Shoreline Feature Extraction from Remotely-Sensed Imagery

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Abstract - **Different methods of delineation were used to extract shoreline features from images with different spatial and spectral resolutions acquired by airborne and spaceborne sensors. The exact location of the shoreline is difficult to obtain from the images and therefore the definition of shoreline was based upon the geomorphological and oceanographic characteristics of the area of study. Extracted shoreline vectors were then compared to existing official shoreline vectors to assess their accuracy and software efficiency. It is expected that the generation of shoreline vectors with a high accuracy will greatly improve the time of work and number of specialised personnel, and allow for the integration of the resulting shoreline vectors into cartographic databases.**

I. Introduction

The coastal zone can be simply described as the area where land and sea meet. Despite covering a very small area on global scale, it is the most widespread boundary on the planet, extending along all continental margins. The observation of changes along the coasts using aerial photography began in the early 1930's and since then methods for studying these variations have substantially improved through the analysis of data acquired by satellites [1].

The use of satellites has enabled the acquisition of imagery for virtually the entire globe. Observing coasts and shorelines with the help of remotely-sensed images has expedited updating maps and charts, enabling analysts and researchers to detect changes and extract information directly from images onto the maps.

The improvement of mapping procedures has led to the investigation of automated and semi-automated methods of feature extraction. Computers have made it possible to gather information from imagery in order to generate new shoreline vectors and to update existing maps. Great care must be taken when deciding on what features to consider as part of the shoreline. This is a key issue in the area of digital feature extraction.

II. Objective and Area of Study

The purpose of this project was to develop an algorithm to facilitate semi-automated shoreline feature extraction from remotely-sensed images. Other image processing programs were also used for further image manipulation.

The area of study covers 350,000 ha of Clayoquot Sound, located on the west coast of Vancouver Island, British Columbia. It extends approximately from 49°40'N, 126°35'W to 49°N, 125°35'W. The area provides habitat for a wide variety of wild animals and is known for its vast, old-growth forests. Several different types of coasts can be found in the area, including gently-sloping sand beaches, rocky coasts, estuaries, barrier islands and tidal flats, thus making it an ideal area for testing the performance of the shoreline extraction algorithm.

III. Shoreline Determination

The process of determining shorelines from remotely-sensed images is not simple. This is due to the gradation between land and sea, and the change of forms, which make separating and following features very challenging. Boundaries would be best described by checking them in the field, but information can be extracted much faster and with less expense using remote sensing techniques [2].

The difficulty in tracing the shoreline may be due mainly to the slightly different spectral responses of water and land in some specific wavelengths. However, even when it is possible to make a clear distinction between land and water, there is a certain lack of confidence about the real position of the shoreline due to tidal movement and wave action. In general, it might be simpler to adopt the vegetation line or high-water level as the shoreline, rather than try to account for tidal variations.

IV. Data Description

The images used for this research were acquired in different years and at different times of day. Initially, efforts were made to keep some sort of time consistency between images in order to minimise the influence of tides. However, due to time constraints, data availability and a lack of tide information, tidal influence would only be considered a direct factor in the determination of shorelines when it could be visually verified on the images. At this stage, only optical sensors were used. Radar data will be used when the expected

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minimum accuracy of the software has been met. Table 1 shows which images were used.

TABLE 1
RESOLUTION OF IMAGERY USED

	Spatial Resolution (m)	Spectral Resolution (μm)
Aerial Orthophotos	1	0.30-0.90
KFA-1000 Photograph	4	0.49-0.68
Landsat 7	15	0.50-0.90
	30	0.45-0.52 0.52-0.60 0.63-0.69 0.76-0.90 1.55-1.75 2.08-2.35
SPOT 1	20	0.50-0.59 0.61-0.68 0.79-0.89
SPOT 3	10	0.51-0.73

V. METHODOLOGY

Radiometric calibration was not performed on any of the images because no quantitative analysis of the images was required. The accuracy of the extracted shoreline vectors was assessed by a visual inspection and also by comparing them to existing vectors of the area.

The KFA-1000 image was geocoded to existing vectors (compiled at a 1:20,000 scale by the Terrain Resource Information Management (TRIM) program of British Columbia) using a linear model and was subsequently used to geocode all other images. This method was used in order to try to minimise the geocoding errors to a maximum of 2 pixels in each x- and y-direction of all images. These large image files (ranging from approximately 600 MB to 2GB) were then subset into smaller areas to accommodate memory requirements of the extraction software and also to minimise the number of different shoreline types per image.

1) *Enhancements*: Initially the geocoded subsets had their histograms stretched to try to make use of the entire 8-bit range. The type of enhancement used was intimately connected to the shape of the histogram and to the qualitative (visual) aspects of the shoreline. Adjustments of brightness and contrast of individual features within the image were also performed.

2) *Filtering*: The process of delineating the shoreline automatically looks for abrupt changes in pixel values. This is usually accomplished by applying edge enhancement and edge detection filters. Again, several different filter types were experimented with in order to obtain edge-enhanced images. The filters tested were *Laplacian*, *Sobel*, *Prewitt*, *Canny*, *Roberts*, *Frei-Chen* and *Pixel Difference* [3]. Each filter employs different kernel coefficients and sizes, and the effects of altering these parameters were evaluated.

3) *Feature Extraction*: The most promising approach to delineating the shoreline based on the detected edges consists of 'guiding' the software. In this case, the image analyst seeds points along the shoreline of the original image (the selection of starting and ending points is the minimum requirement), and the software then examines the edges on the processed (or *cost*) image following the seed-points. It is important to note that the parameters on which to base the shoreline must have been previously determined. This *heuristic search* is faster and somewhat reliable due to the input of previously gathered information by the analyst. Finally, a line identifying the shoreline is traced on the image [4].

4) *Results*: The extracted shoreline vectors were then compared with TRIM vectors to check the performance of the algorithm on the cost image.

Fig. 1 summarises the methods used.

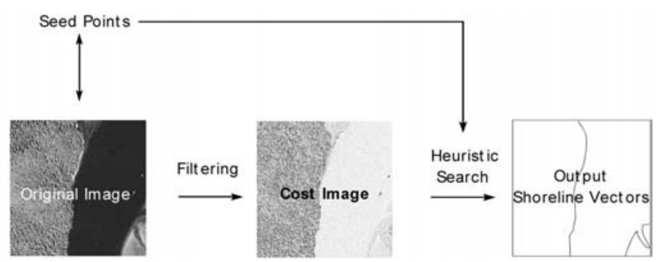

Fig. 1. Flowchart of the Shoreline Extraction Process

VI. RESULTS AND DISCUSSION

The most accurate shoreline vectors were extracted from cost images created by using the negated Roberts filter. Fig. 2 shows 148 by 205 pixels 1-m resolution subset images at three different stages.

The following figures (Fig. 3 and Fig. 4) offer a visual comparison between the positional accuracy of the TRIM vectors and the shoreline vectors extracted by the algorithm for the same area at two different resolutions. It can be seen that the TRIM vectors are not as accurate in the 4-m resolution image as they are in the 30-m resolution image. On the other hand, the vectors extracted by the algorithm seem to be consistently more accurate in both situations and also in the 1-m resolution image (Fig. 5).

The performance of several other cost images is still being evaluated but in general coarser-resolution images (larger than 4 meters) allow for the creation of a much simpler cost image.

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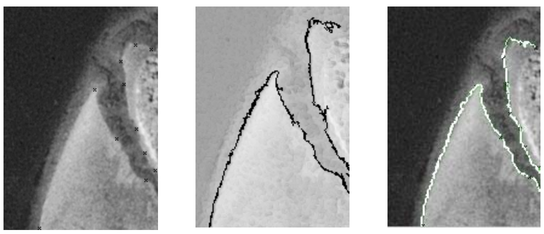
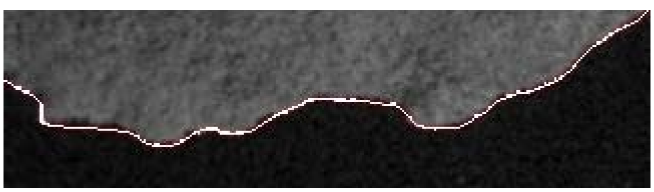
The influence of shadows due to trees and coast geomorphology is much greater in finer-resolution images (smaller than 4 meters). In order to minimise these effects it is necessary to create a more complex cost image by using more than one simple filtering operation.

Fig. 5 shows an example of another method employed in the creation of such cost images for a 1-m resolution image of the same area. Here four different threshold values (104, 121, 169 and 212), about which an image is quantized, were used in order to overcome the difficulties imposed by the level of detail. These values were picked along the shoreline to facilitate the search process.

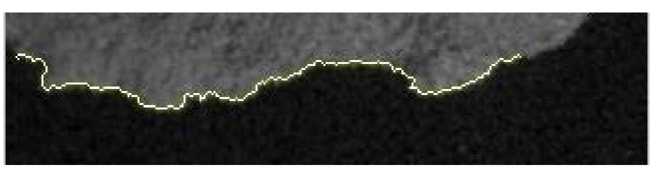


(a) (b) (c)

Fig. 2. Three stages of the process: (a) seed points on the original image, (b) path (in black) being traced on cost image, and (c) extracted shoreline (in white) on original image.



(a)



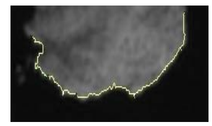
(b)

Fig. 3. Subset of a 4-m resolution image (323 by 163 pixels): (a) TRIM vectors overlaid on original image and (b) extracted vectors (in white).

VII. Conclusion

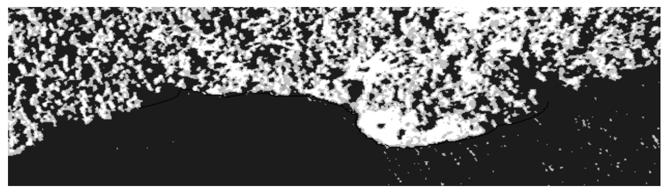
The accurate determination of shoreline position using remote sensing techniques is a difficult task to be undertaken carefully. When evaluating the position of the shoreline the researcher must consider the physical, geological, biological and chemical aspects involved in the evolution of the shore.

Semi-automated shoreline delineation techniques have been found to be more efficient than automated ones. This is because they incorporate the input of an analyst who assists the algorithm by inputting seed-point along the most likely location for the occurrence of the shoreline before running the edge extraction.

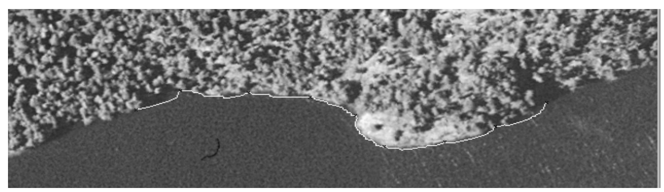


(a) (b)

Fig. 4. Subset of a 30-m resolution image (103 by 55 pixels): (a) TRIM vectors overlaid on original image and (b) extracted vectors.



(a)



(b)

Fig. 5. Subset of a 1-m resolution image (634 by 196 pixels): (a) thresholded image and (b) extracted vectors (in white) overlaid on original image.

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