or bottom truth figure tends to be (region of interest) that has to be segmented from the whole picture, and that is used to decide how the algorithms worked. In Figure 3.3, the ground truth image is shown inside the outer line. The darkest place is the oil spill detection area. The below formula 3.12 is used to compute the commission error.

$$CE = \frac{N_C}{N_C+N_E+N_{COR}} \tag{3.12}$$

N_C and N_E represents the commission areas and elimination areas respectively. N_{COR} represents the numbers of the pixels correctly detected as oil spill detection method. Likewise, elimination areas from the ground truth area are calculated as equation 3.13.

$$EE = \frac{N_E}{N_C+N_E+N_{COR}} \tag{3.13}$$

Also, the detection accuracy can be calculated as equation 3.14.

$$DA = \frac{N_{COR}}{N_C + N_E + N_{COR}} \quad (3.14)$$

The oil spill detection and detection accuracy depends on the noise level of the image. According to the noise level of the image, the partition, super-pixel clustering and segmentation accuracy increases. In this stage, there are five different SAR images are taken as input and the experiment is executed. The input images used in this stage is shown in Figure 3.3.

Figure 3.3 Different Input Images used in the Experiment

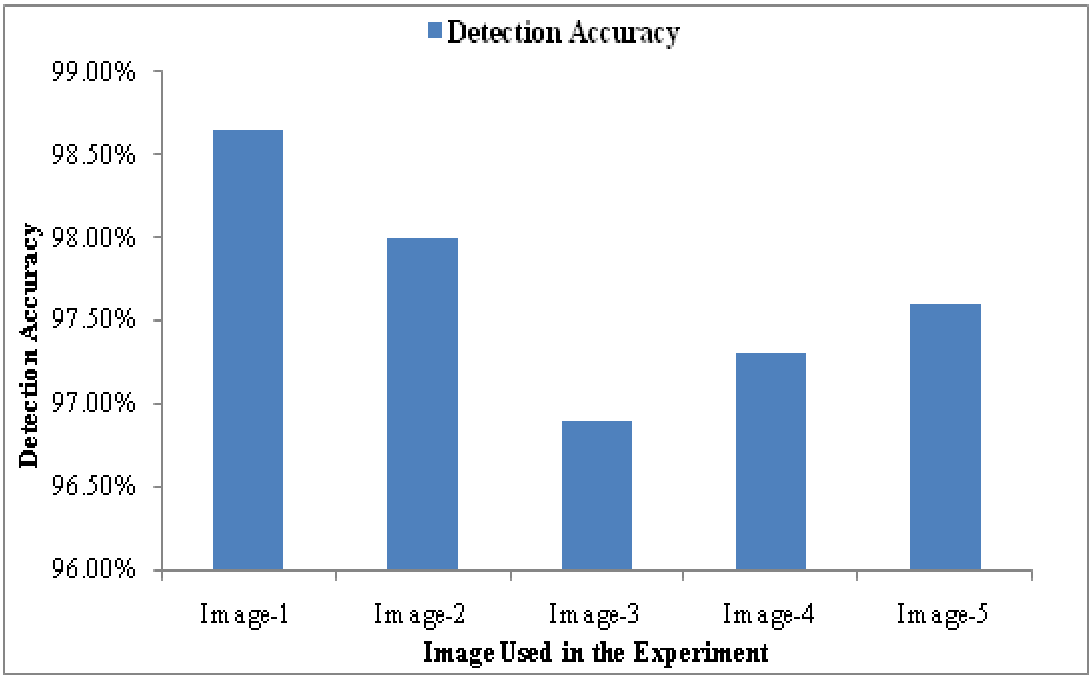


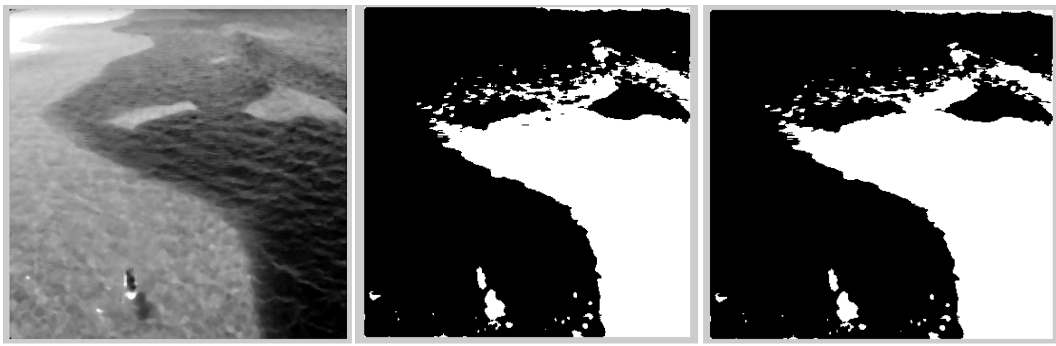
Figure 3.2 Performance Evaluations over Detection Accuracy

The performance evaluation of the proposed approach is calculated in terms of noise level and it is shown in Figure 3.5. The stepwise procedure obtained in the experiment is shown in Figure 3.6. The image in Figure 3.6

(a) shows the input image
(b) The gray scaled image
(c) The noise removed image
(d) Enhanced image
(e) Entropy image and
(f) Binarized image

clearly showing the oil spill portion in the image. That is the positive and negative classified image according to the super-pixels in the image. The main feature Entropy is taken from GLCM features. The entropy feature is defined below and it means mainly about the intensity values of the pixels in the image.

(a) Input Image (b) Gray Scale Image (c) Noise Removed Image



(d) Enhanced Image (e) Entropy Image (f) BW-Operation Image

(g) Extracted Oil Spill Portion

Figure 3.5 Experimental Results Obtained in Each stage of the Proposed Approach

In this stage, the input images are taken based on its size, intensity, and background, the proposed method the image is compared with Image Constraints such as (Same kind of images, Different kind of Images, well defined and are not well defined) these Constraints are compared with Commission Area (NC), Elimination Area (NE) and Detection Accuracy (DA), that gives the Elapsed Time.

The Variation in accuracies obtained by the proposed method for different Constraints shown in Table 3.2. The obtained accuracy range is from 96.89% to 98.98% for the best scenario. For the worst scenario, the obtained detection accuracy is from 91.23% to 92.88%. The noise occurs in the image is from 4% to 6%.

Table 3.2 Variation in Accuracies Obtained by the proposed method for different Constraints

Image Constraints	NC	NE	DA%	Elapsed Time
Same Kind of Images	0.009	0.0134	0.98	5
Different Kind of Images	0.016	0.0154	0.97	6
Well-Defined	0.034	0.012	0.97	8
Not-Well-Defined	0.035	0.029	0.96	7

The maximum accuracy detection obtained by the proposed approach is 98.98% and it is efficient for oil spill detection using SAR images under different constraints.

3.4 Sensitivity and Specificity

The sensitivity and specificity are the statistical measures of the performance of a binary classification. Sensitivity is also called as true positive rate (TPR) measures the proportion of actual positives that are correctly identified as oil which is correctly identified. Specificity is true negative rate (TNR) which measures the proportion of actual negatives that are oil is correctly identified. The proposed approaches is also evaluated by computing the performance evaluation using the metrics such as, True Positive Rate and False Positive Rate, and are calculated by using the following formula, TPR (3.15), TNR (3.16), FPR (3.17) and FNR (3.18)

$$\text{TPR} = \frac{\text{Number of OSD correctly obtained}}{\text{Total number of images to be Detected}} \quad (3.15)$$

$$\text{TNR} = \frac{\text{Number of images correctly}}{\text{Total Number of OS images}} \quad (3.16)$$

$$\text{FPR} = \frac{\text{Number of OSD incorrectly obtained}}{\text{Total Number of images to be Detected}} \quad (3.17)$$

$$\text{FNR} = \frac{\text{Number of Non Oil Spill images incorrectly identified as OS}}{\text{Total Number of Non Oil Spill}} \quad (3.18)$$

OSD – Oil Spill Detection

OS – Oil Spill

Non-OS – Not having Oil Spill

Using more number of SAR image the experiment carried out a various number of times and the detection accuracy is calculated.

Table 3.3 Detected OS and NON-OS Images

	No. of OS	No. of Non-OS	No. of OS Images Correctly Detected	No. of OS Images incorrectly Detected	No. of Non-OS Images Correctly Detected	No. of Non-OS Images incorrectly Detected
OS	**50**	**50**	**49**	**1**	**49**	**1**

The details about the Total number of Oil Spill, Non-Oil Spill, detected accurately and not detected accurately given in Table 3.3. The total number of images is 100 in that 50 images are having OS and 50 images are having OS (Non-OS), the TPR(True Positive Rate), TNR(True Negative Rate), FPR(False Positive rate), FNR(False Negative Rate), are calculated in 3.19, 3.20, 3.21 and 3.22 equations as shown below

$$\text{TPR} = \frac{49}{50} + \frac{49}{50} = 98\% \qquad (3.19)$$

$$\text{TNR} = \frac{2}{100} = 2\% \qquad (3.20)$$

$$\text{FPR} = \frac{1}{100} = 1\% \qquad (3.21)$$

$$\text{FNR} = \frac{1}{100} = 1\% \qquad (3.22)$$

From the TPR and FNR, it is concluded that the proposed approach is efficient for detecting oil spills in SAR images.

3.5 Summary

The main objective of this stage is to detect oil spills on the ocean using SAR images. In order to save the ocean properties this, research becomes most necessary. This stage uses three different internal processes like super-pixel calculation, clustering the pixels, partitioning the image for fast comparison for oil spill detection. Each contribution of this stage increases the efficacy of the oil spill detection. Also, this approach is decided as the better approach because it can able to do oil spill detection for any SAR image under various constraints. Because of the partitioning, the computational complexity is also reduced. The main advantage of this approach is it provides detection accuracy for different condition based SAR images from 96.89% to 98.98%.In future this method can be compared with the various conventional approaches and the performance is evaluated.