Oceanologia (2017) 59, 311—317

Available online at www.sciencedirect.com

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journal homepage: www.journals.elsevier.com/oceanologia/

ORIGINAL RESEARCH ARTICLE

An improved Otsu method for oil spill detection from SAR images

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Received 29 December 2016; accepted 16 March 2017
Available online 1 April 2017

KEYWORDS
Remote sensing images;
Adaptive threshold segmentation;
Edge extraction;
Region growing

Summary In recent years, oil spill accidents have become increasingly frequent due to the development of marine transportation and massive oil exploitation. At present, satellite remote sensing is the principal method used to monitor oil spills. Extracting the locations and extent of oil spill spots accurately in remote sensing images reaps significant benefits in terms of risk assessment and clean-up work. Nowadays the method of edge detection combined with threshold segmentation (EDCTS) to extract oil information is becoming increasingly popular. However, the current method has some limitations in terms of accurately extracting oil spills in synthetic aperture radar (SAR) images, where heterogeneous background noise exists. In this study, we propose an adaptive mechanism based on Otsu method, which applies region growing combined with both edge detection and threshold segmentation (RGEDOM) to extract oil spills. Remote sensing images from the Bohai Sea on June 11, 2011 and the Gulf of Dalian on July 17, 2010 are utilized to validate the accuracy of our algorithm and the reliability of extraction results. In addition, results according to EDCTS are used as a comparator to further explore validity. The comparison with results according to EDCTS using the same dataset demonstrates that the proposed self-adapting

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Peer review under the responsibility of Institute of Oceanology of the Polish Academy of Sciences.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.oceano.2017.03.005

algorithm is more robust and boasts high-accuracy. The accuracy computing by the adaptive algorithm is significantly improved compared with EDCTS and threshold method.

1. Introduction

Oil spill events have caused serious damage to the ocean environment in the past decade. Although the magnitude of most oil spills is less than 7 tons, large spills over 700 tons are likely to degrade and destroy a variety of marine biodiversity and perturb ecosystem functioning according to data from International Tanker Owners Pollution Federation Limited (Ng and Song, 2010). Oil spill accidents have captured people's attention and should be taken more seriously.

At present, there are two methods for oil spill monitoring, SAR and optical method. Remote sensing is considered as an effective method to detect oil spills. Among satellite sensors, the optical method is useful to detect oil floating below the sea surface in terms of the changes of wavelength and sea surface reflectance (Otremba, 2016). Meanwhile, SAR is the most useful for detecting oil spills due to its wide area coverage and day/night capabilities (Garcia-Pineda et al., 2009; Liu et al., 2011; Migliaccio et al., 2012; Zhang et al., 2011). With the increasingly extensive and in-depth application of quantitative SAR images, there is a greater onus than ever placed on the remote sensing community to optimize extraction procedures. Indeed, bespoke algorithms have been developed and presented by scientists from a wide variety of different institutions. As in the earlier study, scientists researched one hundred images of offshore areas in Europe and the seasonality of oil spill patterns was summarized (Gade and Alpers, 1999; Solberg et al., 1999). The results of extraction were crude and this was a time-consuming endeavor. The early classical and effective method (Otsu) is utilized which was proposed by Otsu in 1979 (Ng, 2006; Otsu, 1979; Xu et al., 2011). For the purposes of increasing accuracy, some researchers proposed an improved and merging algorithm for the extraction of oil, which although boasting performance benefits in terms of accuracy, the threshold is single and cannot adapt to variable pixels (Mehnert and Jackway, 1997; Tremeau and Borel, 1997). In the early 20th century, scientists developed an automatic classifier for oil spill detection. A model to automate the identification of oil was operationalized and it could capture range and directional parameters by simulating the diffusion of oil (Marghany, 2001, 2004). Due to the variety of different water areas, a fast region-based detection algorithm for oil spill detection in SAR images was proposed which used a new image segmentation technique. An oil spill model was developed and employed generalized likelihood ratio test (GLRT) detection theory to improve the accuracy of oil spill detection; but when a large number of SAR images must be examined, this could be a labor-intensive task (Chang et al., 2008; Huo et al., 2010). In order to militate against these problems, a modified constant false alarm rate (CFAR) was proposed which combined an edge detection technique and CFAR theory to improve accuracy (Vikhe and Thool, 2016).

However, simple edge detection and the adaptive threshold method cannot extract spills information accurately enough; the boundary of certain oil slicks may not be closed by using simple edge detection; which caused the loss of oil information. Meanwhile, threshold segmentation may mistake some regions influenced by wind and waves, as oil spills. In this paper, we add region growing which can better recognize the gray similarity between one point and the nearby points. This method can offer greater reliability in terms of representing oil film edge information. In order to quantify the reliability of the algorithm, data pertaining to another oil spill event are utilized. Further, the oil films extracted from remote sensing images of the Penglai oil field on June 11, 2011, the Gulf of Dalian on July 17, 2010 and the North Seas on April 11, 1994 by the new algorithm are compared with results according to EDCTS and threshold method.

This paper is structured as follows. The remote sensing images and the method of extracting oil spill information are described (Section 2) followed by the results of the analysis with a focus on discussing the advantages of the new algorithm proposed herein (Section 3). Finally, some conclusions are offered which include suggestions for future research (Section 4).

2. Material and methods

2.1. Dataset

According to our requirements and recognizing the necessity of validating this new algorithm, two sets of remote sensing images are deployed in the study. The remote sensing images are acquired from the ENVISAT-1 satellite, which was launched by the European Space Agency (ESA) on March 1, 2002, and carries an active microwave instrument advanced synthetic aperture radar (ASAR). The ASAR instrument is a multi-mode sensor, which operates at C-band (i.e., center frequency of 5.3 GHz) at several polarizations (HH, VV, HV and VH), incidence angles, and in the following functioning modes: image mode, polarization mode, wide swath mode, global monitoring mode, and wave mode. The remote sensing image of the Bohai Sea (Fig. 1), the Gulf of Dalian (Fig. 2) and the North seas (Fig. 3) are both presented.

2.2. Algorithm for oil spill identification

Preprocessing and image segmentation are the most important stages for oil recognition. The grayscale image is divided