Exploring ImageJ toolbox for Oceanography:
A case study in Malacca Straits

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Abstract: The oil discharges in marinas and coastal areas has adversely affected the marine environment that has become the driving force for the early detection of oil spills to allow timely intervention. Synthetic Aperture Radar (SAR) data represents an effective tool that is extensively used for the detection and identification of oil spills in the marine environment. This paper aims at exploring the plugins available in ImageJ, a popular public domain Java image processing and analysis program at the National institute of Health (NIH), in the detection of oil spills for oceanography. As the popularity of the ImageJ open-source comes from being extensively used in biomedical and medical image processing applications, this study showed that ImageJ is a good choice for the detection of oil spills in oceanography applications throughout the extensibility capability supported by ImageJ framework.
Keywords: Image thresholding; Synthetic Aperture Radar; Oil spill detection; Oceanography; ImageJ; Image analysis.

I. INTRODUCTION

Oil pollution poses a major threat to ocean ecosystems. According to the European Space Agency, 45% of the oil spills pollution comes from the operational discharges from tankers. This is the biggest contributor to oil pollution in the World's oceans as the result of oil dumped during cleaning operations. Approximately 2 million tons of oil is introduced annually by such operations, equivalent to one full-tanker disaster every week. Only 7% of the oil in the sea can be directly attributed to accidents. Land-based sources such as urban waste and industrial discharges, which reach the ocean via rivers, are also a major contributory factor (ESA, 1998). The land Marine oil spills can be highly dangerous since wind, waves and currents can scatter a large oil spill over a wide area within a few hours in the open ocean. When oil is spilled in the ocean, it initially spreads in the water (primarily on the surface), depending on its relative density and composition. Waves, water currents, and wind force the oil slick to drift over large areas, impacting the open ocean, coastal areas, and marine and terrestrial habitats in the path of the drift (Jha et al., 2008).

Synthetic Aperture Radar has been widely used in oil spills detection due to its large coverage, independence of the day and night, and all the weather capability. These characteristics make the radar a very attractive tool for monitoring the ocean surface every few days on a global basis (Elachi, 1980). SAR is an active microwave sensor that operates in radio wave region. Radar waves are reflected by Bragg waves on the ocean and therefore, a bright image is obtained for ocean water. The oil significantly damps these waves. As a result, if oil is present in the ocean, then the reflectance is reduced. Hence, the presence of oil can be detected as a dark part in the bright image for the ocean (Brown et al., 2003). So the detection of oil spills in SAR image relies on the fact that the oil slick has a smoothing effect on the water surface and thus decreases the backscattering of the ocean surface. This creates a darker signature in the SAR images that contrasts with the brightness of the surrounding spill-free ocean, and can be interpreted by experienced analysts as a possible oil slick (Zodiatis et al., 2012).

A large number of image processing tools are available, with varied capabilities for the processing of SAR data. There are commercial software tools available including PCI Geomatica, ENVI-SARScape, and Gamma that provide powerful SAR processing solutions. There are also available software tools that provide open source image processing tools including MapReady, PolSARPro, Next ESA SAR Toolbox (NEST), and Radar Tools (RAT). MapReady version 3.1.24, accessed at https://www.asf.alaska.edu/data-tools/mapready/, is an open source tool that is provided by the Alaska Satellite Facility for processing the radar data for geospatial applications. This tool can provide full radiometric correction of terrain effects, geocodes, apply polarimetric decompositions to multi-pol SAR data, and save to several common imagery formats including GeoTIFF. PolSARPro version 4.2, accessed at

https://earth.esa.int/web/polsarpro/home, is an open source that is distributed by European Space Agency (ESA). It is a toolbox for the scientific exploitation of multi-polarised SAR data and high-level education in radar polarimetry. It includes tools for data import, polarimetric data format conversion, speckle filters, data processing, calibration, and Pol-In SAR data processing. It can also offer the possibility to integrate with external software tools. The Next ESA SAR Toolbox (NEST) can be lunched directly from PolSARPro software, thus providing all the functionalities offered by the NEST Software. NEST version 5.1, accessed at https://earth.esa.int/web/nest/home, is an ESA free and open source toolbox suite for reading, processing, analysis and visualization of SAR data. NEST provides basic and advanced tools for SAR user community, such as an absolute calibration, automatic co-registration of detected and complex products, multi-looking, speckle filtering, external precise obit ingestion, geocoding, mosaicking and a Product Library Metadata Database, etc. It also offers a collection of routines for oil spill and ship detection, and wind field estimation. In addition, a fully integrated and featured InSAR processor is being implemented into NEST. Finally, Radar Tools (RAT) version 0.21, accessed at http://radartools.berlios.de/, is open-source software that is under further development at the Department of Computer Vision and Remote Sensing of the Technical University of Berlin. It is a small collection of tools for advanced image processing of SAR remote sensing data that includes features for speckle filters, polarimetric basis transforms and decompositions, as well as some interferometric routines like coherence calculation and interferogram filtering.

In this study, the power of ImageJ is exploited that is found to be adequate for oil spill detection using SAR data. ImageJ accessed at http://imagej.nih.gov/ij, is a public domain program developed by Wayne Rasband at the National Institute of Mental Health. It is based on Java and thus available for Windows, Mac and Linux operative systems. It is free and an open source program designed for scientific image processing and analysis. It is highly extensible, with thousands of plugins and macros for performing a wide variety of tasks, and a strong, established user base. It is mainly used for microscope image analysis, but can be useful for astronomical data analysis.

While ImageJ (and Fiji, derivation and distribution of ImageJ with many bundled plugins) is commonly used as a research and development platform in biology and medical imaging (Abramoff et al., 2004; Collins, 2007; Schneider et al., 2012), the capabilities of ImageJ/ Fiji is investigated in this study to perform the image processing segmentation algorithms using the BioVoxxelToolBox and determine the best segmentation algorithm for oil spill detection in SAR data. The BioVoxxel Toolbox is maintained by Jan Brocher, freely available and downloadable at http://fiji.sc/BioVoxxel_Toolbox.

In this study, Malacca Straits was selected as the study area. Digital image processing techniques such as filtering and thresholding segmentation methods were applied using ImageJ/ Fiji plugins to discriminate the oil spill occurred in 1997.

II.   STUDY AREA AND DATA USED

The RADARSAT data were acquired on 26 October 1997. This RADARSAT fine mode image with C band and HH polarization covered the Malacca Straits between 1020 16' E to 1030 48' E and 10 16' N to 20 13' N. According to Mohd et al (1999), the oil spill occurred in 26 October 1997 due to a collision in Singapore between two ships; MT Orapin Global and MV Evoikos. Mohd et al (1999) reported that this collision caused 25000 tons of crude oil to be spilled into the sea.

III.   METHODOLOGY

This section presents the main steps of oil spill detection shown in Figure 1, is summarized as follows:
1. A preprocessing phase by applying image enhancement technique using the median filter to suppress speckle noise in the SAR image.
2. A thresholding segmentation phase for the detection of possible oil spills by running the 16 automatic global thresholding methods according to user given reference intensity over the SAR imagery using the Auto Threshold plugin.
3. The assessment phase for producing the quality quantitation evaluation of these methods that helps in the decision of the best threshold method.
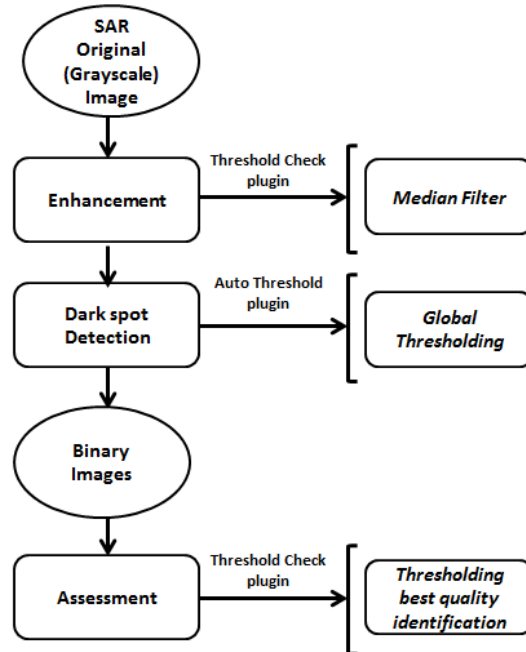
Figure 1.Workflow of oil spill detection

3.1. Image Preprocessing
The following steps are performed for the image preprocessing to ensure that the acquired grayscale raw SAR data is ready for further processing:
1. Geocode the acquired date to UTM, zone 47 North and Datum, WGS-84.
2. Cropping the image for minimizing the data processing, consuming the time, and the data space saving as shown in Figure 2.
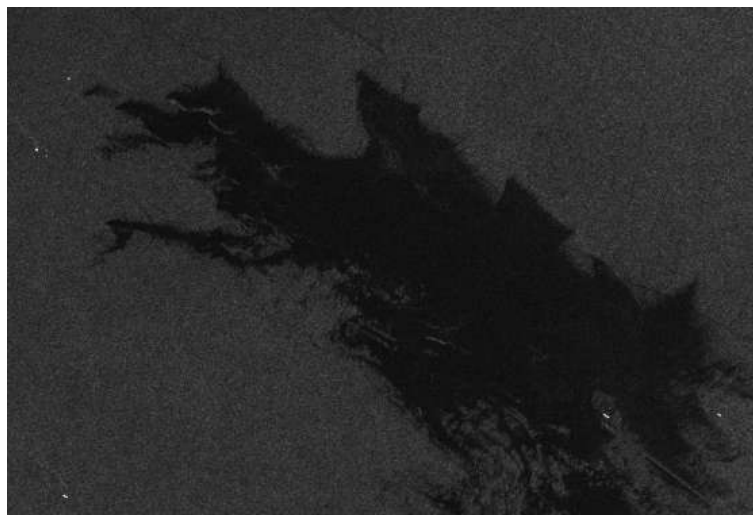3. No radiometric correction was required.

Figure 2.A subset of Malacca Straits SAR image

3.2. Image Enhancement
A 3×3 median filter is used to remove preserves boundaries that is proved to be better than simple mean filter. The median is calculated by first sorting all the pixel values from the surrounding neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value. In case the neighborhood under consideration contains an even number of pixels, the average of the two middle pixel values is used. The pixel value is replaced with the median of itself and its adjacent neighbors.

The median filter can be found in ImageJ using the menu command *Process>Filters* that allows the use to change the kernel size of the filter. The same output can be also produced using the menu command *Process>Noise>Despeckle* that is of 3×3 median filter.

3.3. Dark Spot Detection

After the filtering process, 16 automatic global thresholding methods were run on the SAR data from the Auto Threshold plugin available in ImageJ/ Fiji, developed by Gabriel Landini and available at http://fiji.sc/Auto_Threshold.

This step involves applying the automatic global threshold methods over the grey level SAR data to discriminate the oil spills from its surroundings, namely the default (the original method of auto thresholding available in ImageJ), Huang (Huang and Wang, 1995) which minimizes the measures of background/ foreground fuzziness, Intermodes (Prewitt and Mendelsohn, 1966) with iterative histogram smoothing, IsoData (Ridler and Calvard, 1978) which iteratively update the threshold according to background and foreground intensity means, Li (Li and Tam, 1988) for cross entropy maximization, Mean (Glasbey, 1993) for using the mean of grey levels as the threshold, MinError (Kittler and Illingworth, 1986) that is the iterative implementation of Minimum Error Thresholding, Minimum (Prewitt and Mendelsohn, 1966) that is in similar to Intermodes method, Moments (Tsai, 1985) for selecting a threshold at which the resulting binary images have the same first three moments, Otsu (Otsu, 1979) for minimizing the intra-class variance, Percentile (Doyle, 1962) for using the median of the histogram, Renyi's Entropy (Kapur et al., 1985), Shanbhag (Shanbhag, 1994) to MaxEntropy (Kapur et al., 1985), Triangle (Zack et al., 1977), and Yen (Yen et al., 1995) based on a maximum correlation criterion.

In these types of methods, the threshold values are selected by histogram analysis. A histogram is computed for the image intensity values, color values or any other feature values and analyzed to determine a threshold setting to separate the object from its background. The histogram-based methods are simple to understand, easy to implement and are computationally less involved. As such, they serve as popular tools in a variety of image processing applications such as automatic target recognition, oil spill detection, text enhancement, inspection, and biomedical image analysis (Lee and Chung, 1990). However, all the histogram-based methods have a common drawback because they take into account only the histogram information. As a result, such methods are only good at thresholding images which contain significant degrees of contrast between the objects and its background and in which the objects do not occupy to small a portion of the image (Zhong, 1994).

After thresholding, these methods are then evaluated to identify the one that performs the best. The quality of thresholding technique is a critical issue depending on the type of the thresholding technique and the variable image contents, different histogram shapes as well as specific user requirements regarding the extracted image features. In order to analyze the performance of the thresholding techniques, there are different evaluation methods used to measure the efficiency of the thresholding techniques.

Jan Brocher (2014) proposed a new color-coding-based method which facilitates automatic qualitative and quantitative assessment of the thresholding methods based on the user selection of the pixel intensity as a reference point. This method represents a quick and reliable, quantitative measure for relative thresholding quality assessment for individual images. It can be also applied to all available automatic thresholding methods without any limitation to specific software, image contents or binarization performance (Brocher, 2014). This method is already implemented as an ImageJ/Fiji Java-plugin that is publically available as Threshold Check plugin in the BioVoxel toolbox inside the ImageJ/ Fiji at http://fiji.sc/BioVoxxel_Toolbox#Threshold_Check. This plugin was run on the 16 automatic global thresholding outputs in order to decide which method performed the best for oil spill detection in respect to the reference point selection.

IV.   RESULTS AND DISCUSSION

Figure 3 presents the thresholding results outputs obtained by running 16 automatic global thresholding methods available in Image/ Fiji plugins over the SAR image. The Auto Threshold plugin offers the **Try all** option that produces a montage with the results from all methods as shown in Figure 3. This facilitates the visual inspection and the way to explore how the different algorithms perform on a particular image.
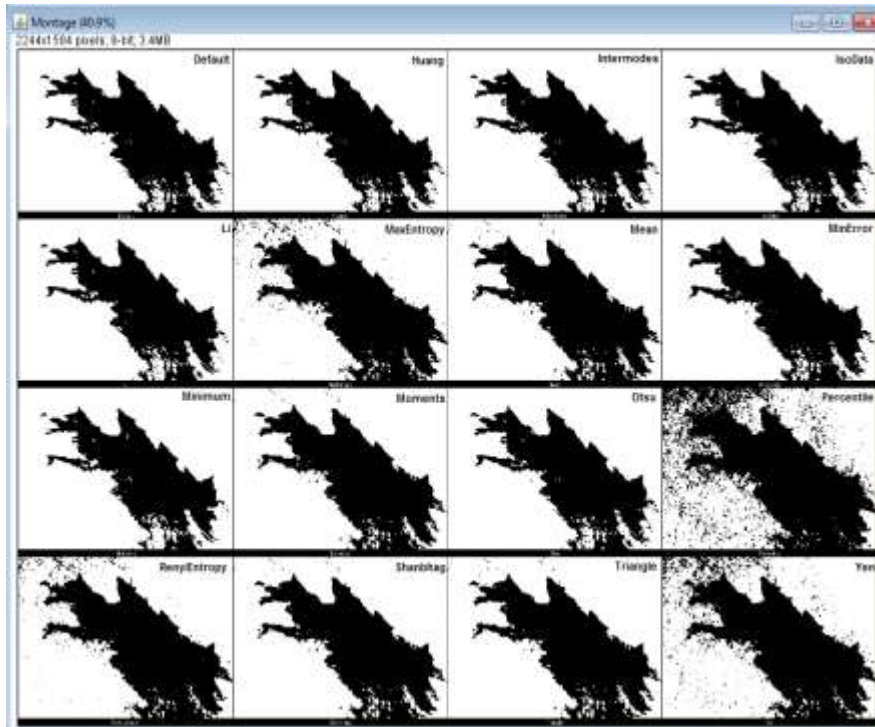
Figure 3.Results of 16 automatic globalthresholding methodsfrom ImageJ using Auto Threshold plugin

Following is the relative quality quantitation of all thresholds according to a user given reference using the Threshold Check plugin (refer to Figure 4). The reference value is critical for the performance of the quantitative evaluation so that it has to be selected as close as possible to the intensity value which should still be recognized and extracted. This makes it easy to detect the "optimal" threshold especially when the results are apparently similar.
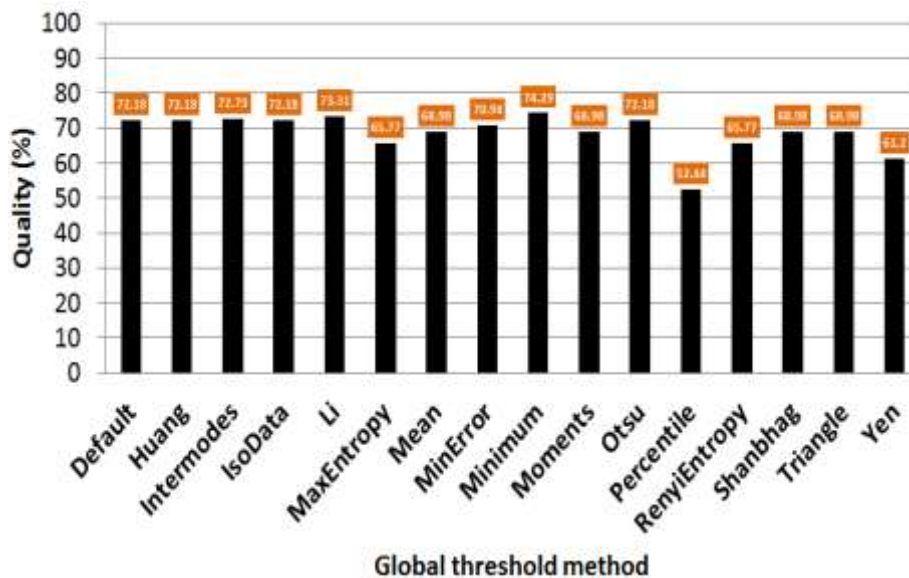

Figure 4. Performance evaluation of 16 automatic global thresholding methods using Threshold Check plugin

According to the quantitation evaluation results, it was found that the thresholding techniques present satisfactory results, and all of them detect the small details of the objects (oil) from the background. The Minimum technique showed the best method on thresholded bimodal images as it provides a quality of 74.29%; it is the most commonly used global thresholding technique that assumes a bimodal histogram.

V. CONCLUSION

ImageJ has evolved to a powerful image processing tool in science and professional environment. The contribution of user community in the update process and the continuous release of new plugins, is keeping it close to new demands. In this study, The Auto Threshold and Threshold Check plugins available in ImageJ/ Fiji facilitates the visual inspection and the quantitative performance analysis to define the best result of the 16 automatic global thresholding methods according to a user given reference intensity. The results ensure the efficiency of these thresholding methods on the thresholded bimodal images, but the Minimum method showed the best method in the separation of the dark spots from its background. Thus, ImageJ/ Fiji plugins proved to be effective in the detection of the oil spill for oceanography using Synthetic Aperture Radar (SAR) satellite images.

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