

## A Roughness Estimation Algorithm for Sidescan

M.L. Gendron, M.C. Lohrenz, G. Layne, and J. Sample  
*Marine Geosciences Division*

**Introduction:** The Naval Oceanographic Office (NAVOCEANO) requires accurate estimates of seafloor roughness (bottom relief) and the density of seafloor clutter (mine-like echoes), typically derived from sidescan sonar imagery (SSI), to determine the bottom type of a geographic area for mine warfare. Determining clutter and roughness manually can be time-consuming and produce inconsistent results. Automated algorithms can derive clutter and roughness from SSI in a consistent and timely manner.

Features such as pockmarks, sand ripples, and rocks on the seafloor are visible in SSI as bright spots (“brights”) with adjacent shadows. The Naval Research Laboratory (NRL) developed a real-time clutter detection algorithm (transitioned to NAVOCEANO in 2001) that quickly and reliably identifies clutter in SSI and clusters the results into polygons. An object’s height (estimated from the length of its shadow) is one measurement used to determine whether the object is mine-like. The authors theorized that height also could be used to automatically estimate seafloor roughness.

NRL has developed a new automated roughness estimation algorithm, based on the clutter detection algorithm, to automatically derive seafloor roughness from SSI. In repeated trials, polygons generated by the new roughness algorithm correlated well (as high as 87%) with manually generated polygons for the same region. This article presents the NRL automated roughness algorithm (transitioned to NAVOCEANO in 2006), including test results and comparisons with manual methods.

**Real-time Automated Clutter Detection Algorithm:** The authors’ clutter detection algorithm ingests one SSI scan line at a time. Across-track bright and shadow positions and lengths are stored in two geospatial bitmaps,<sup>1</sup> one each for shadows and brights.

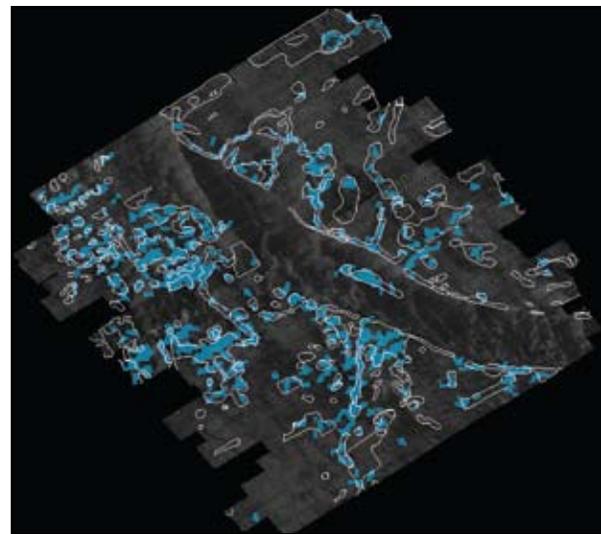
Shadows and brights in a scan line are located by first adaptively obtaining a lower intensity threshold,  $i_{\min}$ , such that all samples of intensity less than  $i_{\min}$  are considered shadows. An upper intensity threshold,  $i_{\max}$ , is set such that all samples of intensity above  $i_{\max}$  are considered brights. An appropriate gamma shift converts image intensities to fit a normal distribution, such that  $i_{\min}$  and  $i_{\max}$  are set to the quartiles of the shifted (normal) distribution.

Next, the bright and shadow geospatial bitmaps are examined from the edges of the scan lines toward the center (nadir) to detect runs of shadows followed by runs of brights. A circular lookup table is created

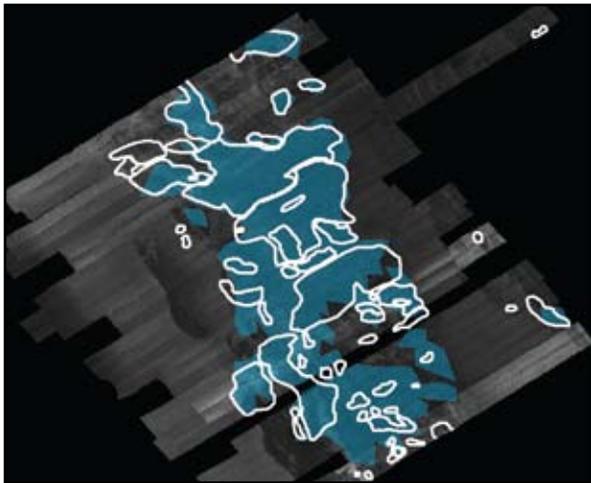
to “window” several scan lines at a time. This lookup table is populated with positions and run-lengths of shadows and brights. The window information is used to determine if a series of scan-line detections comprise an object, and the shadow length is one component in determining the object’s height.

**Automated Roughness Estimation Algorithm:** In the new roughness algorithm, the authors used sensor altitude above the seafloor, distance of the shadow from nadir, length of the shadow (determined by the clutter detection algorithm), and sonar resolution to estimate roughness (depicted as polygons representing smooth and rough areas). The algorithm was first tested on two geographic regions (I and II) and compared with manual roughness estimated by analysts at NAVOCEANO. The detected object locations for each region were clustered and categorized into smooth and rough polygons.

Figures 7 and 8 show the manual polygons (white outlines) overlaid on results of the roughness algorithm (blue-filled polygons) for Regions I and II, respectively. The percentage of agreement between manual and automated polygons for Region I is 60%. (This is the same as %correct for the automated method, assuming the manual method is ground-truth.) Interestingly, both the manual and automated methods clearly indicate a smooth “lane” running through the center of the SSI in Region I. During mine warfare operations, bottom roughness is one of the components considered when choosing which navigation lanes to



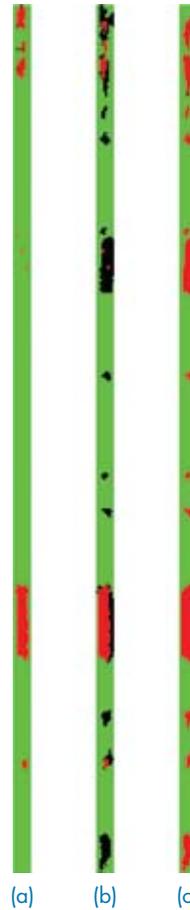
**FIGURE 7**  
Both the manual (white outlines) and automated (blue filled polygons) roughness estimations indicate a smooth lane through the center of Region I. The percentage of agreement between the manual and automated methods is about 60%.



**FIGURE 8**  
Manual roughness polygons overlaying automated roughness polygons for Region II: percentage of agreement between the manual and automated methods is about 84%.

clear of mines, since it is easier to clear a smooth seafloor than a rough one. The percentage of agreement between manual and automated polygons for Region II is approximately 84%. A third test, over Region III in 2006, resulted in 87% agreement (Fig. 9). Table 1 shows how the authors calculated percent agreement.

**Conclusion:** This article describes a new real-time algorithm developed by NRL to estimate roughness. The algorithm was tested on three regions where NAVOCEANO analysts had manually estimated bottom roughness. The algorithm correctly identified a smooth lane in Region I, with 60% agreement between automatically and manually estimated roughness polygons. The algorithm was 84% correct for Region II, and 87% correct for Region III. The algorithm operates in real time, compared with weeks of post-processing time required for manual roughness estimations.



**FIGURE 9**  
Third test of roughness algorithm, for Region III in September 2006: a) manually generated roughness polygons, b) logical AND of manual and automatically generated polygons, c) automatically generated roughness polygons. The percentage of agreement between manual and automated methods is about 87%.

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**Reference**

<sup>1</sup>M.L. Gendron, P.B. Wischow, M.E. Trenchard, M.C. Lohrenz, L.M. Riedlinger, and M. Mehaffey (2001). *Moving Map Composer*. Naval Research Laboratory, US Patent No. 6,218,965. ♦

Table 1 — Calculation of % Agreement Between Manually Generated Roughness (Fig. 9(a)) and Automatically Generated Roughness Polygons (Fig. 9(c)). Figure 9(b) is the Binary AND Between Figs. 9(a) and 9(c), Providing a Comparison Between the Two Methods of Categorizing Roughness, Summarized in this Table.

ID	# Pixels	Image (%)	Description
	3822	79.3	Correct (smooth)
	349	7.2	Correct (rough)
	649	13.5	Incorrect (falsely categorized as rough)
	0	0.0	Incorrect (falsely categorized as smooth)
		86.5	Total correct
		13.5	Total incorrect (conservative errors only)