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Ocean Surface Target Detection to Support Search and Rescue Mission Using Freely Available Satellite Data: Malaysian MH370 Airline Tragedy, a Case Study

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Abstract: This paper presents a simplified approach to detect objects on the ocean surface to aid search and rescue operation using free remote sensing data. In this study, we employed the compressed multi-spectral worldview-2 image to RGB JPEG 2000 file format. The objective is to find a simple method that can be used during search and rescue operation to detect objects on Ocean surface while onboard search vessels without the need for complex image processing tasks. We experimented with six different adaptive filters: Lee, Enhanced Lee, Frost, Enhanced Frost, Gamma, and Kuan filters. For each of the filters, three different kernel sizes, 3x3, 5x5, and 7x7 were tested. The result shows that Enhanced Frost with 7x7 kernels provides better indication of the presence of object on ocean surface. This indicates that without complex image processing and analysis, foreign objects on Ocean surface can be detected.

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Keywords: Ocean physics; remote sensing; disaster; adaptive filter; target detection

1. Introduction

Remote sensing using satellite and airborne sensors is a powerful, operational tool for monitoring coastal zone, providing accurate, large-scale, synoptic environmental information essential for understanding and managing marine ecosystems. Optical multispectral or hyperspectral sensor data allows the assessment of in-water properties, such as suspended debris or phytoplankton concentration, benthic substrate type, vegetation composition (Murugaboopathi, Rajalakshmi, and Jayanthan, 2014). This becomes very crucial for detection of assumed debris of MH370. Remote sensing has played the most vital roles in the search operation for MH370 from the first day of disappearance.

The international passenger flight left from Kuala Lumpur International Airport to Beijing Capital International Airport. The flight which took off at 12:41am MST on Saturday, 8 March (16:41 GMT, 7 March) from KLIA with 227 passengers and 12 crew members of 14 nationalities on board and was supposed to land at Beijing commercial Airport at 6:30am (22:30 GMT) was reported to have lost contact in less than an hour of take off after sending its last ACARS transmission (Aircraft Communications Addressing and Reporting System - a service that allows computers aboard the plane to "talk" to computers on the ground). According to military radar data and radio "pings" established between the aircraft and an Inmarsat satellite (a British satellite telecommunications company, offering global mobile services), investigators arrived at a conclusion that it had first headed west across the Malay Peninsula, then continued on a northern or southern track for approximately seven hours causing more search efforts to be focused on the southern part of the Indian Ocean headed by the Australian Maritime Safety Authority.

Earlier search and rescue investigations reported oil slicks detected by the Vietnamese navy from radar contact with the aircraft off the coast of Vietnam was later tested negative for aviation fuel by the Vietnamese air force. There was also a report that debris measuring about 140 km (87 mi) in south-west of PhúQuốc Island of Vietnam was discovered.

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In addition, four large orange-colored objects found by search aircraft described by media as "the so far most promising lead" was later confirmed by the Royal Australian Air Force pilot, Flight Lieutenant Russell Adams, to be fishing equipment. Another team investigating the incidence used the Chinese satellite Gaofen 1 images. From the analysis of the imagery, a floating objects measuring about 24 × 22 meters (79 × 72 ft.) was sighted in southern part of the Indian Ocean. The identified object was assumed to be debris of the airplane (China National Space Administration). This further intensify search but this time around narrowed to the southern part of the Indian Ocean, by combing the surface and floor of the ocean employing all available high-tech search devices from different countries. Describing the complexity of the area, the Australian Prime Minister, Tony Abbott, said that Indian Ocean is "as close to nowhere as it's possible to be". This emphasizes intolerably harsh environmental conditions notorious for strong winds, inhospitable climate, hostile seas, and deep ocean floors. Two main preprocessing operations, image enhancement and filtering were entirely used in this study. Considering the cost and time required in deploying Hi-Tech search and rescue equipment for disaster of that nature, this study examines the use of freely available remote sensing data, to facilitate field operation using simple but yet effective processing technique without complex image analysis.

2. Challenges of Rescue Operation in the Ocean

The Air and Sea research and rescue missions faced great challenges due to the fact that the Indian Ocean as the world's third largest ocean, has an average depth of more than 12,990 feet, where investigators suspect that missing MH370 may have collapsed, is one place where any plane can crash without being spotted by a ship or being plotted by radar or even a satellite picking it up. The physical and oceanographic characteristics of this environment pose the greatest challenges on the search and rescue operations on this area.

First is the roaring forties referred to as the belt of ripping westerly winds, aided by the Earth's rotation, between roughly 40 and 50 degrees latitude in the southern hemisphere (Samenow, 2014). The searchers will fight against "the Roaring Forties", which circle the earth usually, around 30-40mph, moving west to east (TheManilaTimes, 2014). Therefore the only remedy is to use physical eyes or binoculars on these objects – though eyeballs will struggle in poor visibility." The high winds, shifting temperatures and varying pressure mean a lot of sudden, powerful storms, bringing with them huge swells up to 20-30ft (6-9m) high, heavy rain and bouts of dense fog (Figure 1). Authorities suspended search efforts severally because of dangerous weather.

Another difficulty is the Ocean hydrography. The physical features of a water body (includes the shape and features of the shoreline, the characteristics of tides, currents, and waves) and the physical and chemical properties of the water itself. The Indian Ocean is well known for its huge amount of trash swirling around its currents, making false leads likely (The Manila Times, 2014). There are large-scale vortices that can go anyway, depending on how large the object is and if it has some buoyancy; if it is suspended it could be carried quite some distance, perhaps even more, because ocean currents can be stronger than wave-induced currents (Michaud et al., 2012). The last issue is spatial extent - The predominant winds and ocean currents in this part of the Indian Ocean would generally move the debris in different directions from the crash site. The speed at which the debris would move would depend on the strength of the winds and the speed of the various surface currents active in that part of the ocean. This left searchers with a huge area covering an area of 600,000 km^2 (230,000 sq. mi) to comb.

3. Material and Methods

Indian Ocean is a body of salt water, covering approximately 20% of the total ocean area of the world. It is the smallest and physically most complex of the world's major oceans. Geographically, part of the search area selected for the study lies between latitude 2^oN and 33^0S and longitude 54^oE and 105^0E (Figure 2). It stretches for more than 6,200 miles (10,000 km) between the southern tips of Africa and Australia and has an area of about 28,360,000 square miles (73,440,000 square km). The average depth of the ocean is 12,990 feet (3,960 meters), and its deepest point, in the Sunda Deep of the Java Trench off the southern coast of Java, is 24,442 feet (7,450 meters). The Indian Ocean is bounded to the north by Iran, Pakistan, India (which has the average area coverage and the originator of the ocean name) and Bangladesh; to the east by Malay Peninsula, the Sunday Islands of Indonesia, and Australia;

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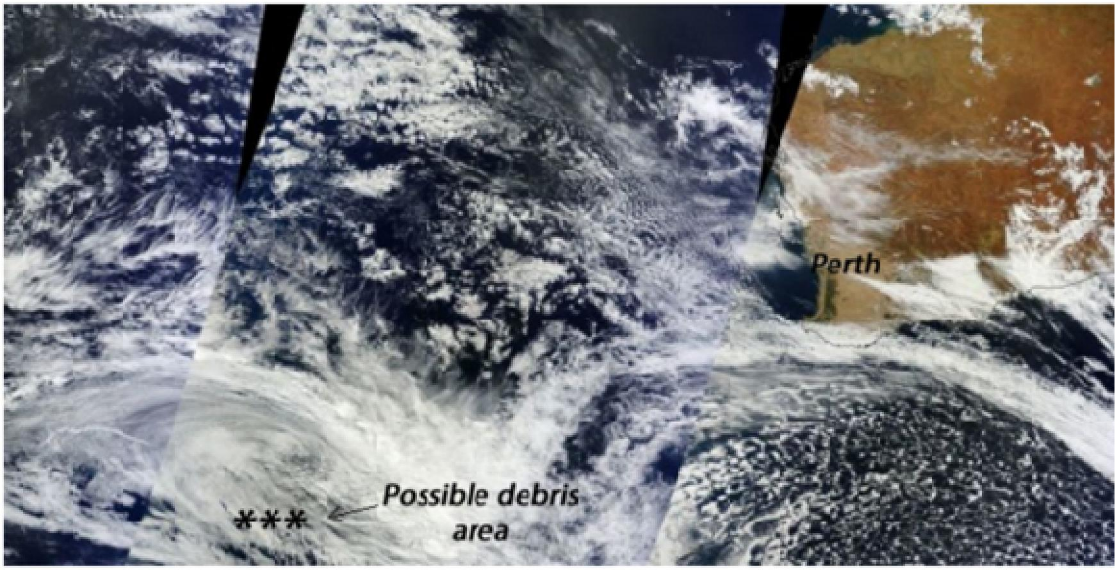
Antarctica to the south; and to the west by Africa and the Arabian Peninsula. It joins the Atlantic Ocean south of the southern tip of Africa In the southwest and its water mingle with the pacific to the east and southeast. Its major contributions are the Arabian Sea (with the Red Sea, the Gulf of Aden, and the Persian Gulf), the Bay of Bengal, and the Andaman Sea.



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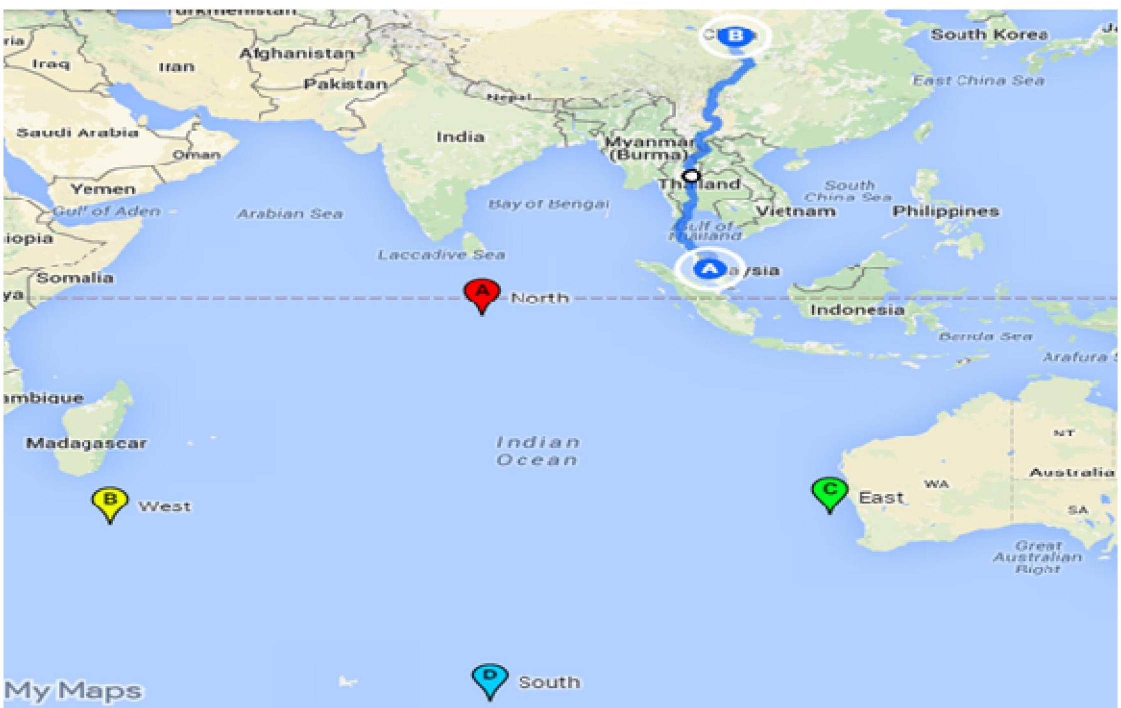

Figure 2: Map of the Indian Ocean captured from GoogleMap: the blue line connecting A and B is the route connecting Malaysia and China.

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In this study, we makes use of optical remote sensing data (worldview-2) downloaded from the Tomnod (www.tomnod.com). Tomnod provides high resolution multispectral worldview 2 satellite imagery of approximately 0.5m resolution of the study area captured on 16th March, 2014. Worldview-2 is powered by DigitalGlobe. It has 8 multispectral bands and a panchromatic band of 1.85 meter and 46cm spatial resolutions respectively (DigitalGlobe, 2009). The image as applied in this study is a compressed version to a single RGB band for efficient storage and web display using loose-less compression method (Fung, Fraser, and Gauthier, 1998). With its characteristic high spatial accuracy and spectral properties, it is found to be suitable for this type of application because no complex image manipulation is required. Image processing and analysis was entirely done in ENVI.

Data processing started with image enhancement. Image enhancement is necessary to remove un-necessary noise, defects caused by image acquisition, and geometric distortion to improve the visual effects of the original image for better computer processing and accurate digital analysis (Kotkar and Gharde, 2013). Following the enhancement operation, we employed filtering. Image collected with imaging systems cannot be used directly for digital quantitative analysis due to spectral corruption by random variation in intensity, variation in illumination, or poor contrast that must be eliminated for vision processing. Digital manipulation of image spectral produces different effects on the output image. Hence we experimented with many filtering algorithms in this study in order to identify foreign objects on the Ocean surface that could be used as possible link for rescue operation. Therefore, we used Lee, Enhanced Lee, Frost, Enhanced frost, Gamma, Kuan filter, which are the most widely used adaptive filters (Tsymbal et al., 2005).

Lee and Enhanced Lee - The enhanced Lee filter is an improvement of the Lee filter that reduces noise in image effectively by preserving image sharpness and characteristics (Jaybhay and Shastri, 2015). Enhanced Lee requires a damping factor that defines the extent of smoothing which by default is 1.0 but the greater the damping factor value the more the smoothing. At the same time, increase in kernel size have significant effect on the image visualization (Masoomi, Hamzehyan, and Shirazi, 2012) as it suppresses the image noise and make the object more visible. This, eventually, produces smoothing level in a homogeneous cover that assists object detection with this high pass filter (Hatwar, 2015).

Frost and Enhanced Frost - The Frost filter reduce image noise while preserving important image features at the edges with an exponentially damped circularly symmetrical filter which uses local statistics within individual filter windows (Vanithamani and Umamaheswari, 2010). Like the Enhanced Lee, Frost also need damping factor value to define the extent of exponential damping (Stella, 2013) but contrary to the former, the smaller the value of the damping factor, the higher the smoothing ability and filter performance. The enhanced Frost reduces the image noise much more effectively by preserving image sharpness and characteristics than any Frost filter and enhances object visualization (Shanthi and M.L. Valarmathi, 2011).

Gamma and Kuan - Both filters have similar characteristics in terms of image noise reduction and edge preservation but they differ in assumptions of the data structure. Gamma assumes that the data is gamma distributed and the pixel value of the output filtered image is computed based on the local statistics (Deepika, V., and Srikanth P., 2014). Kuan transforms the multiplicative noise model into an additive noise model but uses a different weighting function (Argenti, Lapini, Bianchi, and Alparone, 2013). Similar to the Gamma filter, output pixel values are calculated based on the local statistics.

Adaptive filters accommodate changes in local properties of the terrain backscatter and reduce noise while preserving the edges (sharp contrast variation) (Wang, Ge, and Xiaojing, 2012). The noise is modeled as being stationary; however in this case the target signal is not stationary since the mean backscatter changes with according to the ocean velocity and other hydraulic characteristics. The analysis focused on producing a clearly identifiable image of the assumed debris captured from the assumed debris from MH370 wreckage using kernel of varying sizes (3x3, 5x5, and 7x7). Kernel size determines the degree of smoothing.

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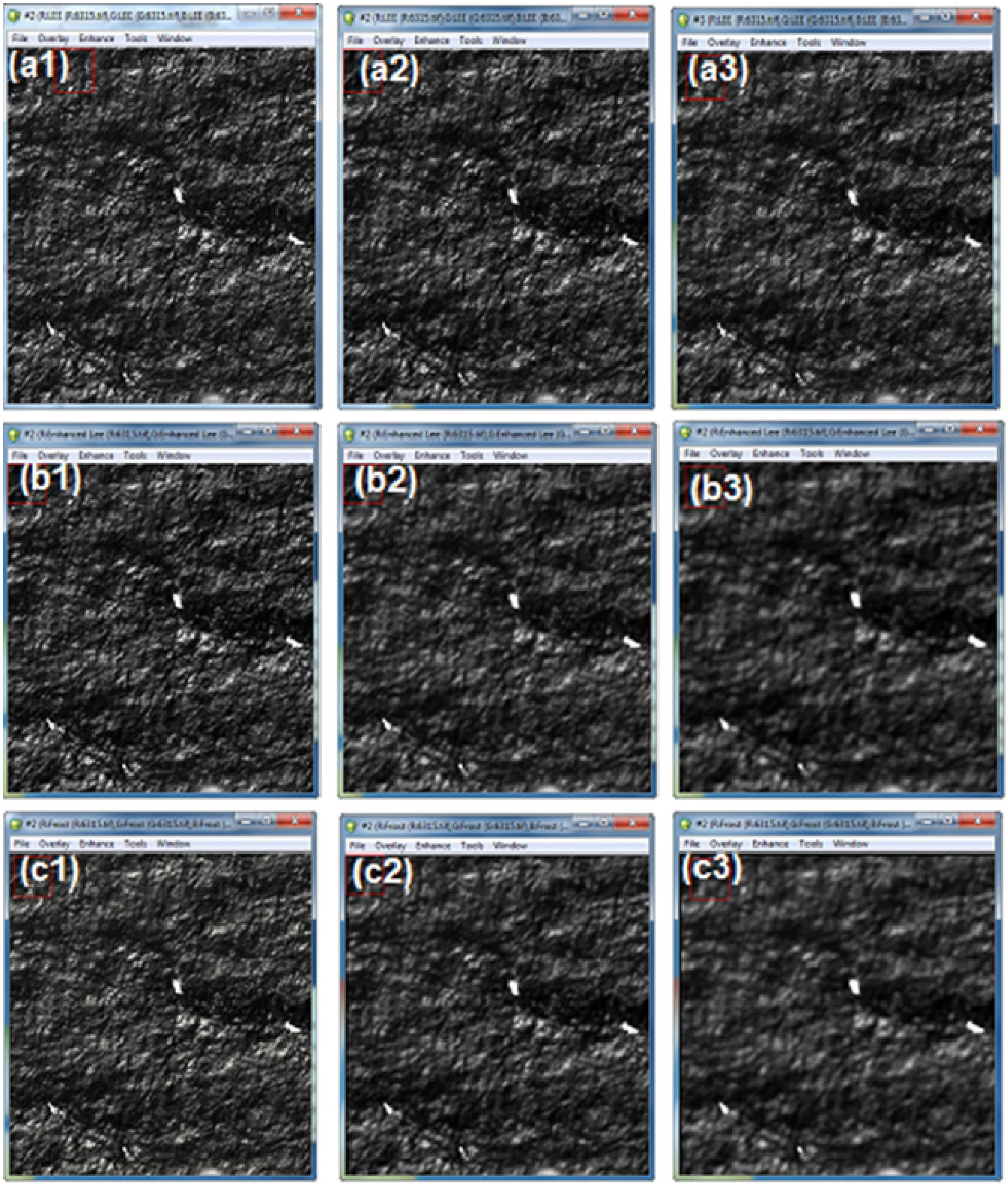

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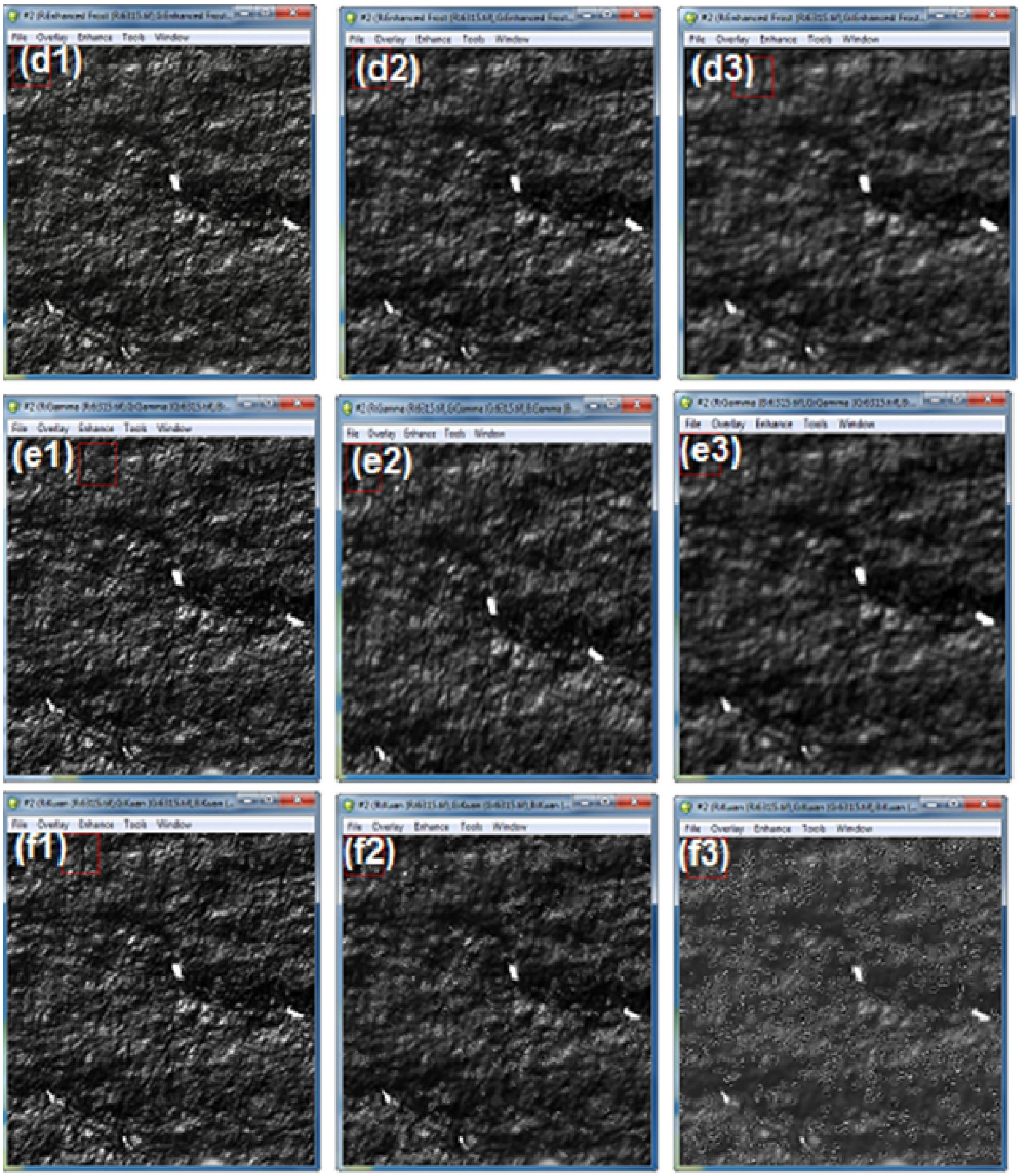

Figure 3: Result of filters using 3x3, 5x5, and 7x7 kernels. (a) Lee filter (b) Enhanced Lee filter (c) Frost filter (d) Enhanced Frost filter (e) Gamma filter, and (f) Kuan filter.

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4. Results

Figure 3 is the experimental results of each filter using three different kernel sizes as earlier mentioned. The result analysis was done on the bases of the performance of each method and examined with result published from hi-tech rescue systems during the intensive global search for the wreckage. The outputs are arranged in increasing order of kernel sizes.

5. Discussions

The result of this experimental study is first discussed based on the behaviour of the kernels with each filter as displayed in Figure 3. Generally for all the filters, increase in the kernel size increases the level of smoothing but it can be observed that 3x3 and 5x5 kernel sizes displays similar pattern in terms of visual appearance for both the background pixels and foreign objects. As opposed to high frequency image that characterizes vegetated and urban environment, ocean surface has low frequency with relatively uniform tone that makes it easier to amplify contrasting objects on its surface. 7x7 filter size increased the level of smoothening, suppressing the background to highlight targets foreground targets (Wang et al., 2012). Although in quantitative remote sensing analysis, smoothening of the image spectral results to loss of information content[13], nevertheless for target identification on ocean surface for search and rescue operation, spectral information loss does not affect target identifying and locating such targets.

In all the filters, except Kuan, 7x7 window sizes produced better visualization and target identification than 3x3 and 5x5 kernel sizes. Kernel size 7 increased the level of smoothing while it preserves the edge of the objects in the image that differs from the background ocean surface (Jaybhay and Shastri, 2015). For Kuan filter, both 5x5 and 7x7 filtered images are noisy making target identification difficult. Kuan filter changes the multiplicative noise model into an additive noise model similar to the Lee filter but applies a different weighting function replaces the pixel of the filtered image with a calculated value based on the local statistics (Hatwar, 2015). This results in increase in spectral noise with increasing kernel size. On the other hand, Enhanced Frost exhibits the best performance for target and identification based on qualitative assessment. Furthermore, the algorithm balances the background suppression of ocean surface uniformly and enhanced the contrast of foreign objects of the surface (Figure 3). In addition to identifying ocean surface objects, we observed that all the filters maintain good quality edge preservation (Masoomi et al., 2012).

To validate the result of this study, we used qualitative approach. This involve comparing in space and size the detected object from our result with the widely published result of assumed detected debris using hi-tech search and rescue system published on the 16th March, 2014 by Chinese Gaofen-1 satellite (Figure 4b). The result indicates that our detected object coincides precisely with the published report in space and dimension through visual assessment of both results (Figure 4).

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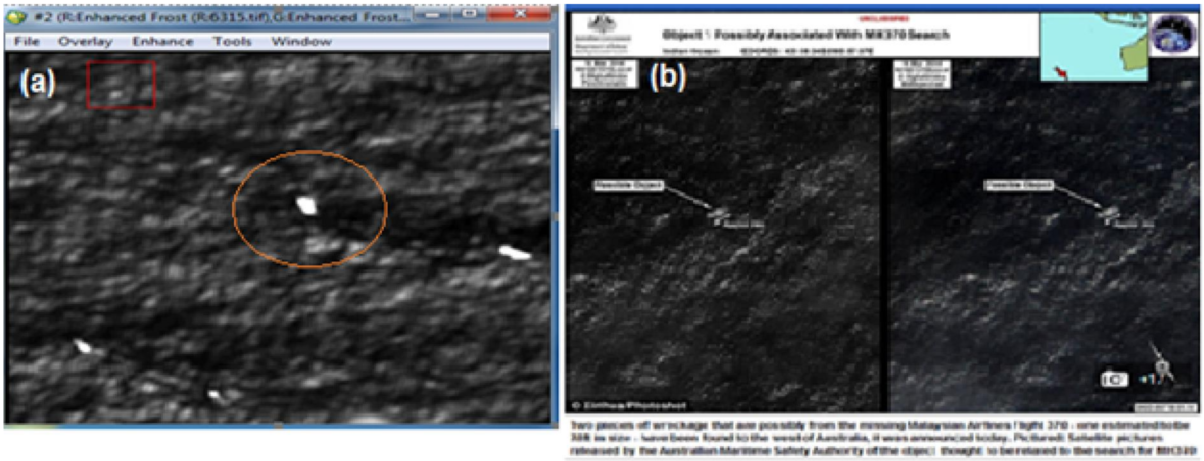

Figure 4: Comparison of result of enhanced frost with Gaofen-1. (a) 7x7 Enhanced frost filtered image and (b) Chinese Gaofen-1 satellite debris location published on the 16th March, 2014 by Submarine matters.

6. Conclusion

The disappearance of the ill-fated Malaysian Carrier, MH370, and the subsequent conflicting report of its whereabouts generated heated debate as to what role a simple remotes sensing approach using freely available satellite data can offer to support search and rescue efforts. This study provides indication of the likely role the involvement of remote sensing experts could be during search and rescue in Ocean environment. Unlike the standard remote sensing image processing, where spectral information take preeminence in result delivery, the loss of this information in a homogenized land cover type, as demonstrated in this work, increases the detectability of objects. So the larger the kernel size the smoother the background spectral and, therefore, the better the visibility of foreground targets. Although the approach is effective in the Ocean environment, it may not be applicable in urban environment because of the high frequency associated with complex mix of land cover features

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Compressed WorldView-2 RGB image used in this study is made freely available by Tomnod, a project owned by Colorado-based satellite company, DigitalGlobe that uses crowd sourcing to identify objects and places in satellite images. We thank Prof. Dr. Shattri mansor of Geospatial Information Science Research Center (GISRC), UPM, for his valuable contribution and inspirational advice on this work.

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