Assessing the Plausibility of Hough Transforms for Automated Detection of Biofouling and its Associated Agents

Midshipman First Class M. Jordan Davidson

Advisor: CDR Joseph P. Smith

Abstract:

Biofouling, or the growth and colonization of marine organisms on marine surfaces, causes significant problems to the U.S. Navy and merchant fleets. Biofouling organisms reduce the fuel efficiency of ships by increasing frictional drag. They also lead to damage requiring dry dock repairs on hulls, causing estimated losses of $4 Billion/year to the U.S. Navy. Because of the time intensive methods used to assess biofouling, such as divers hand-counting barnacle growth of ships hulls, using object recognition software to analyze images of hull surfaces to analyze barnacle growth can help save government and civilian companies time and money. A simple object recognition program using a Hough Transform was employed to assess the plausibility of using computerized analysis of sample hull plates to perform a first-order determination of barnacle growth. Results showed an average success rate of 45.8% in identifying barnacles on hull plates. The average presence of barnacles per plate was 12 barnacles with an average false positive level of 246.8% and a false negative level 54.2%. Results demonstrated that with further refining and filtering methods, object recognition software can potentially be used to assess the level of biofouling growth more quickly and more cost effectively than current, manually intensive means.

Study Area and Methods:

Figure 1. Google Earth map showing overhead view of U.S. Coast Guard Station (USCGS), Miami, FL and adjacent area where the biofouling experiments were conducted. Highlighted yellow area indicates the floating pier at the northern end of USCGS Miami where the research took place.

Field testing took place at USCGS, Miami under a floating pier. The location provided well mixed, nutrient rich waters at the intersection of three water masses and simulated growth on a moored ship (**Fig. 1**).

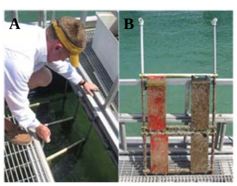

Figure 2. (**A**) Floor paneling being removed to lift out the mock hull plates. The deck lattice allowed ample light transmission. There are no obstructions to natural flow of water and natural processes taking place on the mock deck plates. (**B**) Mock hull plates removed from water to be photographed for analysis. Note the significant natural growth of algae, barnacles, bryozoans and other true biofouling agents.

- Plates were suspended under a floating dock vertically to simulate side hull plates of a ship (**Fig. 2A**). After 60 days, the plates were removed and soft biofouling was rinsed off before photographing (**Fig. 2B**).
- Photographs were uploaded to Image-J where they were cropped, converted to grey-scale, and received a contrast increase.
- Images were then run through the object recognition program in employing a Hough Transform in MATLAB (Peng, 2005).

Results:

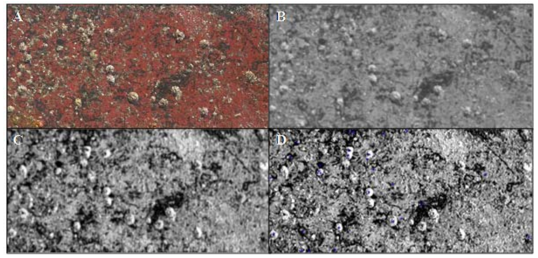

Figure 3. Series of mock hull plate images showing: (**A**) Hull plate picture without any contrast or color change; (**B**) Hull plate after an RGB split into a grey scale image with the Image-J software; (**C**) Hull plate with 5% contrast increase from initial grey scale image. Notice the drastic increase in distinction of barnacles from the rest of the hull plate, and; (**D**) Hull plate showing result of a full panel analysis trial.

Figure 3A-D shows the results of a full plate analysis using the Hough Transform. Copped images of biofouling plates (**Fig. 3A**) were converted to grey scale (**Fig. 3B**) and then contrast was enhanced (**Fig. 3C**) using Image-J software. The cropped, enhanced images were then analyzed for object recognition using a Hough transform written in MATLAB (Peng, 2005). **Figure 3D** shows a fully analyzed image. The object recognition program determined the presence of barnacles (indicated by blue "+" on **Fig. 3D**) by shape and contrast on the cropped enhanced images.

Table 1. Results of analysis run on select plates. The base count is the number of barnacles present in the image via hand count. Computer count is the number of barnacles detected via object recognition software. The true count is the number of barnacles the software accurately detected. % ID is the percentage of barnacles identified via object recognition, and % False Pos. and % False Neg. is the ratio of false negatives to base count, and false positives to base count.

Image Name	Base Count (#)	Computer Count (#)	True Count (#)	False Pos. (#)	False Neg. (#)	% ID	% False Pos.	% False Neg.
Control	3	3	3	0	0	100.0%	0.0%	0.0%
DECRight	4	9	2	7	2	50.0%	175.0%	50.0%
DECLeft	12	30	6	24	6	50.0%	200.0%	50.0%
DECTot	16	28	9	19	7	56.3%	118.8%	43.8%
MARRight	5	32	2	30	3	40.0%	600.0%	60.0%
MARLeft	12	39	5	34	7	41.7%	283.3%	58.3%
MARTot	19	37	7	30	12	36.8%	157.9%	63.2%
NOVRight	7	38	2	36	5	28.6%	514.3%	71.4%
NOVLeft	14	29	3	26	11	21.4%	185.7%	78.6%
NOVTot	21	56	7	49	14	33.3%	233.3%	66.7%
Average	11.3	30.1	4.6	25.5	6.7	45.8%	246.8%	54.2%

Table 1 shows the results of the object recognition analysis on select biofouling plates. On average, 45.8% of barnacles were identified correctly resulting in an average false negative rate (actual barnacle not identified as barnacle) of 54.2% . The analysis had an unexpectedly high rate of false positive identifications (non-barnacle identified as barnacle). The average percent of false positive identifications for all plates analyzed was 246.8%. The MARRight and NOVRight plates had the highest levels of false positives with nearly twice the level of other samples. Little deviation occurred in the % false negative and % ID levels between plates.

Discussion:

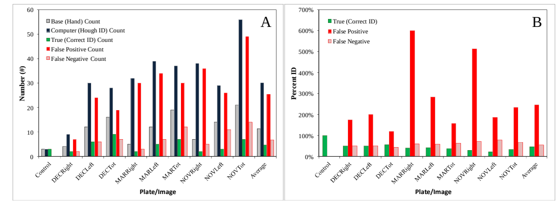

Figure 4. (**A**) Graphical comparison of results (**Table 1**). Note the anomaly in the NOVTot image results. (**B**) Comparison of correct ID and percent 9%) of false positives and false negatives rate (%) for each image.

Figure 4 shows a graphical representation of the results in **Table 1**. Again, note the high number of false positive identifications. The large numbers of false positives identify a need for increased filtration of results and refinement in the Hough Transform voting procedure.

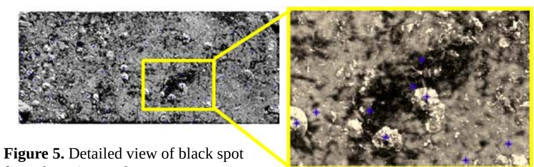

Figure 5. Detailed view of black spot from the NOVTotal image.

The high rates of false positives may have stemmed from over contrasting of images which creates some large dark-colored spots (NOVTot image; **Fig. 5**). Such contrasting may skew the overall Hough Transform voting process. The large range of barnacles sizes on each plate (NOVTot image; **Fig. 5**) may have lead to many barnacles falling outside the search conditions and thus being overlooked.

Conclusions:

Results reveal that an average of 45.8% of barnacles present on hull plate images can be identified by a simple object recognition software program using the Hough Transform. The addition of more advanced image generation and filtering techniques, such as synthetic confocal imaging and high-frequency sonar, may result in more accurate and precise results with an acceptable level of false positive and false negative identifications. The results of this study do not support immediate field and commercial use of computerized object recognition techniques for biofouling analysis. The recognition levels demonstrated, however, do suggest that, with fine tuning and additional filtering, object recognition employing the Hough Transform has the potential to expedite biofouling analysis, saving time and money for the U.S. Navy, Coast Guard, Merchant Marine, and commercial fleets worldwide.

Acknowledgements: This work was conducted, in part, at the Center for Corrosion Science and Engineering (CCSE), U.S. Naval Research Laboratory (NRL Code 6130), Key West, FL through the U.S. Naval Academy (USNA) Summer Internship Program. Thanks to everyone at NRL Key West who supported and contributed to this work, especially my Internship hosts and sponsors, Dr. Lisa Drake and Dr. Matt First. Special thanks to CAPT William Schulz for help with the image recognition software used in this work.

References: Peng, T., 2005, "Detect circles with various radii in grayscale image via Hough Transform", The Mathworks, Inc.,. MATLAB Central File Exchange webpage: http://www.mathworks.com/matlabcentral/fileexchange/9168, accessed 01 Feb 2012.