

COMPARISON OF TWO SIMPLIFICATION METHODS FOR SHORELINE EXTRACTION FROM DIGITAL ORTHOPHOTO IMAGES

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ABSTRACT:

The coastal ecosystems are very sensitive to external influences. Coastal resources such as sand dunes, coral reefs and mangroves has vital importance to prevent coastal erosion. Human based effects also threats the coastal areas. Therefore, the change of coastal areas should be monitored. Up-to-date, accurate shoreline information is indispensable for coastal managers and decision makers. Remote sensing and image processing techniques give a big opportunity to obtain reliable shoreline information. In the presented study, NIR bands of seven 1:5000 scaled digital orthophoto images of Riga Bay-Latvia have been used. The Object-oriented Simple Linear Clustering method has been utilized to extract shoreline of Riga Bay. Bend and Douglas-Peucker methods have been used to simplify the extracted shoreline to test the effect of both methods. Photogrammetrically digitized shoreline has been taken as reference data to compare obtained results. The accuracy assessment has been realised by Digital Shoreline Analysis tool. As a result, the achieved shoreline by the Bend method has been found closer to the extracted shoreline with Simple Linear Clustering method.

1. INTRODUCTION

Global warming and its effects are one of the main topics for scientists (Deng et al., 2014). According to International Union of Geological Sciences (IUGS), shorelines are one of the vital and vulnerable environmental heritages (Li, et al., 2001). Coastal areas are very complex ecosystems and socio-economic environment (Raju et al., 2015). They contain large variety of habitats which are important for survival of biodiversity and (Gammal, et al., 2016). The biological and physical characteristics of coastal areas can change because of physical reasons and anthropogenic processes (Pareeth, et al., 2017). Therefore monitoring of shoreline is essential to protect environmental heritage areas (Addo, 2013). Up-to-date and reliable shoreline information is indispensable for coastal managers (Jawak, et al., 2015).

Remote sensing and geographical information system (GIS) provides new technologic advantages in costal monitoring studies (Maiti and Bhattacharya, 2009). Monitoring of shoreline is fundamental for planning, defining of hazard zones, and predicting of erosion and sediment transport (Bayram et al., 2013).

Image processing techniques can provide reliable solutions for shoreline extraction issue. Several pixel and object-oriented methods have been proposed. Iterative Self Organized Data Analysis (ISODATA) (Guariglia, et al., 2006), thresholding and morphological filtering (Pardo-Pascual, et al., 2012, Bayram et al., 2008), non-separable wavelet transform (Yu, et al., 2013), active contour models (Shmitt, et al., 2015), genetic algorithm based methods (Yousef and Iftekaruddin, 2014), particle swarm optimization method (PSO) (Bayram, et al., 2016), Random forest method (Erdem et al., 2017), mean-shift segmentation (Wu, et al., 2009), object-oriented fuzzy classification

approaches (Bayram et al., 2017; Bayram et al., 2015), Support Vector Machine (Kalkan, et al. 2013) can be counted as mainly used methods for shoreline extraction.

In the presented study Simple Linear Clustering segmentation method has been employed and shoreline Gulf of Riga (GoR) has been extracted. Douglas-Peucker and Bend simplification algorithms have been implemented for simplification of extracted shoreline and their effect on accuracy assessment has been tested. The photogrammetrically digitized shoreline of GoR has been taken as reference data for evaluation of the results.

2. STUDY AREA

The Latvian shoreline is about 500 km. The 85% sandy beach coastline is under threat of erosion, deposition, increasing of inhabitants and urbanisation, summer houses (Ebehards, et al., 2006). GoR is rich of coastal resources and natural biodiversity. Buļļusala Island located in the south part of the GoR, between entry of river Daugava in the East, entry of river Lielupe in the West and river Bullupe in the South. Island has been formed in the 18th century during the floods of Lielupe. Also at present peripheral rivers influence the coastline changes of Buļļusala and its surroundings. This study is focused on the 16 km part of GoR which is selected as the study area (Figure 1).

3. MATERIAL AND METHOD

In this study NIR band of the 1:5000 scaled seven digital orthophoto images of Buļļusala and Buļļupe in Riga-Latvia in the year of 2013 were used. Presented study consists of main three parts which are (i) shoreline extraction using Simple Linear Clustering (SLIC) method, (ii) simplification of extracted shoreline by Douglas-Peucker and Bend algorithms, (iii)

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searching effects of both simplification methods with Digital Shoreline Analysis System (DSAS).



Figure 1. The study area.

3.1. Implementation of SLIC

In the first step of the study, shoreline extraction has been accomplished. For this purpose, Superpixels have been created to obtain homogeneous segments. SLIC algorithm is an efficient object-oriented segmentation method which is based on spatially localized version of K-means clustering method. The detailed information about SLIC can be found in Achanta, et al. (2012).

K-means is based on the standard Lloyd algorithm (Lloyd, 1982). Compare to K-means algorithm, by SLIC, each pixel is assigned only to the centre of neighbour tiles. Once superpixels are created, the area of superpixel is checked according to user defined minimum region size (Vedaldi and Fulkerson, 2010). MATLAB environment has been used for utilizing SLIC algorithm. For all seven orthophoto images the same parameters have been used. The number of the superpixels and compactness were chosen 15000 and 0.5 respectively. The created superpixels are given in Figure 2.

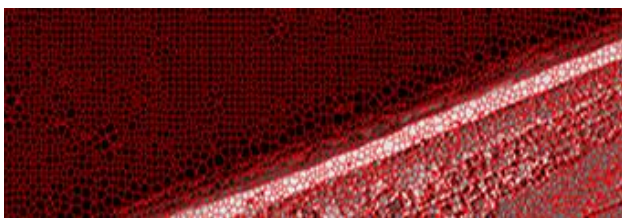


Figure 2. Created superpixels.

In the next step, thresholding has been implemented to create Land and Water-body classes from segmented image. The thresholding parameters are given in Table 1. Following to thresholding, editing has been employed. Editing module has been created to edit wrongly classified segments after thresholding. The aim of the editing is to add or to delete segments from image which are belonging to wrong class by using selected superpixels. A sample of the editing process is given in Figure 3. Noise removal step has been implemented to eliminate noisy pixels by using region analysis tool of MATLAB after editing. The final binary image is given in Figure 4.

Image No	Thershold value
1	124-255
2	110-255
3	50-255
4	113-255
5	150-255
6	30-255
7	90-255

Table 1. Thresholding parameters.

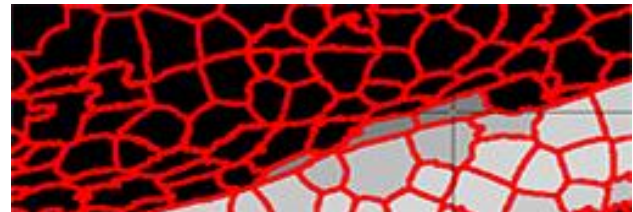


Figure 3. Editing process.



Figure 4. Resulted binary image.

The shoreline of GoR has been obtained by applying raster to vector transformation after creation of all seven binary images from orthophoto maps.

3.2. Simplification of extracted shoreline

Generalization is needed in order to represent relevant information on an appropriate level of detail (Ai et al., 2014). Simplification approach reduces the number of points of the feature, with the restriction that the characteristic shape of the feature is preserved. Simplification approach eliminates insignificant vertices of the feature with the restriction of preserving the essential shape (Sester, 2000).

There are two main restrictions in the shoreline generalization. One of them is preserving the pattern of coastline, which is related with geomorphologic properties. The other one is keeping important characteristics such as estuary sources. (Ai et al., 2014).

Wang and Muller (1998) proposed an algorithm for generalization based on bend simplification. The algorithm preserves the overall structure with line bends by detecting their size, shape and context mathematically and eliminating insignificant ones. The algorithm preserves the overall structure with line bends, which are mathematically defined related to size, shape and context. According to (Wang and Muller, 1998), a bend is defined by the algorithm as a part of a line in which a number of subsequent vertices are contained. A Bend contains inflection angles of all vertices with positive or negative sign. Opposite signs set the two end vertices of a bend's inflection. The bend elimination depends on the comparison of the tolerance value and the geometric measures of the bend. Other commonly proposed simplification method is Douglas-Peucker algorithm

(1973) which takes into account the maximal perpendicular distance of points from a hypothetical generalized trend line. Perpendicular distance measurement is taken as unique criteria for point selection by the algorithm. If the distance between trend lines and vertices are smaller than the tolerance value than these vertices are eliminated (Sester, 2000).

The tolerance values of Douglas-Peucker and Bend simplification methods are determined by considering of cartographic legibility and aesthetic aspects (Burghardt and Schmid, 2009). In the presented study, tolerance values have been taken as according to limit of visual perception as approximately 0.2 mm at a reading of 30 cm (Burghardt and Schmid, 2009) which corresponds to the ground sample distance of digital orthophoto images.

Both simplification methods have been utilized to simplify extracted shoreline and compared with the photogrammetrically digitized shoreline of GoR. The total length and the number of vertices of the raw data and simplified shorelines are given in Table 2. As it can be seen in Table 2, Douglas-Peucker simplification results of extracted shoreline get closer to the photogrammetric digitizing. However, the Douglas-Peucker algorithm produced some sharp bends which were illegible at the target scale (1:5000) and caused self-intersection issues as shown in the brown box in Figure 5. The Bend algorithm produced the simplified features which were smoother than the Douglas-Peucker, and closer to the line extracted by SLIC algorithm.

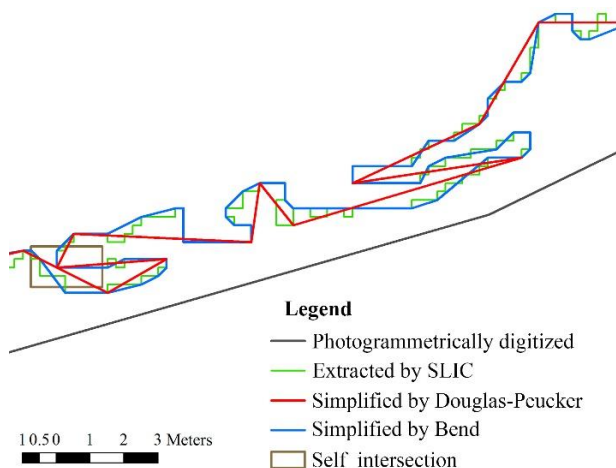


Figure 5. Results of Douglas-Peucker and Bend methods.

Extracted shoreline by SLIC and photogrammetric evaluation results are given in Figure 6.

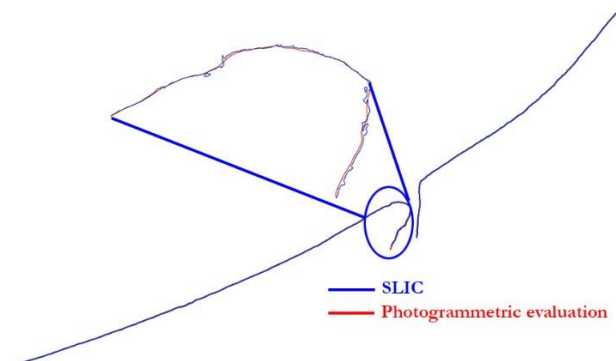


Figure 6. Shoreline extraction by SLIC

Methods	Length (km)	Number of Vertices
Photogrammetric evaluation	15.86	907
Extracted by SLIC	23,35	59404
Douglas-Peucker to SLIC line	17,19	1798
Bend to SLIC line	18,56	18438

Table 2. Total length and the number of vertices of shoreline.

In the last step of the study, the extracted and simplified shorelines have been compared with created shoreline by photogrammetric process of GoR. This step has been realized by Digital Shoreline Analysis System (DSAS) (Thieler et al., 2009). DSAS is a tool for evaluation a shoreline with reference data (Jayson-Quashigah et al., 2013). The Net Shoreline Movement function of DSAS has been employed for comparison which calculates perpendicular distances with defined spacing between input and reference data (Oyedotun, 2014).

The spacing, transect length and buffer size has been chosen as 10m, 75m and 30 m respectively.

A sample for evaluation of Bend method with photogrammetrically digitized shoreline is given in Figure 7. The accuracy assessment results are given in Table 3.

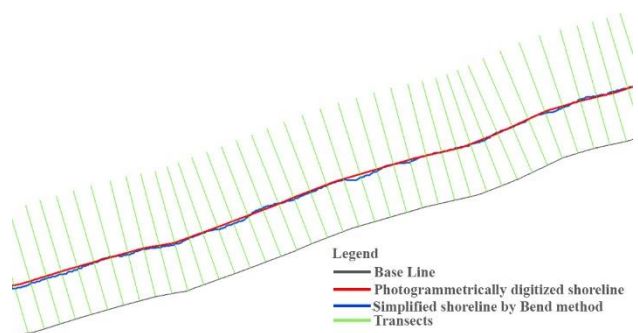


Figure 7. Evaluation of shoreline simplification with reference data.

4. RESULTS AND CONCLUSIONS

According to Table 3, the results of Bend method are closer to original extracted shorelines. While calculated ratios in 0.0-1.0 m distance for SLIC and Bend method are 50.65% and 50.98% respectively, the ratio for Douglas-Peucker method is 49.71%. Similar to this, the ratios for 1.0-2.5, 2.5-5.0, 5.0-7.5 and >7.5 m distance of Bend method are close to calculated distances for SLIC. The statistical analysis results are given in Table 4.

Method	Calculated distance (m)	0.0-1.0	1.0-2.5	2.5-5.0	5.0-7.5	>7.5
SLIC	Number of transects	776	496	181	50	29
	Ratio (%)	50.65	32.38	11.81	3.26	1.89
Bend	Number of transects	781	489	182	52	28
	Ratio (%)	50.98	31.92	11.88	3.39	1.83
Douglas-Peucker	Number of transects	762	509	185	46	31
	Ratio (%)	49.71	33.20	12.07	3.00	2.02

Table 3. Accuracy assessment results.

Statistics (m)	BEND	DOUGLAS	SLIC
Minimum	-13.81	-13.82	-12.58
Maximum	13.54	13.80	10.91
Mean	0.28	0.30	0.46
Standard deviation	2.40	2.38	3.66
RMS	2.41	2.40	3.69

Table 4. Statistics of the methods.

As a result of the statistical analyses, standard deviations have been found 2.4 m, 2.38 m and 3.69m for Bend method, Douglas-Peucker method and unsimplified shoreline respectively. The % 95 of distance difference values have been found in ± 4.69 m for Bend method, ± 4.66 m for Douglas-Peucker method and ± 7.18 m for unsimplified method according to confidence interval ($\alpha=0.05$). The statistics show that the results of Bend and Douglas-Peucker methods are close to each other and provides more precise results than the unsimplified shoreline data. From this point of view it can be said that simplification process can be used for shoreline extraction.

In the future studies, more complex shoreline data will be simplified using Bend and Douglas-Peucker methods to test their effects to the accuracy assessment.

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