Development of Algorithms for the Detection and Identification of Bottom-Moored Objects from Sidescan Sonar Imagery

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Abstract

A set of algorithms were develop in MATLAB for the automated detection of bottom-moored objects from sidescan sonar imager. The algorithms were evaluated using imagery collected over a series of targets, some false targets and some simulating bottom-moored mines. Target strings were deployed on land and surveyed using an aerial drone with a high-resolution camera to perform initial algorithm design and testing. Target strings were then deployed on the bottom of the Severn River, MD and surveyed using sidescan sonar to evaluate the capability of the algorithms developed to detect and identify bottom-moored objects. Results will be used to aid in the future development of automated methods for the detection of bottom-moored objects in coastal systems.

Methods and Approach

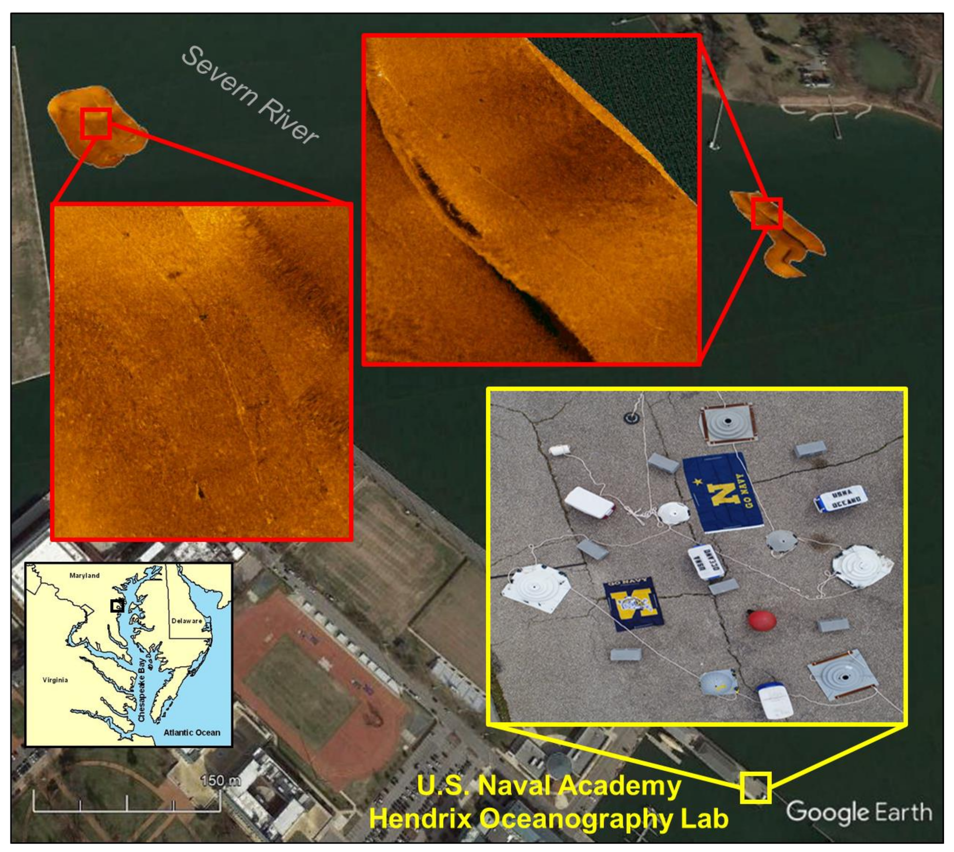

Figure 1. Study area showing location of land-based target-string imaging using an aerial drone at the U.S. Naval Academy, Hendrix Oceanography Lab (yellow) and two locations in the Severn River where bottom-target strings were first deployed and imaged using sidescan sonar. Targets were designed to simulate underwater mines. High-resolution sidescan mosaics were produced by Mr. Carter Duval from the University of Delaware.

Figure 1 shows the study area where high-resolution camera images and sidescan imagery were collected. A series of targets simulating bottom-moored mines were linked together as "target strings" along with false targets (cinder blocks, weights). Target strings were deployed on land and surveyed using an aerial drone with a high-resolution camera (DJI Phantom 4) to perform initial algorithm design and testing. Target strings were then deployed on the bottom of the Severn River, MD (**Fig. 2A**) and surveyed using a Klein S4900 sidescan sonar (**Fig. 2B**) to test and evaluate the capacity for algorithms to detect and identify bottom-moored objects. Image processing and object detection and identification was performed using MATLAB R2017a. Imagery was preprocessed using color segmentation to group RGB colors then transformed to binary form to run edge detection operations. A shape detecting operation was run on the binary picture using an eccentricity threshold value followed by an area threshold area limit. A positive detection and identification result was defined as an object in that met threshold criteria for the shape and size for an object of interest.

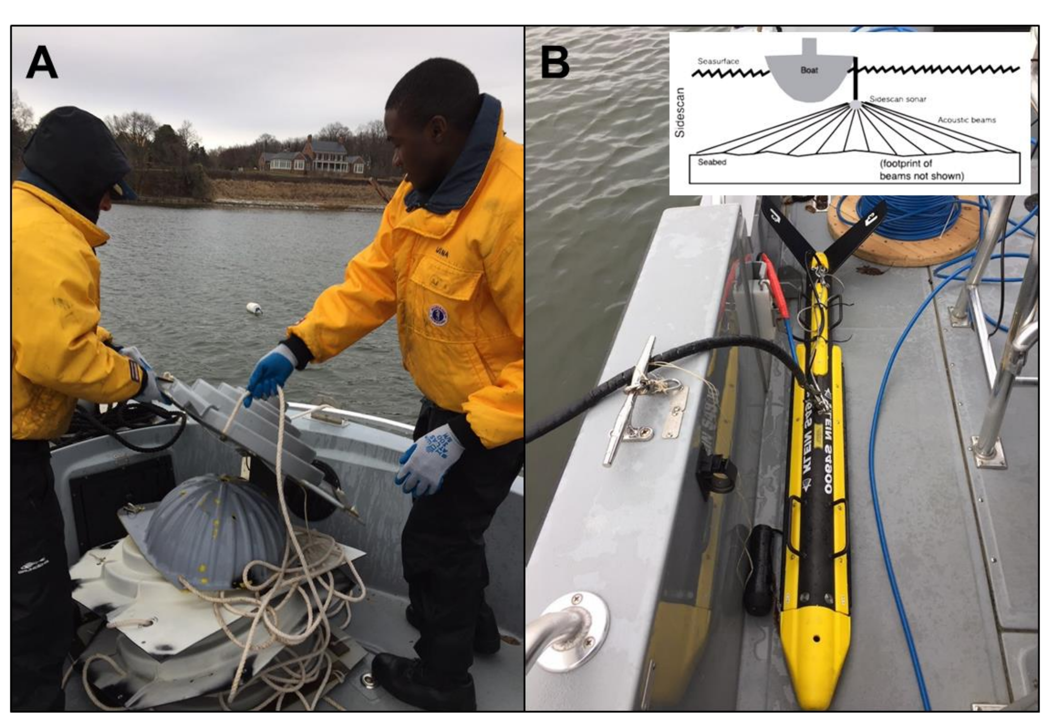

Figure 2. (**A**) MIDN 1/C Abunike and Mr. L. Rodriguez deploying bottom target strings in the Severn River, and; (**B**) the Klein System 4900 SideScan Sonar. Insert is conceptual diagram of acquisition geometry for sidescan sonar (from Fig. 1, Collier and Brown, 2005).

Results and Discussion

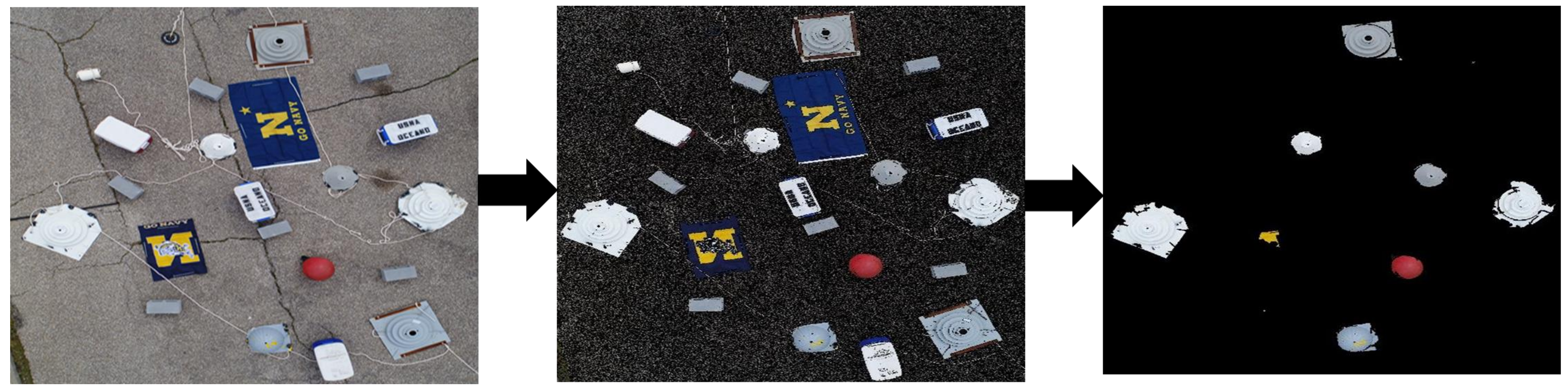

Figure 4. Series of images showing processing (left-to-right) of a control image of a land-based string of test targets taken by a DJI Phantom 4, to a RGB color segmented image, to an image showing positively identified objects that met object threshold criteria.

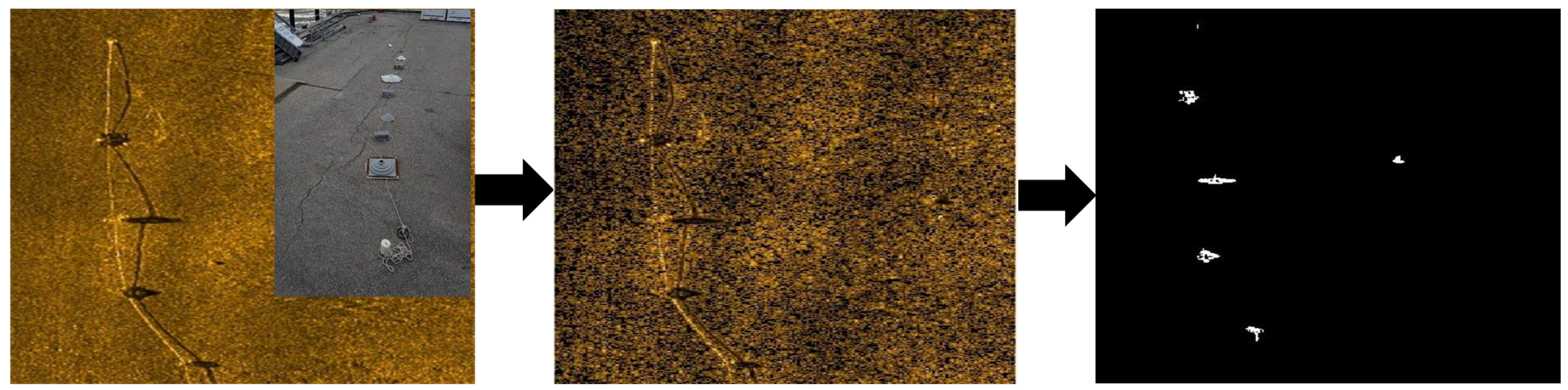

Figure 5. Series of images showing processing (left-to-right) of a control sidescan image of an underwater, string of bottom test targets collected by the Klein S4900 sidescan sonar, to a RGB color segmented image, to an image showing positively identified objects that met object threshold criteria. Note: Inset on control image shows a photo of an underwater target string laid out on land.

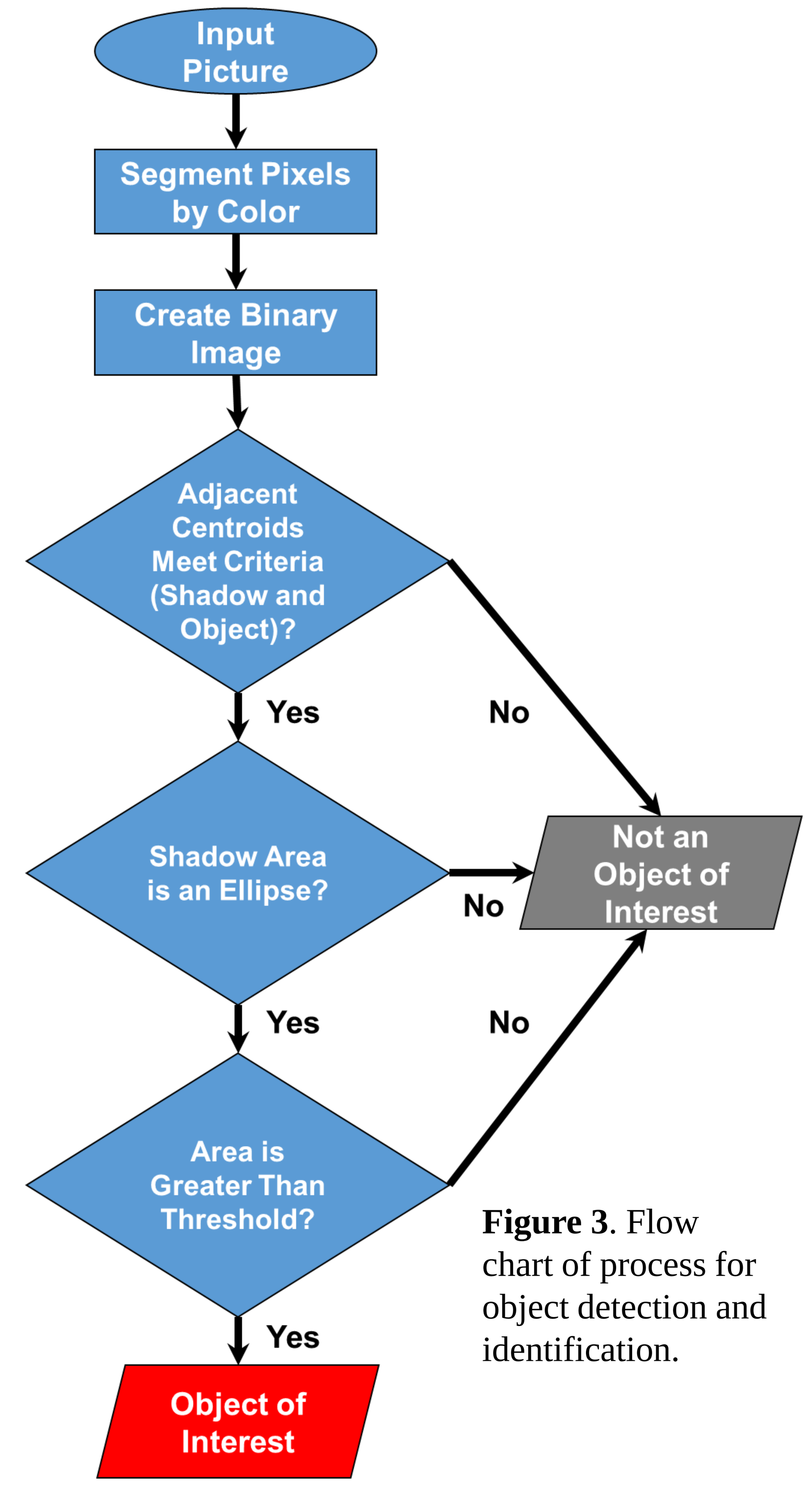

Figure 3. Flow chart of process for object detection and identification.

Table 1. Test results using algorithms developed for object detection and identification. Control Image results represent a process optimized for a land-based target string image, Sonar Image (SI0) represents a process optimized for a an image of underwater target string. Sidescan images SI1-3 are test images of underwater bottom target strings.

Shape and Size Analysis					
	Control Image	SI0	SI1	SI2	SI3
Total # of targets	22	4	3	5	5
# of real targets	9	4	2	3	3
# of false targets	13	0	1	2	2
Total # of computer returns	8	5	3	5	15
# of real targets identified as real	7	4	2	3	3
# of real targets identified as false	2	0	0	0	0
# of false targets identified as real	1	0	1	2	2
# of targets not identified	0	0	0	0	1

Figure 3 shows a flow chart of the process used to detect and identify objects starting with a raw image. **Figure 4** shows image processing optimized for a Control Image of the land-based test target strings. **Figure 5** shows image processing optimized for a control sidescan image (SI0) of an underwater, string of bottom test targets. Objects in sonar images have a corresponding shadow area. This is produced due to the sonar rays being incident at an angle (inset, **Fig. 2B**). The shadow area provides the best detection opportunity for smaller targets, the shadow length will be larger than the object return by tan (ϴ) where ϴ is the incident angle. Smaller incident angles will provide more visible shadow areas, however they can potentially lead to grazing blind spots. In the approach used in this study, shadows were treated as ellipses assuming the increase in major radius of the ellipse (length of shadow) increased the overall area. Treating shadows allowed for the use of an eccentricity value equal to or less than 1 as an object-specific threshold limit. **Table 1** shows the test results for the Control Image of a land-based target string image, SI0, and random test images SI1-3. Bottom type and roughness significantly affected the results obtained and introduced returns that appeared to be target-like and created shadow zones (**Fig. 6**). To increase probability of detection, better filtering process will need to be developed to deal with bottom roughness. Algorithm development will also need to be advanced to account for object height off bottom, object burial, and different bottom characteristics and object material properties.

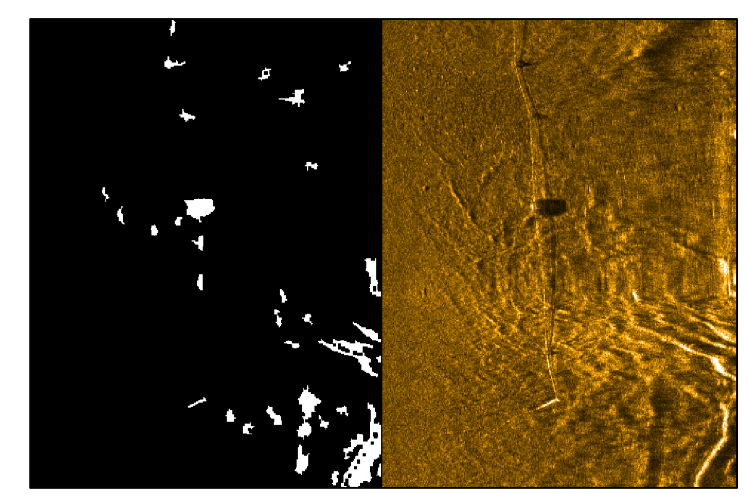

Figure 6. Side-by-side comparison of processed (left) and raw (right) image of an underwater target string in area of the Severn with a non-uniform bottom.

Conclusions

- ***Digital image processing techniques can be used to detect and identify underwater bottom-moored objects in sonar imagery optimized for target classification***
- ***Basic classification can be carried using the shape and shadow area of known targets. It will be necessary to generate classification operators for other shapes and sizes***
- ***Further work is required using geo-referenced images to optimize algorithms for random, unknown target detection and identification in challenging environments. The capability to collect and process imagery dynamically, in real-time will be very useful for surveying in the field***

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