Oil Spill Extraction System Using Synthetic Aperture Radar Imagery

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Abstract

An oil spill is the release of a liquid petroleum hydrocarbon into the environment, especially marine areas, due to human activity, and is a form of pollution. The term is usually applied to marine oil spills, where oil is released into the ocean or coastal waters, but spills may also occur on land. Oil spills may be due to releases of crude oil from tankers, offshore platforms, drilling rigs and wells, as well as spills of refined petroleum products (such as gasoline, diesel) and their by-products, heavier fuels used by large ships such as bunker fuel, or the spill of any oily refuse or waste oil. The model perform Homogeneity texture analysis algorithm on SAR image. Homogeneity reflects the homogeneity/uniformity of the SAR image. Oil film has a larger surface tension, which decreases the surface roughness of sea surface in polluted area. This can cause homogeneous dark patches appear in SAR image with low speckle noise and the oil spill and sea water can be easily discriminated. The proposed method develops an automatic oil spill extraction system, where the spill affected area is extracted from the SAR imagery along with the area measurement, by image processing techniques. Moreover a prototype experiment is also intended to perform, based on the Bragg Scattering Mechanism and Dispersion Relation for the Capillary Waves, which results in the oil type recognition from SAR imagery

Keywords- Oil spills, SAR image, image processing techniques, Bragg Scattering, Dispersion.

1. Introduction

An oil spill is the release of a liquid petroleum hydrocarbon into the environment, especially marine areas, due to human activity, and is a form of pollution. The term is usually applied to marine oil spills, where oil is released into the ocean or coastal waters, but spills may also occur on land. The surface waves that are present on the sea surface, ranges from millimeter scale to hundreds of meters. Considering the ocean surface, the wind induces the capillary waves by friction. A gravity–capillary wave on a fluid interface is influenced by both the effects of surface tension and gravity, as well as by fluid inertia Satellite images can improve the possibilities for the detection of oil spills as they cover large areas. Space born SAR images can be used to screen large areas looking for possible oil pollution, where aircraft are needed to verify the spill and the polluter. The main limitation for the space-borne optical sensor is the need for the daylight and cloud free scenes. SAR imaging has the advantage of being independent of solar illumination and is generally unaffected by cloud-cover [1].

Among the available remote sensing satellite data, Space borne Synthetic Aperture Radar (SAR) imagery is the most efficient and superior satellite sensor for oil spill detection. But it does not have capabilities for oil spill thickness estimation and oil type recognition. RADARSAT-1 and ENVISAT are the two main daily providers of satellite SAR images for oil spill monitoring. In SAR images, the physical mechanism that allows the detection of oil spills is the dampening of capillary waves present on the ocean surface. From SAR point of view, a slick is characterized by a lack of backscattered energy. The capillary waves produce backscattering of the RADAR incident pulse due to a Bragg scattering mechanism [2] Oil film has a larger surface tension, which decreases the surface roughness of sea surface in polluted area. This can cause homogeneous dark patches appear in SAR image with low speckle noise and the oil spill and sea water can be easily discriminated. The proposed method develops an automatic oil spill extraction system, where the spill affected area is extracted from the SAR imagery along with the area measurement, by image processing techniques. This paper is organized as follows. Section II focuses on the slick measurement through SAR data and outlines the main parameters that are to be taken into consideration in an operational frame work. Section III presents the mechanism behind the surface scattering. Section IV describes the methodologies adopted in this paper. Section V describes the conclusion and future scope.

2. RADAR parameters

The radar backscattering coefficient (σ) provides information about the imaged surface. It is a function of the following parameters [3].

a). Frequency

It determines the penetration depth of the RADAR incident pulse as well as the relative roughness of the surface. C-band frequency seems to be most suitable, allowing strong contrast to be measured up to a wind speed of about 10-14 ms^{-1}.

b). Polarization (P)

It describes the orientation of the electric field component of an electromagnetic wave. The commonly used polarization techniques are HH, VV, HV, and VH, where the first term corresponds to the polarization of the emitted radiation and the second term corresponds to the polarization of the received radiation. The term X_{HV} indicates X-band, H- horizontal transmit, V- vertical receive. Polarization provides information on the form and orientation of small scattering elements that composes the surface or target. It also provides information on different layers of the target, where the penetration depth of radar waves also varies with the polarization. Among the various polarization techniques, VV polarization seems to be most suitable for the C-band.

c). Roughness

The surface roughness depends on the wavelength and incidence angle. Inland water bodies tend to be relatively smooth, with most of the energy being reflected away from the radar and only a slight backscatter towards the radar. But the land surfaces tend to have a higher roughness and they backscatter more towards the radar.

d). Incidence Angle

It is defined as the angle between the perpendicular to the imaged surface and the direction of the incident radiation. The backscattering of smooth fields is very sensitive to the incidence angle, where it is almost independent of the incidence angle for the case of rough surface. Most suitable incidence angle is from 20^0 to 45^0

e). Influence of Moisture

RADAR reflectivity increases with increasing the moisture content present in the atmosphere.

f). Nature of the slick

Backscatter damping is a function of the slick nature and slick properties such as viscosity and elasticity

3. Surface Scattering

For flat terrain, the local reflection angle is the same as the incidence angle. Most of the incident energy will be reflected away from the sensor, resulting in a very low return signal. Rough surfaces will scatter incidence energy in all directions and return a significant portion of the incident energy back to the antenna. On the ocean surface, it is the waves that make the surface rough. Whether the surface is perceived rough or not depends on the wavelength of the SAR. The RADAR incidence angle is defined relative to the vertical plane, and is thus smaller at near range compared to far range.

SAR image tend to become darken with increasing the range. Backscatter is related to the local incident angle (as the local incident angle increases, backscatter decreases), which is in turn related to the distance in the range direction. Backscatter is also related to wind speed. In general lower wind speeds generate fewer Bragg waves. This produces a smoother ocean surface that appears in the SAR imagery as a dark area. Below a low wind speed threshold, little of the radar energy will be scattered back towards the SAR and features depending on the modulation of Bragg waves to be imaged will not be visible in the image. The wind direction relative to the plane of the incident radar wave also affects the scattering in a scene. A crosswind (wind blowing perpendicular to the range direction) produces lower backscattering than an upwind or downwind (wind blowing along the range direction).

4. Methodology

Initially the original radar image in the RGB form is converted to Gray scale image (b). A gray scale (or gray level) image is simply one in which the only colors are shades of gray. The reason for differentiating such images from any other sort of color image is that less information needs to be provided for each pixel. In fact a `gray' color is one in which the red, green and blue components all have equal intensity in RGB space, and so it is only necessary to specify a single intensity value for each pixel, as opposed to the three intensities needed to specify each pixel in a full color image. Often, the gray scale intensity is stored as an 8-bit integer giving 256 possible different shades of gray from black to white.

Then image histogram of the Gray scaled image is taken (c). An image histogram is a type of histogram that acts as a graphical representation of the tonal distribution in a digital image. It plots the number of pixels for each tonal value. By looking at the histogram for a specific image a viewer will be able to judge the entire tonal

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distribution at a glance. According to this image histogram, we are fixing the threshold to binarize the image.

The preprocessing step includes the noise reduction of the binarized image. Median Filtering, a kind of noise reduction for reducing impulsive or salt and pepper noise is being used in this paper. The median filter is a nonlinear digital filtering technique, often used to remove noise. Noise reduction is carried out to improve the results of later processing (eg: Edge Detection on an image). Median Filtering preserves the edges while removing the random noise. In a Median Filter, a window slides along the image and the median intensity values of the pixels within the window becomes the output intensity of the pixel being processed.

After the preprocessing step, the noise free binary image is complemented or inverted so that the zeros in the image become ones and the ones become zeros. That is the black and white pixels are reversed (d).

Then the edges of the connected components within the inverted binary image are detected by means of Canny Edge Detector (e). It is the most commonly used image processing tool for detecting the edges in a very robust manner. Edges in images are areas with strong intensity contrast- a jump in intensity from one pixel to the next. Edge detecting an image significantly reduces the amount of data and filters out useless information, while preserving the important structural properties in an image. The canny edge detector is an optimal edge detector which first smoothes the image to eliminate the noise. It then finds the image gradient to highlight the regions with high spatial derivatives. The algorithm then tracks along these regions and suppress any pixel that is not at the maximum. The gradient array is now further reduced by Hysteris. Hysteris is used to track along the remaining pixels that have not been suppressed. Hysteris uses two thresholds and if the magnitude is below the first threshold, it is set to zero (made a non-edge). If the magnitude is above the high threshold, it is made an edge. And if the magnitude is between the two thresholds, then it is set to zero unless there is a path from this pixel to a pixel with a gradient above T2.

The labeled image may contain a large number of connected components. This labeled image is again smoothed by means of a Mask to eliminate the unwanted small connected components and to reduce the small speckle noise.

Finally the spill affected area is alone extracted from the whole SAR image and by making use of the area calculation techniques; the area of the extracted phase is also calculated (f). Fig. 1, shows the flowchart used for processing the SAR images for oil spill extraction.

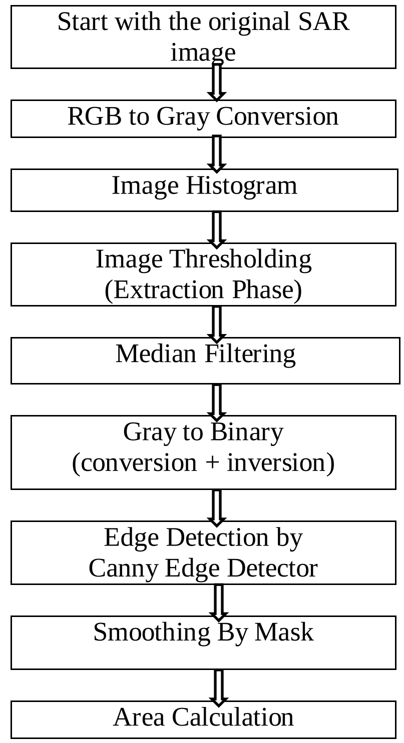
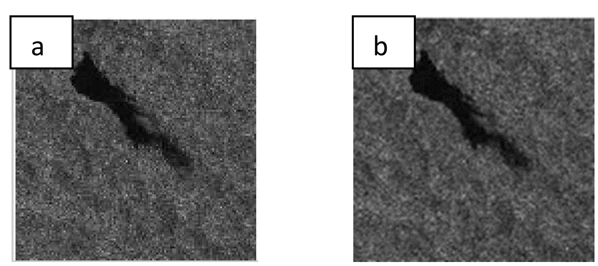


Fig 1. Oil Spill Extraction Algorithm Using SAR Image.

5. Results and Discussions

The oil spill Extraction Model was used on various SAR images recording oil spill accidents in sea water and coastal areas. Following results demonstrate analysis of SAR images taken from CEARAC database 2003. Analysis of the SAR images with the developed model shows a very good result on oil spill extraction.



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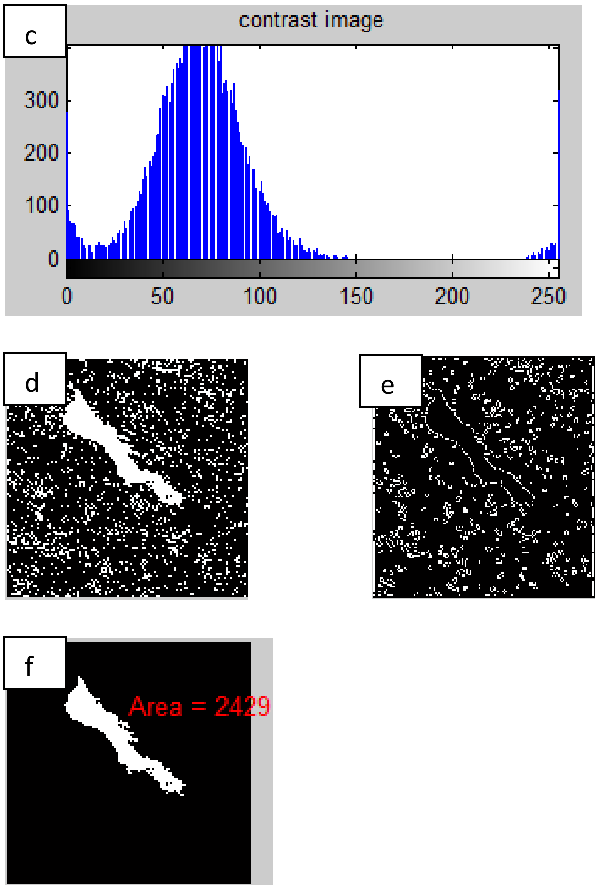

Fig 2. (a) SAR image from CEARAC database 2013 (b) Gray scaled image (c) Image Histogram (d) Inverted Binary Image (e) Canny Edge detected Image (f) Extracted Image.

6. Conclusion

The paper describes a new and efficient technique that can be very effective and helpful for extracting the oil spill affected area from the background, by making use of the SAR images. This simple method, using various digital image processing techniques, can be helpful to the researchers in this field. The future research may redesign this algorithm using neural networks [5] and other advanced digital image processing techniques, so as to obtain more accurate results. Moreover, it is also possible to recognize the type of the oil, by combining this method with several other pattern recognition techniques [4], from the SAR images.

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