COASTLINE EXTRACTION FROM AERIAL IMAGES BASED ON EDGE DETECTION

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Objective:

A coastline is the boundary line between land and large water mass like sea or ocean. The knowledge about coastline position, orientation and geometric shape is critical for autonomous navigation, geographical exploration, coastal erosion monitoring and modelling, and coastal resource inventory and management. Today the coastline extraction and tracking of its changes has become very important because of the climate change, global warming and rapid human population growth. With a specific reference to the hydro-geological and morphological aspects of the coastal environment, the global climate changes and the human activities in the coastal zones could cause pollution, erosion, landslides and more in general landscape's alterations. This phenomenology affects both on life's quality and on the exploitation of coastal resources. The lack of an overall comprehension of the natural and anthropogenic processes which determine the evolution of the coastal environment is often the reason for its incorrect management. The project aims to develop a solution for the detection and extraction of the coastline from the aerial images.

Challenges in the Coastline Extraction:

Coastal areas are unique environments in which atmosphere, hydrosphere and lithosphere meet each other. The dynamic nature of the coastlines leads to the frequent lack of consistent, sufficient intensity contrast between land and water regions and the complexity in distinguishing coastline edges from other object edges. Most of the general-purpose edge detection and image segmentation techniques are inadequate for a coastline extraction task. A comprehensive procedure is required for the coastline extraction process.

Methodology for the Coastline Extraction:

The method for automatic extraction of the coastline is based on the 4-step algorithm.

1. Pre-processing:
   It is used for reducing the noise in the aerial images and for enhancing the edges in the image.

2. Region Segmentation:
   This step provides a local threshold to divide the image into blocks of different content.

3. Post-Processing:
   Morphological operations and edge detection to extract the coastline.

4. Coastline Modelling:
   An Active Contour Model method is used to optimize the result of the previous stage.

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Block diagram of the methodology:

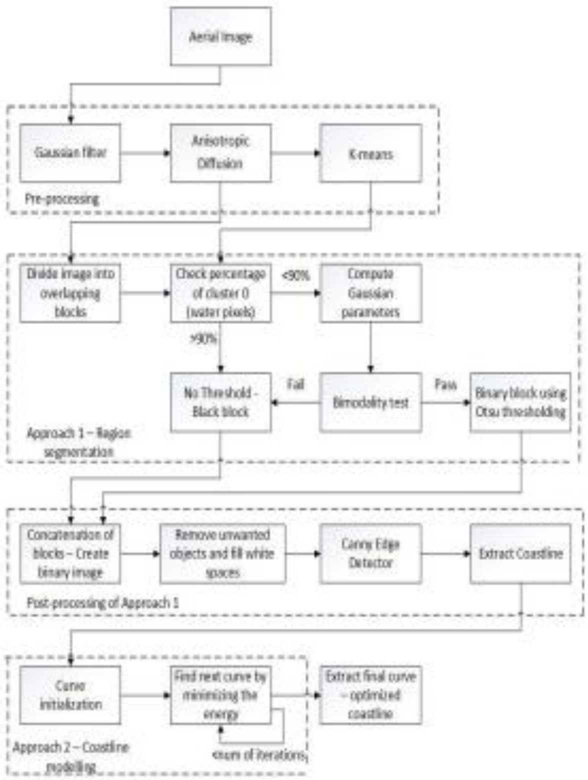

Figure 1. Block Diagram of the proposed methodology

Step 1: Pre-processing:

The aerials images obtained using remote sensors contain inherent noise and aberrations. There can be aberrations introduced due to atmospheric effects, and geographical features like rotation of earth. Applying a pre-processing algorithm usually increases performance of image processing. The noise contained in the image is reduced by using a Gaussian filter. The Gaussian filter removes noise without blurring the edges. The deformation of the image due to unexpected factors, like sun light, shadows or clouds is encountered using an anisotropic diffusion algorithm. The algorithmic enhances strong edges, like coastal area and land and suppresses weak edges like the sea area.

<u>Results of Pre-processing stage:</u>

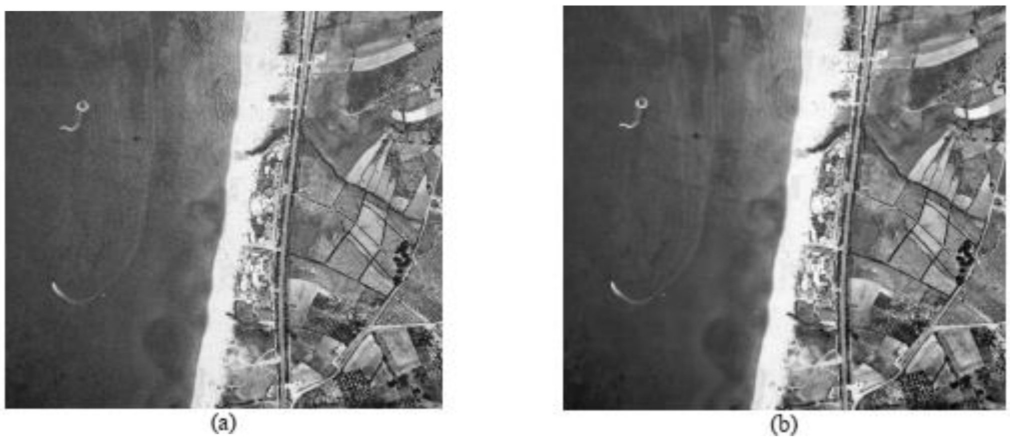

Figure.2 a) Initial Image b) Image after Pre-processing [Ref.1]

Step 2 Region Segmentation:

The image is segmented into two regions, land and sea. The pixels that belong to the borders of these two regions compose the coastline. Local adaptive thresholding is used to avoid false estimations due to the heterogeneous intensities present in the image.

1.Clustering of the image using K-means algorithm:

The K-means algorithm must initially define the number of clusters. In this case, there will be three clusters. K=3 i.e. sea (cluster = 0), coast and buildings (land, cluster = 1, 2). Then k-cluster centre are chosen randomly. The distance between each pixel to each cluster centres are calculated. The distance may be of simple Euclidean function. Single pixel is compared to all cluster centres. The pixel is moved to cluster which has shortest distance among all. Then the centroid is re-estimated. Again, each pixel is compared to all centroids. The process continuous until the centre converges.

2. Divide the image into small blocks (regions) and specify a different threshold adjusted to each of them. The image into square overlapping blocks of width ‘w’ large enough for each block to cover the necessary spatial information to reflect the appropriate edge structure for the targeted application. The reason behind this is that some of the blocks will be made of entirely sea or land pixels, so that there is no need to process such blocks.

3. To further reduce the processing time, the percentage of zero value pixels is estimated for each block. If a block has total number of zero pixels above of 90 percent of the whole image, it does not need to be processed. The motivation behind this is that these blocks contain mostly sea area and maybe waves or other masses on the sea surface.

4. The remaining blocks are tested for bimodality. If a block contains only water area or land area pixels, the mixture of the Gaussian distribution will only reflect one peak (unimodal). If a block is part of the coastline area, the mixture of distributions will consist of one valley and two peaks (bimodal). To be able to identify whether we have a bimodal or unimodal distribution, the valley to peak ratio of the total histogram of the block is used as the criteria.

5. If a block is bimodal, then the threshold is calculated using ‘Otsu’s method’. The algorithm assumed that the block contains two classes of pixels (land, sea) through bimodal histogram and then calculates the optimum threshold that classifies the two classes so that their combined spread is minimal by maximizing the between class variance.

The weighted between-class variance is:

$$\sigma_b^2(t) = q_1(t)q_2(t)[\mu_1(t) - \mu_2(t)]$$

where q_i are the probabilities of the two classes separated by a threshold t and μ_i denote the means of these classes. The class probabilities estimated from the class histograms are:

$$q_1(t) = \sum_{i=1}^{t} p(i) \quad q_2(t) = \sum_{i=t+1}^{I} p(i)$$

The class means are given by:

$$\mu_1(t) = \sum_{i=1}^{t} \frac{p(i)x(i)}{q_1(t)} \quad \mu_2(t) = \sum_{i=t+1}^{I} \frac{p(i)x(i)}{q_2(t)}$$

where x(i) is the value of the i histogram bin.

Using an iterative process, the optimal threshold is found for which the between class variance is the maximum. This threshold is applied on each block and the block is converted into a binary block using the thresholding process given by:

$$b(x,y) = \begin{cases} 0, \text{ if } I(x,y)<\mathrm{T} \\ 1, \text{ if } I(x,y)>\mathrm{T} \end{cases}$$

where T is the threshold of the block and I (x, y) is the intensity value of image pixel at points x, y. For every block that fails to pass the bimodality tests a binary image is created with zero values at every point.

Step 3 Post-processing:

1. The blocks are concatenated to recreate the image in a binary form. In case of overlapping blocks, the final value of the pixel is calculated using the 'OR' logic. i.e. the final pixel value is 1 if any one of the overlapping blocks is 1. The reason is that blocks with over 90% of pixels in the sea area do not pass the bimodality test. However, in extreme cases, a small part of the coastline may be involved in such a block. It is expected that a neighboring block will identify the coastline, because it will contain both parts of sea and land area. The use of the proposed conjunction condition aims to protect such edge pixels across the coastline that appears only at a portion of overlapping blocks.

2. Waves, ships or other objects on sea surface can create false edges. To eliminate these effects, we apply the morphological operations of erosion and dilation. An opening operation. i.e. erosion followed by a dilation is applied to remove the undesired objects like waves and ships and preserve the original abstract shape of the image. The structuring element H used for the morphological operations is such that stray foreground structures larger than H must be preserved. A closing operation, which is a dilation followed by an erosion is applied on the image. This operator fills black holes smaller than H but also keeps the original shape of the image.

Fig. 3 a) Fig. 3 b)

Figure.3 (a) Image after concatenation of binary blocks (b) Image after morphological operations [Ref. 1]

3. Finally an edge detector is applied on the image, which at this stage consists of a white area belonging to land and a dark area belonging to sea and the boundary defines the coastline.

'**Canny edge detector**' is used for the edge detection. It mainly consists of 3 steps.

Step1. Find the intensity gradient of the image:

The edges should be marked where the gradients of the image have large magnitudes. Gradient of the image was calculated using Sobel's filter or any other gradient filter like Prewitt's filter.

Step2. Apply non-maximum suppression:

Compare the edge strength of the current pixel with the edge strength of the pixel in the positive and negative gradient direction. If the edge strength of the current pixel is largest; preserve the value of the edge strength. If not, suppress (i.e. remove) the value.

Step3. Hysteresis is applied to eliminate gaps:

Finalize the detection of edges by suppressing all the other edges that are weak and not connected to strong edges.

Results of Canny edge detection:

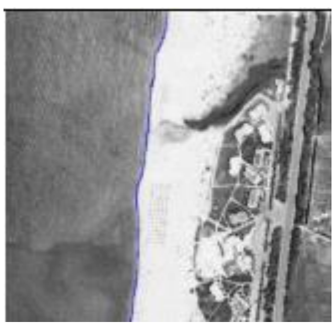

Fig 4. a)

Fig 4. b)

Fig 4 (a), (b) close-up of the initial image in two separate locations. Blue line reflects the estimated coastline.

Step 4. Coastline modelling:

Some random factors across the coastline, such as people, moving cars, or waves, which cannot be captured correctly by the previous steps may produce wrong estimations. So, the open active contour method, which is based on snakes and extends the classical active contour model with the condition of free boundary conditions is adopted to improve the estimated coastline in the previous step.

A simple elastic snake is defined by a set of n points $v_i$where i=0,1,2,…n-1, the internal elastic energy term $Eint$, and the external edge-based energy term $Eext$. The purpose of the internal energy term is to control the deformations made to the snake, and the purpose of the external energy term is to control the fitting of the contour onto the image. To obtain these deformations we need to minimize the energy function formed by two energy terms regarding the intensity distribution of the image around the edge and reflect the internal and external regions of the edge itself. This functional can be expressed by:

E_{snake} = Eint + Eext

Where Eint = $\int_0^1 (\alpha|C'(s)|^2 + \beta|C''(s)|^2)dt$

Eext = $-\lambda \int_0^1 |\nabla I(C(s))| dt$

Therefore, $E_{snake} = \int_0^1 (\alpha|C'(s)|^2 + \beta|C''(s)|^2 - \lambda|\nabla I(C(s))|)dt$

Where s is the curve parameter. C(s) = (x(s), y(s)) is the initial curve in the original image I, parameters α and β induce the elasticity and rigidity in the curve. λ indicates the level of the gradient regions that the curve will attract to and ∇I is the gradient of the image intensity.

One boundary curve on the top and one on the bottom of the image. The two end points of curve are restricted to lie on the boundary curves. The curve is initialized using the coastline extracted from the previous step. The next possible position of the curve is estimated iteratively for 150 iterations by minimizing the energy of the snake bounded by the two boundary curves.

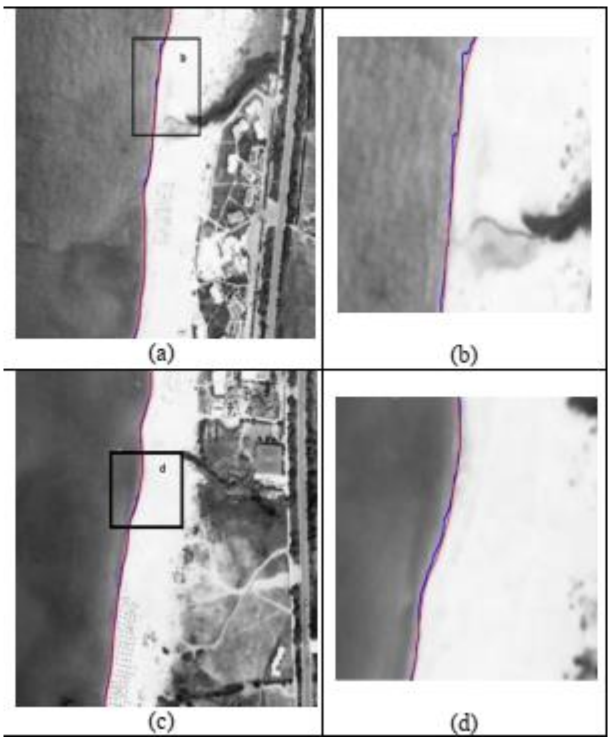

Fig 5. (a), (c) close-up of the initial image in two different locations showing the results of the two steps i.e. canny edge detection and the open active contour model. (b), (d) provide a more detailed aspect of (a), (c) respectively Blue line refers to the estimated coastline extracted from the canny edge detection while red line refers to the optimized coastline obtained from the open active contour approach.

Comparing the two results, the added benefits of curve fitting resulting in smoother estimates that are less affected by other physical formations close to the coastline can be realized.

Conclusion:

This methodology provides and automated coastline extraction using the aerial images utilizing the image processing techniques aiming at region segmentation and edge detection. The processes of local adaptive thresholding, edge detection using Canny edge detector and active contour fitting help in improving the accuracy of the extracted coastline.

As a future scope, the accuracy of the coastline estimation can be improved by implementing the transform for moving from image coordinates to real-world coordinates and view the image as a projective mapping from the 3D word coordinate system. This can be implemented by using geo-referenced images. This conversion can help real-world measures, such as coastline length, coast surface and erosion levels.

References:

The main paper used as reference for the project:

1. V. Paravolidakis, K. Moirogiorgou, L. Ragia, M. Zervakis, C. Synolakis, ”Coastline Extraction From Aerial Images Based On Edge Detection”, ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume III-8, 2016,XXIII ISPRS Congress, 12–19 July 2016.

Additional papers:

2. H. Liu, K. C. Jezek, “Automated extraction of coastline from satellite imagery by integrating Canny edge detection and locally adaptive thresholding methods”, Int. J. Remote Sensing, Vol. 25, No. 5, 937‑958, 10MARCH, 2004.
3. John Canny, “A Computational Approach to Edge Detection”, IEEE Transactions on Pattern Analysis And Machine Intelligence, Vol. Pami-8, No. 6, November 1986.
4. DongjuLiu, JianYu,” Otsu method and K-means “Ninth International Conference on Hybrid Intelligent Systems,2009
5. Muhammet Baştan, Syed Saqib Bukhari, Thomas Breuel, “Active Canny: edge detection and recovery with open active contour models”, IET Image Processing,2017