Gamma Correction-Based Image Enhancement and Canny Edge Detection for Shoreline Extraction from Coastal Imagery

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Abstract*—This paper investigates the potential of using a Gamma Correction-based image enhancement and Canny edge detector to extract the shoreline position from coastal video images. Within the framework of the shoreline extraction system, Gamma correction has updated the contrast of coastal imagery to segmented and classified efficiently in land, sea and sky areas. In this study, the value of the Gamma correction factor was determined to be 1.3. At this value, the validation of the cluster value in the Self Organising Map (SOM) segmentation has shown an increasing perform of cluster, from the reasonable cluster to the strong cluster. Furthermore, the mechanism of classification of land, sea and sky objects in coastal imagery is done by extracting the texture features on each cluster. Then, feature information is stored for the classification training process using K-Nearest Neighbor (K-NN). The shoreline extraction procedure is based on the identification of the land class in the K-NN testing process. This study has implemented a binary image transformation method combined with a Canny edge detector to define pixel boundaries of land and non-land areas. The experimental results have shown that the proposed method capable of producing a continuous shoreline in accordance with the texture of the coastal path in coastal imagery

Keywords—Coastal video imagery; Shoreline extraction; Gamma correction; SOM; K-NN; Canny Edge Detector

I. INTRODUCTION

Changes to the shoreline are an endless process through various processes of both abrasion and beach accretion. These processes are caused by sediment movement, wave action and land use. This can damage the coastal environment. Therefore, monitoring of shoreline positions is the most urgent activity have to do, given the high socioeconomic value and population density in coastal areas[1].

In general, the coastal area can be easily identified because of the homogeneous nature of the area, i.e., the ocean. However, in a video-based coastal monitoring system, the identification of coastal areas becomes very complex, as it relates to physical conditions during image capture, such as position of camera placement, camera sensors, and weather phenomena. The characteristic of coastal images obtained from not too high camera placement, itis always changing. This is caused by reflection and inhomogenety in the oceans when changes in wind conditions, local currents and changes in ocean depth. The atmospheric conditions such as fog and clouds also contribute to changes in video image characteristics. Therefore, in the process of shoreline extraction, a more complex image enhancement mechanism is needed to acquire areas within sea, land, and sky clusters.

In an effort to develop video-based shoreline extraction techniques, some researchers have proposed the application of image improvement techniques prior to segmentation and classification. Reference [2]has used a Chebyshev Polynomials-based histogram approach before Fuzzy clusteringThe histogram-based analysis approach is also proposed by [3] using Otsu method combined with HSV color space analysis for the determination of dry and wet areas on shoreline extraction. Another approach by integrating locally adaptive thresholding and Canny edge detection methods in the segmentation process is proposed by [4]. Application of Canny edge method was able to improve accuracy and accelerate the determination of boundaries of land and sea areas.

The author has also proposed a shoreline extraction framework by combining several methods, including: contrast stretching, SOM segmentation, K-NN classification, and binary image transformation[5], [6]. In[6], the accuracy of shorelinedetection is strongly influenced by the segmentation

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process. The SOM segmentation analysis has shown that the value of the cluster is validated in the weak criteria. This condition causes the K-NN classification technique not yet optimal in detectingthe land area. Furthermore, the detected land area is used as a reference area in shoreline extraction.By scanning the edges of the land area, each pixel of 0 will be expressed as shoreline.

The above explanation has shown that the image improvement stage plays an important role in the segmentation of objects in the coastal image, namely land, sea and sky. This is closely related to coastal image characteristics that change dynamically due to weather factors. Therefore, a mechanism to manipulate the image histogram is required without disturbing the coastal image saturation. For the case of images with dynamic contrast, some researchers have applied the Gamma Correction technique as a method of image enhancement [7], [8]. The basic principle of the Gamma correction is to increase contrast for low intensity pixels and avoid decreasing contrast in high intensity pixels. Thus, enhanced image brightness can be maintained better than the original image.

The main contribution of this research is to improve the accuracy of shoreline detection from the framework [6] by applying Gamma correction techniques inimage pre-processing stage, and Canny edge detection in shoreline extraction. The goal is to improve the performance of SOM segmentation, and to reinforce the shoreline by detecting edge pixels. When cluster criteria become strong, then the K-NN classification can classify the land area accurately. Furthermore, the Canny edge detector is applied to identify the mixed pixels (edges) along the land area within the coastal image.

This paperwill be divided into some sections. Section I describes research backgrounds, Section II explains data and methods used in this proposed study, section III shows results and discussion, and finally, in Section IV, the conclusion is explained.

II. DATA AND METHODS

A. Data

This study has used video data in the form of a video dataset of Egmond Beach, Nederland, which was downloaded from Deltares Argus Archive website[9]. Video data is an image in TIMEX (Time Exposure) format, i.e. the average image of the snapshot image set, taken in a stationary viewpoint. The average image is taken periodically per 10 minutes on 600 snapshots images. Averaging is formed on each pixel, then each pixel of the Timex image is an average of that pixel over the 600 snapshots [10]. The TIMEX image is expressed on the RGB color model.

B. Proposed Methods

Fig. 1 shows the proposed shoreline extraction framework adapted from[6], consisting of 3 (three) steps: image pre-processing, image processing, and shoreline extraction. The proposed improvement is directed to the application of Gamma correction techniques at the pre-processing stage, and Canny edge detection at the stage of shoreline extraction.

1) Image Pre-processing

To improve the quality of segmentation of objects in coastal imagery, this paper has applied Gamma correction techniques. The goal is to improve the quality of the contrast of images, so that objects in the coastal image will appear more clearly.

Gamma correction techniques pre-compensates for image data before being sent to the display system. In principle, if L_{org} is the original image before it is sent to the display system, gamma correction will substitute the L_{org}value with the following equation[11]:

$$L_{in} = L_{org}^{\ 1/\gamma} \tag{1}$$

where, $L_{in}$is input illumination intensity of the display system, and γ is gamma correction factor.

$$L_{out} = L_{in}^{\ \gamma} = \left[L_{org}^{\ 1/\gamma} \right]^{\gamma} = L_{org} \tag{2}$$

Equation (2) has shown that the illumination intensity output on the display system (L_{out}) can be generated as the original image by inversing gamma correction.

In this study, the gamma correction factor is set to 1.3, because it provides the most optimal results in the SOM segmentation. At this value, the coastal image is made darker to sharpen the differences in objects in the coastal image. As shown in the image histogram in Tabel I, after corrected gamma, image pixels with lower intensity values are higher, compared to the contrast stretching method.

Furthermore, gamma-corrected images are transformed morphology by morphological contrast enhancement techniques to overcome the effects of overly strong solar lighting on coastal imagery. Morphological techniques use top-hat and bottom-hat transformations[12].

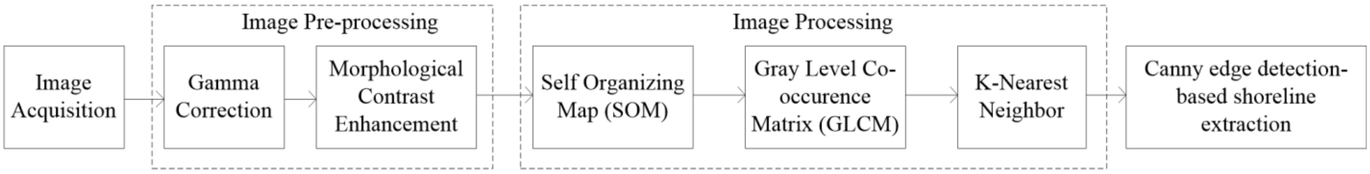
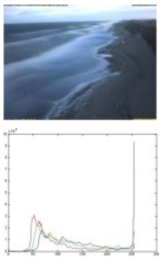
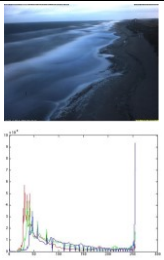
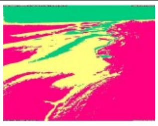
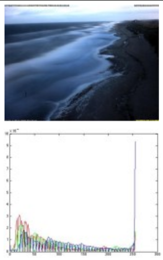
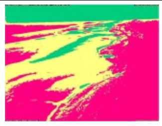
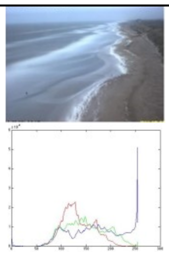
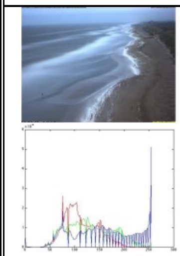
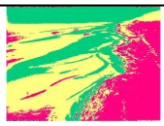
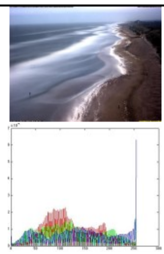
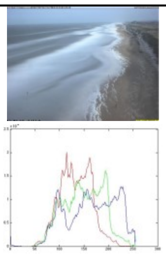
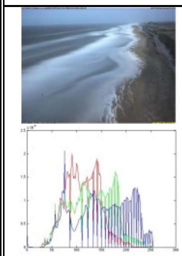
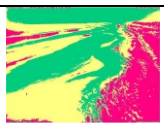
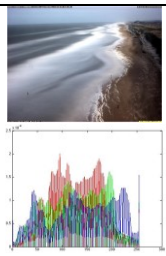
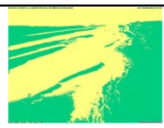


Fig. 1. The proposed shoreline extraction framework

TABLE I. COMPARISON OF IMAGE HISTOGRAM AND CLUSTER CRITERIA ON APPLICATION OF GAMMA CORRECTION AND CONTRAST STRETCHING TECHNIQUES ON SHORELINE EXTRACTION FRAMEWORK [6]

No.	Sample Image	Image Histogram after Gamma Correction ($\gamma = 1.3$)	SOM	Cluster Criteria	Image Histogram apter Contrast Stretching	SOM	Cluster Criteria
1				0.7692 (Strong cluster)			0.3610 (Weak cluster)
2				0.7018 (Reasonable cluster)			0.5290 (Reasonable cluster)
3				0.6702 (Reasonable cluster)			0.5447 (Reasonable cluster)

2) *Image Processing*

Image processing includes SOM segmentation and K-NN classification of objects in the coastal image, i.e. land, sea and sky. SOM's segmentation technique offers Artificial Neural Comparison Of Image Histogram And Cluster Criteria On Application Of Gamma Correction And Contrast Stretching Techniques On Shoreline Extraction Framework [6]. Network (ANN) training techniques based on winner take all, where only neurons are the winners to be updated in weight. Therefore, SOM generates maps consisting of outputs in low dimensions (2 or 3 dimensions) [13].

In this study, the application of SOM algorithm in the separation of land, sea and sky objects on coastal imagery is based on the similarity of RGB color features. Base on [13], the following is the SOM procedure used for segmenting objects in coastal imagery:

Algorithm 1:

1) Initialize the neurons with randomly generated weights (W_{ji}), initial learning rate, learning function, number of iteration, and number of cluster

2) As long as the maximum number of iterations has not been reached, do steps *3-7*.

3) For each input vector x (feature RGB), do steps *4-6*

4) Calculate all j with:

$$D_j = \sum_i \left(w_{ji} - x_i\right)^2; \quad i = 1, 2, ..., N \tag{3}$$

5) Determine the index j such that the minimum D_j

6) For each unit j around J, modification of weight with:

$$w_{ji}(new) = w_{ji}(old) + \eta\left(x_i - w_{ji}\left(old\right)\right) \tag{4}$$

7) Modifications learning rate

Furthermore, the implementation of SOM algorithm is done by arranging several parameters, including: number of clusters is 3, maximum number of iterations is 100, learning rate is 0.5, and learning function is 0.2.

As shown in Table I, in general, the result of SOM segmentation combined with gamma correction technique can increases the cluster validity from weak cluster to reasonable cluster, and from reasonable cluster to strong cluster. The validation of the cluster index value is obtained by the silhouette coefficient method[14]. This shows that gamma correction on factor 1.3 can provide better RGB color features than contrast stretching techniques.Furthermore, the segmentation output is improved by morphology operation to remove noise on unnecessary objects. Morphology operation uses dilation and erosion operations [15].

The object classification mechanism of the coastal image begins by extracting the texture features on the segmentation output using the Gray-Level Co-occurrence (GLCM) method [16]. The texture feature is used to identify the class labelfor each segmentation area into land, sea and sky label. The texture features used are entropy, energy, contrast and homogeneity. The extraction of texture features is then stored and used asdata in the process of classification training. The K-NN technique establishes a classification based on the distance between the train data and the test data[17]. Distance is calculated using Euclidean distance. The following is the K-NN algorithm used to classify land, sea and sky objects on coastal images:

Algorithm 2:

1) $Z = (x', y')$, is the test data as a function of a vector x', and the class label is unknown (y')
2) Calculate the distance $d(x', x)$, which is the distance between the test data (Z) to each vector training data, store it in D
3) Select $D_Z \subseteq D$, that is K-NNs of Z
4) Calculate the class:

$$y' = \arg\max_{v} \sum_{(x_i, y_i) \in D_z} I\left(v = y_i\right) \tag{5}$$

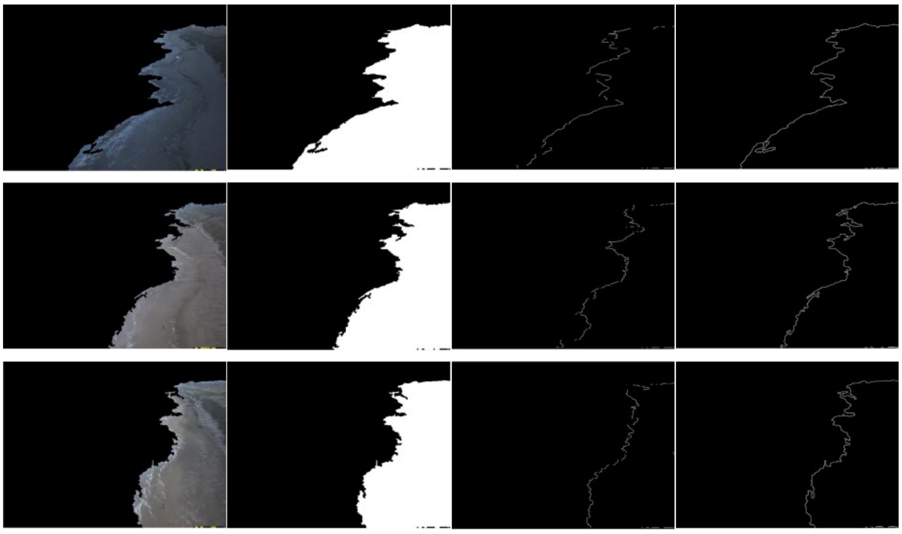
3) *Shoreline Extraction*

This is the most important part of the shoreline extraction framework of [6]. The shoreline detection mechanism is based on the recognition of the land area after the KNN classification process. In [6], the detection of the shoreline is performed directly based on the result of binary image transformation, i.e. the pixels 0 is expressed as the land area, and vice versa is expressed as the non-land area when the pixels are 1. As shown in Figure 2(c), this method has resulted in a non-continuous line, i.e. a broken line in the curved areas.

In effort to improve the shoreline detection, this research has proposed a combination technique of binary image transformation and Canny edge detector.As shown in Figure 2(d), the Canny edge detector algorithm [15] is applied to extract the shoreline based on the identification of the land area. As known, Canny edge detector has two main parameters to be set, namely the standard deviation of the Gaussian function, and the low and high threshold values for hysteresis analysis of edge detection. We have used the standard deviation equal to 1, and the low and high thresholds are 0.4 and 0.7, respectively, of the binary image pixel value. Fig.2(c) has shown that the Canny edge detector algorithm has been able to produce a continuous shoreline.

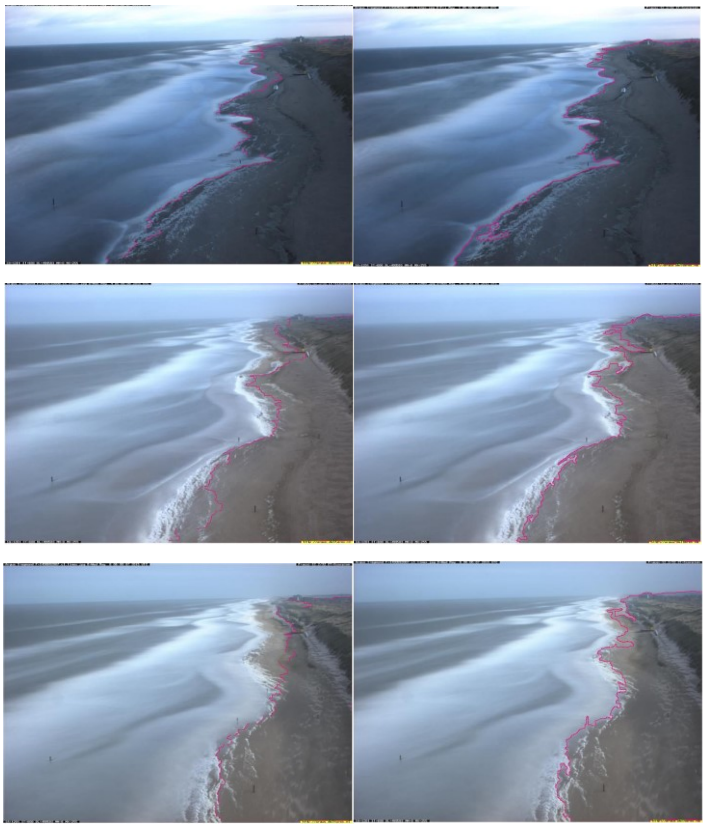
III. Result and Discussion

The performance measurements of the proposed shoreline extraction framework using coastal imagery with different contrast levels are to illustrate the ever-changing coastal image characteristics due to weather changes. A performance comparative analysis was performed on the shoreline extraction framework in [6]. To obtain a balanced analysis, this study used a coastal image test sample as used in [6]. As shown in Table I, the coastal image test sample has different contrast levels. Differences in the degree of contrast of the coastal image are shown on the distribution of pixel intensity in the Histogram graph.



(a) (b) (c) (d)

Fig. 2. Comparison of shoreline extraction process results based on the recognition of the land area in framework of [6], (a) Area with land label, (b) Binary image transformation, (c) Shoreline detection using Image Binary, (d) Shoreline detection using Canny edge detection.



(a) (b)

Fig. 3. Comparison of shoreline detection results (a) Framework with binary image transformation [6], (b) Framework with combination of binary image transformation and Canny edge detector (proposed method)

A. Pre-processing Analysis

The main target of image pre-processing within the proposed shoreline extraction system framework is to decrease the correlation of land and non-land features. As shown in Tabel I, at the low contrast (Sample 1 and Sample 2) as well as in high contrast (Sample 3), objects in coastal imagery have similar features, such as the land area is similar to the inner sea, and also, in the sky area which has a resemblance to the sea area near the beach. This characteristic of coastal imagery indicates that image enhancement requires a decreasing in pixel value at high intensity, and on the other hand elevates the pixel value at low intensity, while maintaining the pixel value at mid-intensity. The experimental results have shown that in the correction factor of 1.3, compared with the contrast stretching technique in [6], the application of Gamma correction can improve the contrast of coastal image, where the difference of land and sea object can be highlighted.

B. Extraction Shoreline Analysis

The analysis of shoreline extraction is shown on the quality of resulting line to map the shoreline path. As shown in Figure 3(b), in general, the application of a combination technique of Gamma correction, SOM, binary image transformation and Canny detector to the shoreline extraction framework capable to producea continuous shoreline. Compared to the existing framework [6], the application of a combination of binary image transformation and Canny detectors is able to improve the detection of lines on the edge of the image with complex textures, such as the basin portion of the land.

IV. Conclusion

This paper has presented an evaluation of the application of Gamma correction techniques and Canny edge detectors to the framework of the shoreline extraction system from [6]. Research has established a Gamma correction factor of 1.3, to accommodate the contrast in coastal images due to weather dynamics. Analysis of the quality of SOM segmentation on Gamma image based on the validation of the Silhouette index has indicated the occurrence of reinforcement in the cluster. This increase in clustering criteria is also consistent with increasing accuracy in shoreline extraction. Based on the identification of the land area, the combination of binary image transformation and Canny edge detector has been able to produce a continuous shoreline along the coastal path in the coastal image.

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