ISSN 2229-5518

Automatic Waterway Detection Applying K-means Clustering

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Abstract— Detection of transportation network from geographical map image is an important task of document analysis and recognition. The extracted segments are applied to different machine vision and embedded system. The task is very complex because of having overlapping objects, intersected lines etc in map. Keeping this in mind, the present thesis paper describes an adaptive method, which has been applied to extract efficient waterway (an important portion of transportation network) that ove overcome the previous limitations. Different from the existent methods, proposed approach is efficient both in segmentation results and further reconstruction. And the experimental results are close to human perceptions; therefore this method provides better and more robust performance than either of the individual methods. We hope this method will find diverse applications in Automatic waterway from geographical map and also image analysis.

Index Terms—image analysis, image segmentation, k-means clustering, L*a*b color space, map, regions of interest, transportation network

1 Introduction

IMAGES are considered as one of the most important medium of conveying information. An image can have thousand times better impression than hundreds lines of document. Understanding images and extracting the information from them such that the information can be used for other tasks is an important aspect of Machine learning. An example of machine learning form image can separate road network from image which helps the car to choose optimum path from source to destination. Color image segmentation [1], whose purpose is to decompose an image into meaningful partitions, is widely applied in multimedia analysis.

A map is a visual representation of an area, a symbolic depiction highlighting relationships between elements of that space such as objects, regions, and themes. A city map will include not only the city's transport network, but also other important information, such as city sights or public institutions [14]. The extraction of Region of Interest (ROI) from overlapping objects of city map such as transportation network is a challenging problem in color image analysis. The problem is much complex in city map analysis is more complex since there are more types of data, various types of lines, possible curvature and even branching of graphics[10][11][12].

Clustering is a feature-space method of Color image segmentation. This method classifies pixels to different groups in a predefined color space. K-Means clustering is popular for its simplicity for implementation [16], and it is commonly applied for grouping pixels in images. The choices of color space may have significant influences on the result of image segmentation. There are many kinds of color space [19], including RGB, YCbCr, YUV, HSV, CIE L*a*b*, and CIE L*u*v*. Although RGB, YCbCr, and YUV color spaces are commonly used in raw data and coding standards but they are not close to human perceptions. Unlike the RGB and CMYK color models, Lab color is designed to approximate human vision. It aspires to perceptual uniformity, and its L component closely matches human perception of lightness [15]. It can thus be used to make accurate color balance corrections by modifying output curves in the 'a' and 'b' components, or to adjust the lightness contrast using the L component.

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2 Literature Review

The separation of text from map was done by researchers till date. Fletcher and Kasturi [3] developed an algorithm for text string separation from mixed text/graphics image. Taking account of curving labeled road names in the map, Tan and Ng [4] developed a system using the pyramid to extract text strings. Both methods, however, assume that the text does not touch or overlap with graphics. Touching lines with text is important for engineer drawings [9-11], especially maps [12]. This problem is much more complex since there are more types of data, various types of lines, possible curvature and even branching of the graphics. An approach in [5] introduced an algorithm which permits to extract text on binary images. Then regions may have characters is selected using the maximum connected components. The characters are merged into words using Hough Transform. But, it does not support the overlapping of text and graphics elements of images which is a common problem of topographic maps. In [11], authors develop a model to extract black characters in city maps. They use street lines data to recover the characters composing street names. Due to the possible overlapping between street names and street lines describing the street, they develop a specific

OCR algorithm to produce an efficient text file of street names. More recently, a text/graphic separation method applied to color thematic maps has been described in [10],[9],[15]. The authors describe a segmentation technique based on 24 images obtained by a combination of color components (R,G, B, (R+B)/2, etc.). The resultant binary image constructed from the mix of theses 24 images is then used in an OCR-based recognition system with neural networks.

3 Automatic Waterway Separation Process

Color map contains several overlapping objects with different in color, shape and size. The ROI is focused to the water-way. The process of extraction of transport network deals with maximum connected waterway detection. This separation process using k-means clustering is depicted in figure 1 which is explained in the following section

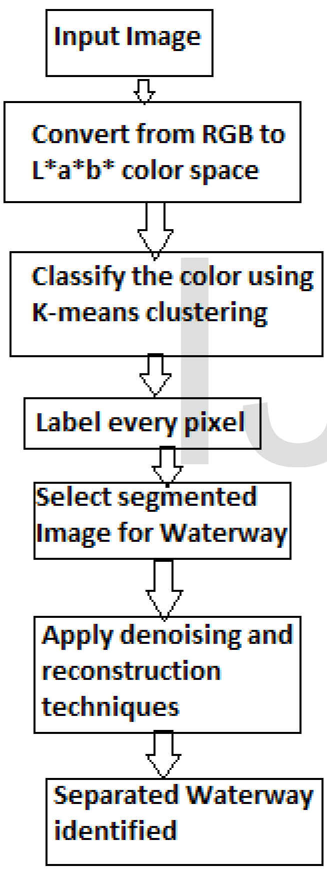

Figure- 1: Waterway Detection Process

a. Data Resources and Software used

For this research purpose we used K-Means Clustering Technique for color based Image segmentation. The images are of parts of different regions of Bangladesh. The entire work is carried out using MatLab R2010a, Adobe Photoshop 7.0 and MS-Office.

b. Image Acquisition

The first stage of any vision system is the image acquisition stage. Color images of scenes and objects can be captured on photographic film by conventional cameras, on video tape by video cameras, and on magnetic disk or solid-state memory card by digital cameras. Digital color images can be digitized from film or paper by scanners. After the image has been obtained, various methods of processing can be applied to the image to perform the many different vision tasks required today. The images used in this paper are acquired from google map in RGB image format.

c. RGB to L*a*b* Conversion

As next step in the processing, measured RGB values in the map image are converted to CIE L*a*b*. Here L* describes lightness; its values can range between 0 (black) to 100 (white). The other two variables describe the actual color, with a* representing green (negative values) or red (positive) and b* representing blue (negative) or yellow (positive values). The conversion of RGB to the L*a*b* system is done via an intermediate step, by translating RGB values into CIE XYZ values. The standard conversion from RGB to XYZ values, which was used shipboard, uses the following equation [16]:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} (X_R.C_R) & (X_G.C_G) & (X_B.C_B) \\ (Y_R.C_R) & (Y_G.C_G) & (Y_B.C_B) \\ (Z_R.C_R) & (Z_G.C_G) & (Z_B.C_B) \end{bmatrix} \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (1)$$

Where X, Y, Z are the CIE tri-stimulus values of a color. R, G, B are the red, green, and blue channels of a color as measured in the image. XR, YR, ZR, and so on are the chromacities of the RGB primaries of the camera; and for R, G, and B.

$$C = \frac{tristimulus \ value \ of \ unit \ amount \ of \ camera \ primary}{chromacity \ of \ the \ primary}$$

However, for computational purposes, the terms (XR · CR), (YR · CR), (ZR · CR), and so on are taken together as a single unknown constant each, giving

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} X'_R & X'_G & X'_B \\ Y'_R & Y'_G & Y'_B \\ Z'_R & Z'_G & Z'_B \end{bmatrix} \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (2)$$

This standard conversion implies that the lines calculated for X, Y, and Z intersect the origin of the axes i.e., that pure black has values equal to, or very close to (0,0,0) in both the XYZ and RGB vector space.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} + \begin{bmatrix} X'_R & X'_G & X'_B \\ Y'_R & Y'_G & Y'_B \\ Z'_R & Z'_G & Z'_B \end{bmatrix} \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (3)$$

In this case, information about four colors is needed to solve the constants (i.e. the red, green, blue, and gray chips). Writing out the matrix multiplication and rearranging the sets of linear equations yields the following for the X-values of the four color chips used:

$$\begin{bmatrix} X_r \\ X_g \\ X_b \\ X_{gr} \end{bmatrix} = \begin{bmatrix} l & R_r & G_r & B_r \\ l & R_g & G_g & B_g \\ l & R_b & G_b & B_b \\ l & R_{gr} & G_{gr} & B_{gr} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ X_R \\ X_G \\ X_B \end{bmatrix} \quad (4)$$

Here, Rr, Gr, and Br, and Xr, Yr, and Zr are the measured channels and the known XYZ values respectively for the red chip; subscripts g = green, b = blue, and gr = gray apply to the other three color chips used. Typically, values for the constants a1, a2, and a3 are found to range between 1.5 and 4.5, demonstrating that an offset from the origin of the X, Y, and Z axes is indeed present.

The XYZ values estimated for the data in the line scan are then further converted to CIE L*a*b* values using the following equations [16]:

$$L^* = 116\left[f\left(\frac{Y}{Y_n}\right) - \frac{16}{116}\right] \quad (5)$$

$$a^* = 500\left[f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right)\right] \quad (6)$$

$$b^* = 200\left[f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right)\right] \quad (7)$$

with f(Y/Yn) = (Y/Yn)1/3 for Y/Yn > 0.008856 and f(Y/Yn) = 7.787(Y/Yn) + 16/116 for Y/Yn ≤ 0.008856; f(X/Xn) and f(Z/Zn) are defined similarly. Xn, Yn, and Zn are the tristimulus values of a reference white. For this study, the known XYZ values of the white color chip are used as reference values.

d. K-Means clustering in L*a*b Color Space

Clustering is a way to separate groups of objects. K-means clustering treats each object as having a location in space [15]. It finds partitions such that objects within each cluster are as close to each other as possible, and as far from objects in other clusters as possible.

The K-means algorithm [17] is an iterative technique that is used to partition an image into K clusters. The basic algorithm is:

- Pick K cluster centers, either randomly or based on some heuristic
- Assign each pixel in the image to the cluster that minimizes the distance between the pixel and the cluster center.
- Re-compute the cluster centers by averaging all of the pixels in the cluster
- Repeat steps 2 and 3 until convergence is attained (e.g. no pixels change clusters)

In this case, distance is the squared or absolute difference between a pixel and a cluster center. The difference is typically based on pixel color, intensity, texture, and location, or a weighted combination of these factors [18]. Here the color information exists in the 'a*b*' space. ROI objects are pixels with 'a*' and 'b*' values. The process used K-means to cluster the objects into three clusters and pixel values distance is measured [18] by the Euclidean distance metric.

e. Connected component labeling of Image

Connected component labeling is used in computer vision to detect connected regions in binary digital images, although color images and data with higher-dimensionality can also be processed.[22][20][2] When integrated into an image recognition system or human-computer interaction interface, connected component labeling can operate on a variety of information.[2][3] Blob extraction is generally performed on the resulting binary image from a thresholding step. Blobs may be counted, filtered, and tracked. We have used this technique to filter pixel value based thresholding for separate connected components from K-Means clustered imaging output. 8-connected component algorithm is applied to label connected neighbor.

f. Process of Waterway

After getting the segmented image several de-noising and reconstruction techniques [8] are applied for identifying waterway from the map. In map water portions are colored with blue color. Smaller sized water colored for pond, small lake, ditch etc. are removed. Then labeling is applied to detect the boundary of waterway.

g. De-Noising:

For removal noise from the waterway, we have applied color based thresholding [8]. Then image is converted into binary image. This binary image is then feed for reconstruction the missing water portion.

h. Reconstruction of Waterway:

Because of removal of overlapping objects, text and line segments, some portions of waterway disappeared. We have applied structuring elements to reconstruct [12] the missing portion of the waterway.

i. Maximum connected waterway Identification:

After removal of noise and reconstruction, we have applied bounded area labeling and identified the largest connected water area from the image.

5 Results and Discussions

At first RGB map image is converted to L*a*b color space. Then color based K-Means clustering algorithm is applied into map image to segment different colored portions from map image. After that road and waterway is separated into different segment.While processing, the approaches was to denoising by color-based threshold and removal of small sized objects as treated as noise. The segmented and noise removed image converted into binary for blob analysis for reconstruct. Different types of structuring elements are applied for reconstruct the waterway as a part of transportation network. Finally get the bounded waterway, which is close to human perceptions.

The input and output images are shown below as order as workflow. The input images we trial, are shown below:


Image 1 Image 2

After K-Means clustering in L*a*b Color Space

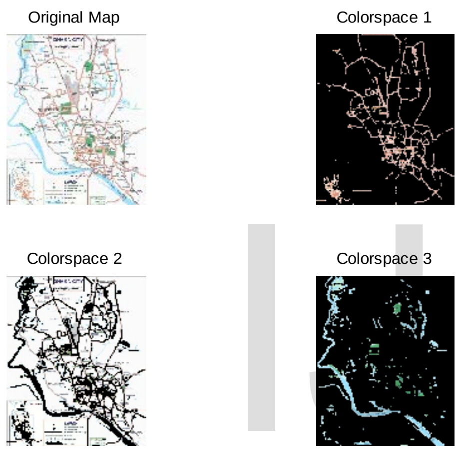

Figure 2 : K-Means Output of Map Image 1

After Processing of Waterway we get the following output:

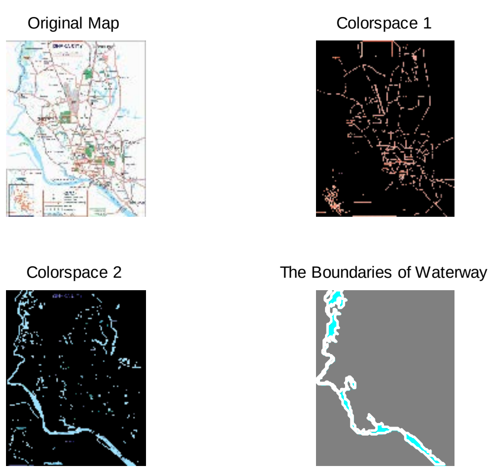

Figure 3: Sepaterated Waterway after processing of Map Image 1

After K-Means clustering in L*a*b Color Space

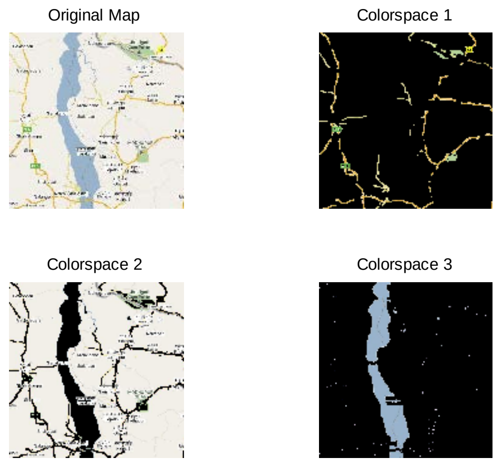

Figure 4: K-means Output of Map Image 2

After Processing of Waterway we get the following output:

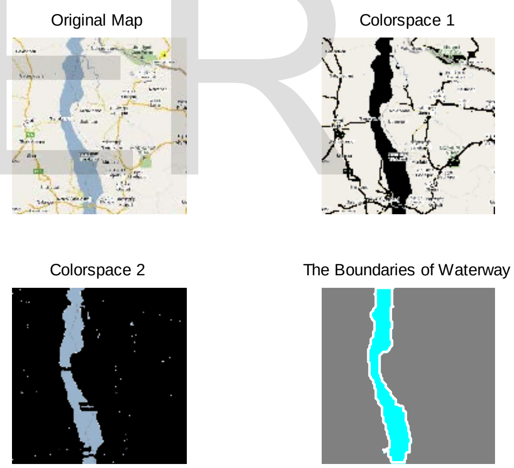

Figure 5: Separated Waterway after Processing of Map Image 2

We know that, Extraction of Region of Interest from geographical map image is very complex because of having overlapping objects, intersected lines etc in map. Here our Regions of interest is the main waterway, which is a unique work done so far.

Here the achievement is the separation of waterway from a map image with overlapping object, text and color. But map to map it may vary. At the outset, we research on various map images to get idea about the extraction process. Always try to find the answers of the question; what will be the best process for which types of map, how could get the closest outcome to

ISSN 2229-5518

our projected ROI i.e. the main waterway. In this way, finally we selected the map images from google map and from government site of Bangladesh, which are of parts of different areas of Bangladesh, and applied K-means clustering for segmentation which is appropriate for that map and general template matching technique to check the performances of those two methods. Finally, we get the end result that is close to human observation.

6 SUMMARIES

Extraction of Region of Interest from geographical map image is an important task of document analysis and recognition. The extracted segments are applied to different machine vision and embedded system. The task is very complex because of having overlapping objects, intersected lines etc in map. Segmentation based on a single feature such as color, Shape or object often lacks adequate discriminatory information and so is unable to obtain accurate result. In this work, the method have been applied to extract efficient waterway region from geographical maps is color based segmentation applying K-means clustering awhich overcome the previous limitations. Different from the existent methods, this proposed approach is efficient both in segmentation results and further reconstruction also. And our experimental results are close to human perceptions; therefore our methods provide better and more robust performance than either of the individual methods. We hope these methods will find diverse applications in ROI extraction from geographical map and also image analysis.

7 LIMITATIONS AND FUTURE WORKS

Performance of efficient Regions extraction from maps depends and varies for map to map. Color based K-means clustering is not applicable when there are less color variations. The map images we exercise here give satisfactory results for waterway by this technique.

For future developments, this output can be converted into graphs which can be processed by embedded system in to drive vehicle and vessel automatically from source to destination and follow optimum path. More works need for extraction of rail network, roads and narrow waterways. If clustering of different maps on the basis of scale can be implemented, then accurate extraction of the whole transportation network will be founded.

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