Determination of The Ship Motion Direction with Digital Image Processing on Sea Water Surface to Avoid Collisions

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Abstract. As the largest archipelagic country in the world, Indonesia has 17,499 islands from Sabang to Merauke. There is a country with an area of water greater than the land area. Data on shipping accident investigations from the National Transportation Safety Committee (NTSC) throughout 2010-2016 of fifty-four accident cases at sea, seventeen of which were accidents caused by collisions on ships in Indonesian waters. This is equivalent to twenty percent of accidents that have occurred, a human error causes as many as 80% of collision accidents from the crew or people in the sea transportation system, and natural factors or machinery cause only a few. The success of this research aims to avoid ship breaking, by giving directions on the direction of the ship obtained by the results of digital image processing. This study proposes a digital image processing model on sea surface using object recognition. It used the morphological operation in the preprocessing stage; this method can remove non-uniform illumination and reflection in sea surface. Then, noise in the image data will decrease. The result of this object recognition will be used to determine the direction of ship movement. Experimental results with our own dataset verify the high efficiency of our proposed method.

1. Introduction

Ship accidents are unexpected events. This accident can be caused by technical, natural disasters, or human negligence. Twenty percent of accidents are ship accidents that occur due to collisions. Collision accidents are caused by human error, which is around 80% [3]. Based on the National Transportation Safety Committee (NTSC), in the period from 2010 to 2016, the number of accidents in the Indonesian sea was fifty-four accidents. Whereas, seventeen of which were accidents caused by collisions [3].

The incidence of ship accidents caused by human negligence can be reduced by using technological developments, especially collision accidents. One technology that can be used to avoid collisions is using the object recognition model for collision avoidance. This method uses digital image processing on the sea surface to determine the ship motion direction. Image processing is a visual data processing process. The process of taking visual data using a camera. This camera was placed on the ship. Image data will be analyzed to detect objects in front of the ship. When an object was detected in front of the ship, it will display information to avoid the object by changing the direction of the ship. So, no collision will occur.
The objects recognition system for collision avoidance in this paper uses the image processing model. The first step is Image acquisition. This process is the initial process of image processing to get images. Each picture has its characteristics. So, features cannot be general but are very dependent on the model and image object used. The basic feature used in this study is the color feature. The second step is preprocessing the image data. This process is for enhancing digital images. The segmentation process is the third stage. It is used to distinguish between Foreground and background. The next step is object recognition. This process is to identify objects in front of the ship. Then the results of this process will result in determining the direction of the ship whether the direction of the ship must turn or stay straight.

Many researchers studied and proposed object detection for image-based navigation on an unmanned surface vehicle. Wang proposed improvement obstacle detection system for unmanned surface vehicle in real-time based on a vision [4][5]. Yang proposed ship detection using sea surface analysis based on image from optical satellite [7]. Xin et al, Based on the morphological processing method and the template matching, a combined method for detecting sea surface targets is proposed. In this method, a possible target region can be obtained through morphological open-minus-original operation, and then targets can be located exactly with template matching method [8]. Bobkov et al, propose a method for navigation of autonomous underwater vehicle based on visual odometry about the conditions of the local maneuvers. The method is based on the SLAM algorithm for stereo images and recognition algorithm for re-visited places. The operation of the algorithm for places recognition is based on using the virtual network for coordinate binding, which is constructed at the time of vehicle motion [9][10].

This study proposes a digital image processing model on sea surface using object recognition. It used the morphological operation in the preprocessing stage; this method can remove non-uniform illumination and reflection in sea surface. Then, noise in the image data will decrease. The result of this object recognition will be used to determine the direction of ship movement.

2. Research Method
The object detection system process that is categorized as obstruction runs in several stages, as shown in Figure 1. When the system is running, the system will capture images in real-time while taking pictures. When the resulting image is at an appropriate angle, the image will be analyzed at the stage of preprocessing, object detection, and object filter to obtain object data that is categorized as an obstacle. The results of the analysis are then used as a reference for the direction of the ship's motion.

A. Image acquisition
Image acquisition aims to determine the information needed and the method used. This stage starts with the process of shooting objects until changes to digital image form. Image acquisition results are determined by the ability of the sensor to capture image information.

B. Preprocessing
At this stage the process of improving image quality is done, reducing noise, and remove Reflection on the sea water surface, The steps in this stage are as follows
1. Resize Image, Suppose the stereo camera is calibrated, and the origin HD images with size W x H are rectified. Given the left and right rectified images, we first resize them to relative small size, then the method of [6], which approximates the sea as an exactly planar, is applied to estimate the sea surface. An image height of 600 pixels, a value of 600 pixels is obtained for the upper limit of the segment to represent a distance of 3 meters.
2. Remove all the foreground using morphological opening. The opening operation removes small objects that cannot completely contain the structuring element. Define a disk-shaped structuring element with a radius of 15. This radius is optimal with the size of the image that has been changed.

3. Subtract the background approximation image, background, from the original image, I, and view the resulting image. After subtracting the adjusted background image from the original image, the resulting image has a uniform background for analysis.

C. Segmentation
   The segmentation process is used to distinguish between foreground and background. In this study the segmentation method used is thresholding, with the threshold value used is the value of the upper and lower limits of R (red), upper and lower limits of G (Green), and the upper and lower limits of B (Blue) that have been normalized in the previous process. It’s important for threshold selection of the binary
image. There are two methods for threshold selection, adaptive threshold and global threshold [11]. The global threshold is suited for the image with an even gray background and the double peak feature [12]. The steps in the segmentation stage are as follows:
1. Determine the start value x, start y, the x limit and the y limit of the image according to the cropping image stage
2. Calculate the RGB normalization value in x, y pixels
3. Check for each RGB normalization value
4. If the RGB normalization value is included in the range threshold, then change the color of the x, y pixels with white, and if it is not included in the range threshold then change the color of the x, y pixels in black
5. Save the segmentation results in the array

![Figure. 3 After segmentation](image)

### D. Object Detection

Object detection is a process to identify objects contained in the segmentation results. An object is a collection of foreground pixels that are close together in a range of elements of 8 neighboring. The detection process is carried out using the Connected Component Analysis method, where each object that has been identified as a different label value. This value will be used for the filtering process at a later stage. The steps in the object detection stage are as follows:
1. Determine the central pixel based on the pixel value in the segmentation process
2. Get the pixel value of the array
3. Check the label and the pixel value of the array
4. If the label and the pixel value of the center are 0, then change the pixel color to a certain color and label the pixel
5. Check the neighbors from the central pixel with 8-connectivity.
6. Check the neighboring pixels found
7. If the neighbor's label and the pixel value is 0, then change the pixel color to color according to the center pixel and label the pixel
8. Change the neighbor pixel to the central pixel
9. Re-start the checking process at number 5 until all pixels are labeled
10. Calculate and save the number of pixels per label.

![Figure. 4 Set ROI of image](image)

### E. Decision of Ship Motion
Head on selection situation from the International regulations for avoiding collisions at sea is the guideline used in this paper [16]. There are three of ship direction: 1) Forward, at or toward the front of a ship or further ahead of a location. 2) Starboard, the right side of the ship, when facing forward. 3) Port, the left side of the ship, when facing forward (Figure 5).

**Figure 5** Options ship direction

### 3. Result and Discussion

In this study testing the accuracy of detection with test data as many as 50 images. The image for this test is not taken in real time but by taking several image samples by conditioning the object at a certain time and distance to resemble the image capture in real-time mode. The image is obtained by using a camera placed on the front of the ship that moves in the waters. The object used to determine the direction of movement of the ship is the sea coast, the spread of marine fish, ships, and mangrove trees. For the time used in the shooting are morning and afternoon

**Figure 6** Sea Water Surface Dataset

#### A. Performance Evaluation

The test conducted in this study aims to determine the success rate of the image segmentation process carried out. Successful parameters are certainly needed so that the performance of the line segmentation method carried out in the implementation stage can be measured. The success parameter used is numerical and quantitative computing by calculating Sensitivity and False Negative Rate. The following is the definition of each element used in calculating sensitivity and false negative

- FN, or False Negative, states that the Amount of Determination of ground truth that is not included / is not detected
- FP, or False Positive, states the detected Determination Number which is not included / not a member of the Ground Truth Determination Number
• TP, or True Positive, states the Amount of Determination that is detected that corresponds to the Amount of Direction Determined from Ground Truth
• TN, or True Negative, states the Number of Directions that do not include the Amount of Determination of ground truth and the area of ROI that has been detected

The TN value cannot be calculated, because in the reference image there is no negative amount of direction determination. In measuring accuracy using sensitivity used as a percentage of success, to get the value used equation 4.1.

\[
\text{Sensitivity \% } = \frac{TP}{TP + FN} \times 100
\]  

(4.1)

In addition to using Sensitivity, this study also uses the False Negative Rate (FNR) presentation shown in equation 4.2. Usually besides False Negative, False Positive calculation is also done so that the percentage of Overall Error can be obtained as well. However, in this study it cannot be done because the calculation of the percentage of False Positive requires the True Negative value.

\[
\text{False Negative Rate \% } = \frac{FN}{TP + FN} \times 100
\]  

(4.2)

In this experiment have five scenarios. In each scenario, there are ten tested image data. Scenario 1 of taking pictures from afar goes close to the object of the obstacle. The result of scenario one as described in Table 1. This scenario has 100% of accuracy. Scenarios 2 and 3 have data collection techniques that are almost the same as scenario 1 with taking different places. Scenario 2 and Scenario 3 have 93.4% of accuracy. Scenario 4 and Scenario 5 taking picture randomly with the object of the obstacle. Scenario 4 has 80% accuracy, and scenario 5 have 80.1% of accuracy.

**Table 1. Ship motion direction for different scenario 1**

| Scenario 1          | TP | FN | Accuracy | FNR | Time (s) |
|---------------------|----|----|----------|-----|----------|
| Image01             | 3  | 0  | 100%     | 0%  | 0.385    |
| Image02             | 3  | 0  | 100%     | 0%  | 0.660    |
| Image03             | 3  | 0  | 100%     | 0%  | 0.673    |
| Image04             | 3  | 0  | 100%     | 0%  | 0.670    |
| Image05             | 3  | 0  | 100%     | 0%  | 0.660    |
| Image06             | 3  | 0  | 100%     | 0%  | 0.660    |
| Image07             | 3  | 0  | 100%     | 0%  | 0.665    |
| Image08             | 3  | 0  | 100%     | 0%  | 0.739    |
| Image09             | 3  | 0  | 100%     | 0%  | 0.736    |
| Image10             | 3  | 0  | 100%     | 0%  | 0.675    |

**Table 2. Ship motion direction for different scenario 2**

| Scenario 2          | TP | FN | Accuracy | FNR | Time (s) |
|---------------------|----|----|----------|-----|----------|
| Image11             | 3  | 0  | 100%     | 0%  | 0.666    |
| Image12             | 3  | 0  | 100%     | 0%  | 0.673    |
| Image13             | 3  | 0  | 100%     | 0%  | 0.678    |
| Image14             | 3  | 0  | 100%     | 0%  | 0.702    |
| Image15             | 3  | 0  | 100%     | 0%  | 0.610    |
| Image16             | 3  | 0  | 100%     | 0%  | 0.729    |
| Image17             | 3  | 0  | 100%     | 0%  | 0.660    |
### Table 3. Ship motion direction for different scenario 3

| Image   | TP | FN | Accuracy | FNR | Time (s) |
|---------|----|----|----------|-----|----------|
| Image18 | 3  | 0  | 100%     | 0%  | 0.731    |
| Image19 | 2  | 1  | 67%      | 33% | 0.631    |
| Image20 | 2  | 1  | 67%      | 33% | 0.653    |

### Table 4. Ship motion direction for different scenario 4

| Image   | TP | FN | Accuracy | FNR | Time (s) |
|---------|----|----|----------|-----|----------|
| Image21 | 3  | 0  | 100%     | 0%  | 0.685    |
| Image22 | 3  | 0  | 100%     | 0%  | 0.640    |
| Image23 | 3  | 0  | 100%     | 0%  | 0.633    |
| Image24 | 2  | 1  | 67%      | 33% | 0.770    |
| Image25 | 3  | 0  | 100%     | 0%  | 0.760    |
| Image26 | 3  | 0  | 100%     | 0%  | 0.660    |
| Image27 | 3  | 0  | 100%     | 0%  | 0.645    |
| Image28 | 3  | 0  | 100%     | 0%  | 0.610    |
| Image29 | 3  | 0  | 100%     | 0%  | 0.630    |
| Image30 | 2  | 1  | 67%      | 33% | 0.698    |

### Table 5. Ship motion direction for different scenario 5

| Image   | TP | FN | Accuracy | FNR | Time (s) |
|---------|----|----|----------|-----|----------|
| Image31 | 3  | 0  | 100%     | 0%  | 0.785    |
| Image32 | 3  | 0  | 100%     | 0%  | 0.670    |
| Image33 | 3  | 0  | 100%     | 0%  | 0.663    |
| Image34 | 3  | 0  | 100%     | 0%  | 0.670    |
| Image35 | 2  | 1  | 67%      | 33% | 0.860    |
| Image36 | 2  | 1  | 67%      | 33% | 0.660    |
| Image37 | 1  | 2  | 33%      | 67% | 0.601    |
| Image38 | 3  | 0  | 100%     | 0%  | 0.610    |
| Image39 | 3  | 0  | 100%     | 0%  | 0.630    |
| Image40 | 1  | 2  | 33%      | 67% | 0.628    |
| Image41 | 2  | 1  | 67%      | 33% | 0.650    |
| Image42 | 3  | 0  | 100%     | 0%  | 0.710    |
| Image43 | 3  | 0  | 100%     | 0%  | 0.533    |
| Image44 | 2  | 1  | 67%      | 33% | 0.670    |
| Image45 | 3  | 0  | 100%     | 0%  | 0.660    |
| Image46 | 3  | 0  | 100%     | 0%  | 0.690    |
| Image47 | 3  | 0  | 100%     | 0%  | 0.650    |
| Image48 | 3  | 0  | 100%     | 0%  | 0.710    |
| Image49 | 2  | 1  | 67%      | 33% | 0.530    |
| Image50 | 0  | 3  | 0%       | 100%| 0.681    |
Table 1 until Table 5 illustrates an example of calculating the accuracy of determining the direction of ship motion in 50 test images. By calculating Sensitivity to determine the accuracy of the results of determining the direction of motion of the ship. From the results of testing 50 images of sea surface objects produced an average value of sensitivity of 89.38% while a false negative rate of 10.62%. The higher the sensitivity indicates that the accuracy is getting better, so that the false negative rate is lower, the accuracy is getting better. Process estimation time for each image average 0.6 seconds.

4. Conclusion
Determination of the direction of movement of the ship to avoid the leading object in front of the ship with three direction options, namely 1) Forward, at or toward the front of a ship or further ahead of a location. 2) Starboard, the right side of the ship, when facing forward. 3) Port, the left side of the ship, when facing forward. From the test results to determine accuracy by calculating the average sensitivity value of 89.38% and with overall error 10.62%.

Image processing process estimation time for each image has a period of 0.6 seconds to 0.8 seconds. With this relatively fast detection process, this method can be developed in advance with video input.

5. References

[1] A. Kadar, *Pengelolaan Kemaritiman Memaju Indonesia sebagai Poros Maritim Dunia*, Jurnal Keamanan Nasional Vol. I, No. 3, 2015.

[2] Simela Victor Muhamad, *Indonesi Memaju Poros Maritim Dunia,* Info Singkat Hubungan Internasional, Vol. VI, No. 21, November 2014.

[3] Suyono. Op.Cit, *Buku Laporan Direktorat Jenderal Perhubungan Laut*, RI Tahun 2014

[4] H. Wang, Z. Wei, S. Wang, C. Ow, K. Ho and B. Feng, AVision-Based Obstacle Detection System for Unmanned Surface Vehicle, in Proc. Int. Conf. Robotics Aut. Mechatronics, 2011, pp. 364–369.

[5] H. Wang, Z. Wei, C. Ow, K. Ho, B. Feng and J. Huang, Improvement in Real-Time Obstacle Detection System for USV, in Proc. Int. Conf. Control, Automation, Robotics & Vision, 2012, pp. 1317–1322.

[6] H. Wang, X. Mou, W. Mou, S. Yuan, S. Ulun, S. Yang, an Bok-Suk Shin. *Vision based Long Range Object Detection and Tracking for Unmanned Surface Vehicle*. 2015 IEEE 7th International Conference on CIS & RAM

[7] G. Yang, Bo Li, S. Ji, F. Gao, and Q. Xu. *Ship Detection From Optical Satellite Images Based on Sea Surface Analysis*. IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, VOL. 11, NO. 3 2015

[8] Ruihong Xin, Shaohai Hu, and Shan Ge. Research on Detecting Methods for Sea-Surface Targets. ICSP2006 Proceedings.

[9] V. Bobkov, S. Melman, A. Kudrashov, and A. Scherbatyuk. *Vision-based navigation method for a local maneuvering of the autonomous underwater vehicle*. 2017 IEEE Underwater Technology (UT)

[10] V.A. Bobkov, A.P. Kudryashov, S.V. Melman, and V.P. May. *Image-Based Navigation of Autonomous Underwater Robot and 3d Reconstruction of Environment*. 2018 3rd Russian-Pacific Conference on Computer Technology and Applications (RPC).

[11] JIA Yun, DING Yan, LIU Ze-ping. Study on improved arithmetic of image segmentation. Optical technique, 2005, 155-157.

[12] Xie Xiaozhu, Hong Jingxin, Xiao Sixing. Effective Method for Moving Objects Detection on Sea Surface.IEEE Computer Society 2008.

[13] Xiaoqi Li, Weixin Xie, Lixia Wang, and Jihong Pei. *Ship Detection Based on Surface Fitting Modeling for Large Range Background of Ocean Images*. ICSP2016 IEEE.
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