Enhancing Vector Shoreline Data Using a Data Fusion Approach

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Contents

Abstract

Vector shoreline (VSL) data is potentially useful in ATR systems that distinguish between objects on land or water. Unfortunately available data such as the NOAA 1:250,000 World Vector Shoreline and NGA Prototype Global Shoreline data cannot be used by themselves to make a land/water determination because of the manner in which the data are compiled. We describe a data fusion approach for creating labeled VSL data using test points from Global 30 Arc-Second Elevation (GTOPO30) data to determine the direction of vector segments; i.e., whether they are in clockwise or counterclockwise order. We show consistently labeled VSL data be used to easily determine whether a point is on land or water using a vector cross product test.

Introduction

Automatic target recognition (ATR) systems can potentially utilize prior knowledge of target deployment constrains (both physical and doctrinal) with respect to the terrain/marine background to improve detection/false alarm performance and increase system throughput. Although national geospatial databases are an important source of worldwide information, most available sources of global data have a much lower spatial resolution than the imagery being exploited.

Lack of suitable data for ATR applications has motivated the development of image fusion algorithms for "sharpening" low-resolution databases using higher resolution imagery. For example, the map-based classifier (Carlotto 1996) uses 1:250,000 scale land-use/land-cover maps as 'truth' information for classifying coregistered multispectral imagery. The result is a spatially sharpened land cover map. The elevation sharpening process (Carlotto 2000) uses shape from shading information derived from imagery to spatially enhance digital terrain elevation data.

Vector Shoreline Data

In remote sensing and cartographic applications data may be represented as images (sometimes called rasters) or by lists of points (vectors). NOAA 1:250,000 World Vector Shoreline[1] (WVSL) and NGA Prototype Global Shoreline[2] (PGSL) data are often used as a map visualization layer in systems such as Google Earth. WVSL and PGSL data are polygonal areas represented by one or more line strings. Although small islands and lakes may be represented by a single closed line string (i.e., a polygon), in most cases larger features such as a coastline will consist of multiple line strings that do not form closed polygons within the extent of area of interest (e.g., Fig. 1). As a result standard point-in-polygon tests[3] cannot be used to determine whether a test point (e.g., a detected ship) is on water or land.

Fig. 1 - *Eastern Massachusetts shoreline. With the exception of small islands and lakes VSL data consist of open line strings. Boston harbor is lower left.*

[1] *http://shoreline.noaa.gov/data/datasheets/wvs.html*
[2] *http://msi.nga.milNGAPortalDNC.portal_nfpb=true&_pageLabel=dnc_portal_page_72*
[3] *https://en.wikipedia.org/wiki/Point_in_polygon*

$$\vec{p} \times \vec{q} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ x_1 - x_0 & x_2 - x_1 & 0 \\ y_1 - y_0 & y_2 - y_1 & 0 \end{vmatrix} = z\mathbf{k} = (x_1 - x_0)(y_2 - y_1) - (x_2 - x_1)(y_1 - y_0) < 0$$

Eq. 1 - *Unit Vectors.*

If the VSL is compiled in a consistent direction for land/water vectors such as the convention depicted in Fig. 2 where clockwise (CW) ordered polygons encircle water and counterclockwise (CCW) ordered polygons encircle land, a vector cross product test can be used to determine if a point is on land or on water (Fig. 3). Given a test point (x_0, y_0), find the closest point on the nearest segment (x_1, y_1), and another auxiliary point (x_2, y_2) along the segment. Let $\vec{p}$ be the vector from the test point to the nearest point, and $\vec{q}$ be the vector from the nearest point to the auxiliary point. If the polygon was compiled cording to Fig. 2, the test point is inside a CCW segment (i.e., on land) if where i, j and k are unit vectors. On the other hand if Eq. 1 is positive, the test point is on water. For CW segments the test is reversed (Table 1).

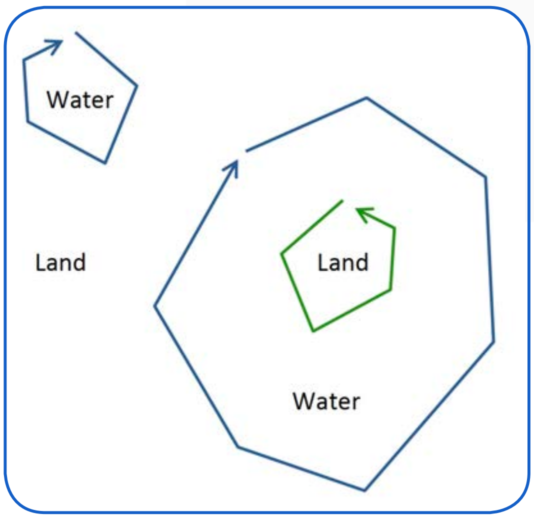

Fig. 2 - *Land/water vector direction convention.*

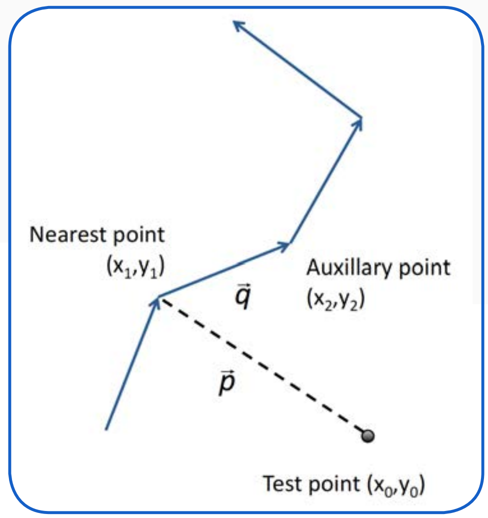

Fig. 3 - *Vector cross-product test.*

Unfortunately the available WVSL and PGSL data are not compiled in a consistent manner (i.e., the convention in Fig. 2 or its dual), and so another source of information is required to determine if a point is on land or water.

	z > 0	z < 0
CCW	water	land
CW	land	water

Table 1 - *Vector cross product test cases*

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The crux of the problem is illustrated in Fig. 4. Assume the full extent of regions **A** and **B** is unknown. Given segment **ab**, it is impossible to know if **ab** is a CCW segment of region **A**, or a CW segment of region **B**.

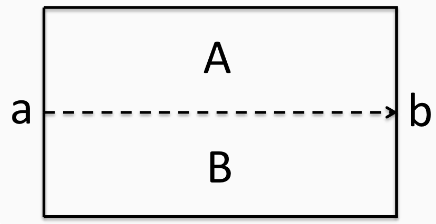

Fig. 4 - *Segment of unknown direction between regions A and B*

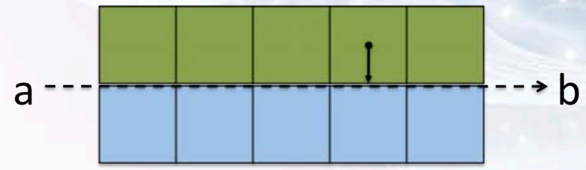

Fig. 5 - *Vector under test registered to low-resolution database. One test location is shown.*

If lower resolution land cover data is available, we can test locations with respect to the boundary (Fig. 5). Let N be the number of grid cells (test points) in the land cover data. Assuming water is defined to be outside and land inside CCW boundaries we can count the number of times the sign of the cross-product from a land cover location (test point) agrees or disagrees with the order of the points in the test segment ab. If the initial ordering of the points is CCW and

#agree > #disagree

then the segment is CCW, otherwise it is CW and the order must be reversed in the database. Iterating this procedure over all vector segments using all grid cells contained within the area of interest produces a consistent CW/CCW ordering of the vector database within the area.

This method is used to first label non polygonal segments. Polygons are then tested against the nearest labeled shoreline segment and labeled an island if the polygon is on water, or a lake if the polygon is on land. We have found that instead of using the nearest and next nearest points for the test, it is better to pick points that are on the order the distance of the test point from the boundary.

Once the VSL data have been labeled as described above, detection locations can be quickly tested by the ATR system as follows: If the detection is within the bounding rectangle of a polygon (a simple bounds test), test it against the polygon; otherwise test it against the nearest non-polygonal segment.

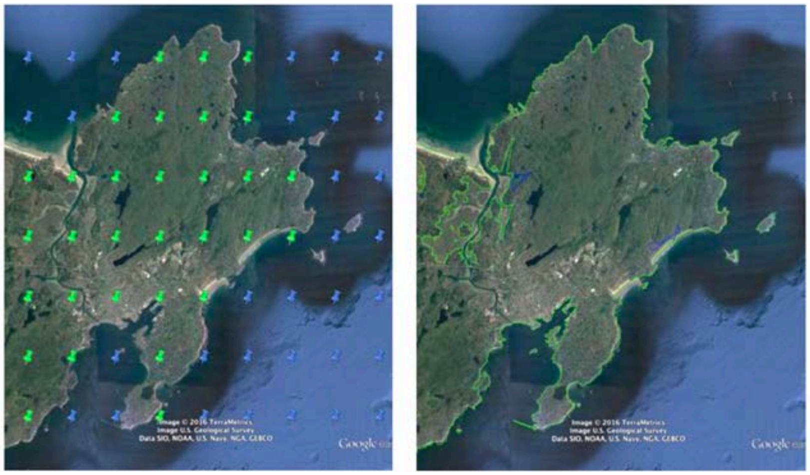

Fig. 6 - *Land/water points derived from GTOPO30 DTED (left) and labeled VSL (right). Green/blue pins are land/water; green/blue lines are CCW and CW segments*

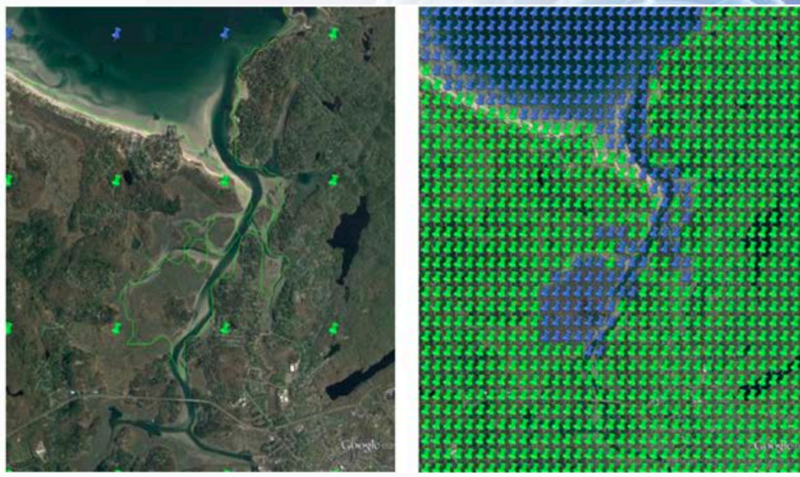

Fig. 7 - *Land/water test points (left) and 10X “raster product” (right) derived from enhanced VSL data*

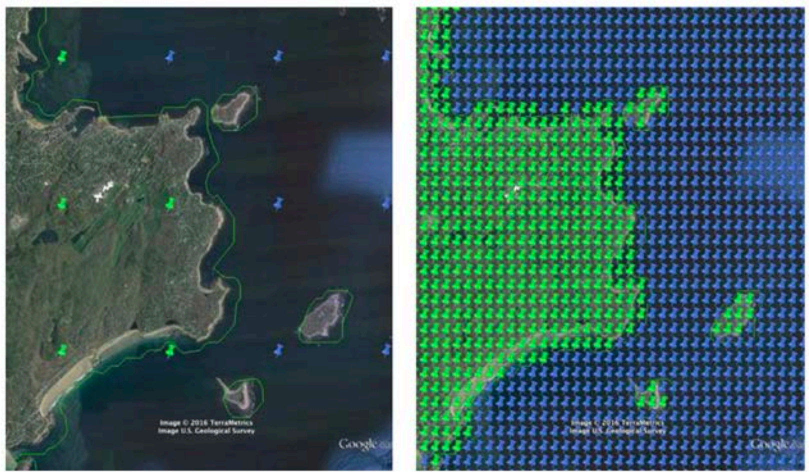

Fig. 8 - *Another example showing land/water test points (left) and 10X product (right)*

Experimental Results

Consider the Cape Ann Massachusetts shoreline (Fig. 6). Each pin is a land/water test point derived from Global 30 Arc-Second Elevation[4] (GTOPO30) data using the rule: if (elevation > 0) then land; else, water. Clearly the global data does not capture the complexity of the coastline. Although the VSL data is a much more accurate land/water boundary delineation it cannot be used “as is” to determine if a test point is on land or water. Fig. 8 compares the original global data (test) points and a 10X raster “product” generated from our labeled VSL data by subsampling the original grid and using the vector cross product test to label a 10X denser grid of land and water points.

It is noted that one does not actually have to generate a raster data layer. Fig. 8 is an example showing how the labeled VSL data can be used by a ship detection system to test and filter detections that are on land.

[4] *https://lta.cr.usgs.gov/GTOPO30*

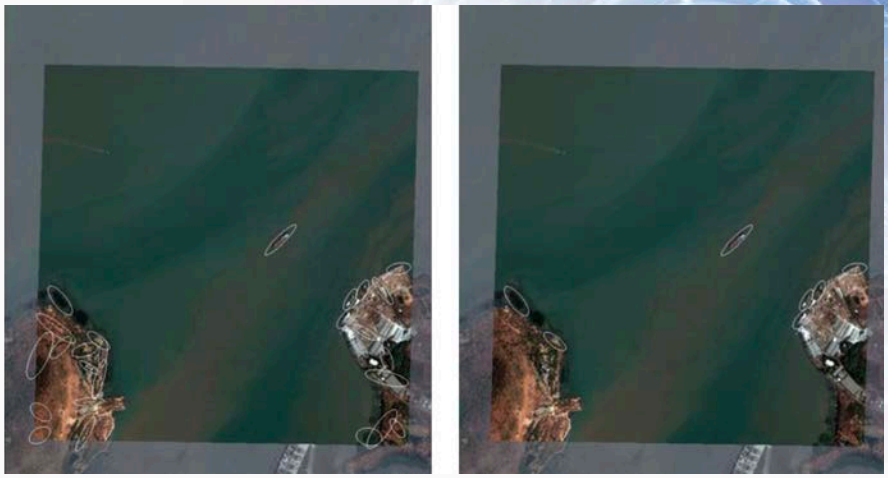

Fig. 9 - Using VSL data to reduce false ship detections on land (GeoEye image courtesy DigitalGlobe)

References

Mark J. Carlotto, "Spatial Enhancement of Elevation Data Using a Single Multispectral Image," Optical Engineering, Vol. 39, No. 2, pp 430-437, 2000.

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