Volume 5, Issue 5, May 2015 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

A Robust Road Extraction Method Using Luminance Color Space & Comparison with Un-sharp Masking Method

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Abstract: Image segmentation has various fields of research, but road extraction is the hot research topic nowadays. Extraction of roads is essential because number of applications is based on road information like vehicle navigation, transportation management, tourism, industrial development, urban or rural development. So automatic manufacturing of the map is important to achieve all these applications. Images used in road extraction are mostly satellite images or aerial images. As the satellite images are of high resolution, therefore there are many obstacles like a shadow of trees and buildings, vehicles, interference from the surroundings, broken roads etc. that curb the automatic extraction of the roads. In our research work, to solve these obstacles morphology operations are used and to boost the boundary of the road Luminance color space is used. The aim of this work is to provide a significant contribution to research on this topic.

Keywords: Road extraction, Automation, Morphology, Unsharp Masking, Color Space.

I. INTRODUCTION

Road networks are of higher use since last decade as urban planning and industrial development highly depends on the road networks. Due to the development of the urban cities, road networks are changing at a rapid pace and it's difficult to update the map of city manually as manual work requires a lot of time [1-3]. So it's important to automate the road extraction to update the maps effortlessly [4].

Basic characteristics of the road as follows:

a) Roads are built of concrete or asphalt, so they have their own spectral signature corresponding to the material.
b) The width of the road is mostly constant and has an upper bound. Upper bound depends on the importance of the road as highways have more width than the normal roads in urban and rural areas.
c) Curvature of roads is also another factor. Maximal curvature is mostly found in rural areas rather than highways.
d) Density of roads (means linkage of large number of roads) higher in urban areas than in rural areas.

As in most cases the roads are detected from the satellite or aerial images. These images can be of high resolution or low one. In low resolution images, roads appear as lines while in high resolution they are appeared well as parallel borders. There are a number of obstacles that appear on roads and affect the efficient road extraction like shadow of trees and buildings, vehicles on roads, marking lines, etc. These obstacles put less effect in case of low resolution images, but create enormous problems in case of high resolution images.

Fig.1. Satellite Image

Road extraction depends on the road marking or simply on the road. In case of road marking extraction rely on bands painted on the roads whose width and color are fixed by technical norms [5]. Extraction based on road marking is difficult as road marking is affected by noise [6].

According to the degree of automation extraction of linear features, road extraction is divided into two methods — automatic and semi-automatic [7]. In semi-automatic there is need of human intervention, such as information on starting points or starting directions, which provide critical assistance in tracking roads. By contrast, automatic approaches have no such requirement as these approaches achieve true operational autonomy [8] [9]. In semi-automatic, extraction is highly effected by the selection of road features [10]. Some use Hough Transform for automatic road extraction deprived of any road width or mark length. But it takes lots of time to compute the results and hamper the real time performance [11]. Also extraction based on edge detection proved unsuccessful due to noises (like broken roads, similarity of color with the buildings etc.) [12].

In this paper, we present an automatic approach to the road extraction using Color space YCbCr. Our method has three stages: 1) Conversion of color; 2) Setting the threshold value of Y; 3) Post-processing using Morphological operations. The rest of the paper is organized as follows. Section II briefly reviews the basics of morphology and color space components. Section III reports experimental results, Section IV presents the evaluation metrices and Section V gives the conclusion.

II. MATHEMATICAL MORPHOLOGY OPERATIONS AND COLOR SPACE COMPONENTS

Morphological operations take two data: First is the image X (binary form of original image) and the second is the structuring element S operate in a 2-dimensional space i.e. Z^2. According to the shape (i.e. square, disk, diamond, triangle etc) of structuring element specific effect on the input image appears.

A. *Binary erosion and dilation:* Erosion means shrink or reduce the image or in technical terms it removes the elements in an image(X) that are smaller than structuring element(S) and also object at boundaries. Erosion is expressed as:

$$X \theta S = \{ p \in Z^2 \mid p + b \in X, \forall b \in S \} \tag{1}$$

where θ denotes the erosion of X by S and p is the set of all points that are result of the erosion. While dilation means add pixels or thicken objects in an binary image. Dilation is expressed as:

$$X \oplus S = \{ p \in Z^2 \mid p = a + b, a \in X, b \in S \} \tag{2}$$

where $\oplus$ denotes the dilation of X by S and p is the set of all points that are result of dilation.

B. *Binary open and close:* Combination of dilation and erosion generation in opening and closing operations [13].
Opening of an image remove the minute objects while preserve the large objects and break the narrow. In opening, erosion is followed by the dilation operation. Opening is expressed as:

$$X \circ S = (X \theta S) \oplus S \tag{3}$$

where $\circ$ denotes the opening operation of X by S .

On contrary, closing fuses narrow breaks, eliminate noise and fill gaps. In closing, dilation is followed by erosion. Closing is expressed as:

$$X \bullet S = (X \oplus S) \theta S \tag{4}$$

where $\bullet$ denotes the closing operation of X by S .

C. *Unsharp Masking:* The process of enhance or to sharpen the images (or edges) by subtracting unsharp version of an image or the blurred image from the original image is called Unsharp Masking(USM) [14][15]. This process amplifies the high frequency components of signals while suppress low frequency components. It is used as preprocessing step and used to sharpen the edge of image [6]. The fundamental idea of Unsharp masking is to subtract the blurred image from the input image itself.

Suppose $f(x, y)$ is an original image and $\overline{f}(x, y)$ is a blurred image of $f(x, y)$, this blurring can be done using Median filter or Gaussian filter. By subtracting the blurred image from the original one we get the mask M_{mask} :

$$M_{mask}(x, y) = f(x, y) - \overline{f}(x, y) \tag{5}$$

Now added the weighted portion of mask into the original image as follows:

$$g(x, y) = f(x, y) + k * M_{mask}(x, y) \tag{6}$$

where $g(x, y)$ is the resulted image. When value of $k = 1$, it is called Unsharp masking and if $k > 1$, it is High boost filtering.

D. *Color Space*: Usually RGB color space is used for image analysis. Other color space can be obtained from linear and non-linear transformation of the R, G and B components of the RGB color space. But in our research, we use YCbCr color space model, which consists of Y (represents luminance or a measurement unit of the energy amount that an observer perceives from a light source), Cb (represents the difference between the blue component and a reference value) and Cr (represents the difference between the red component and a reference value) [8][9]. Conversion into Y, Cb and Cr from R, G, B components is as follows:

$$Y = 65.481 * R + 128.553 * G + 24.966 * B + 16 \quad (7)$$

$$C_b = -37.77 * R - 74.203 * G + 12.00 * B + 128 \quad (8)$$

$$C_r = 112.00 * R - 93.786 * G - 18.214 * B + 128 \quad (9)$$

where R,G,B are the extracted components of RGB colored image. Y, C_b and C_r can be calculated using above equations.

II. EXPERIMENTS RESULTS OF PROPOSED ALGORITHM

This algorithm is implemented using MATLAB software on the satellite images. The overall steps of the proposed method
are as follows:

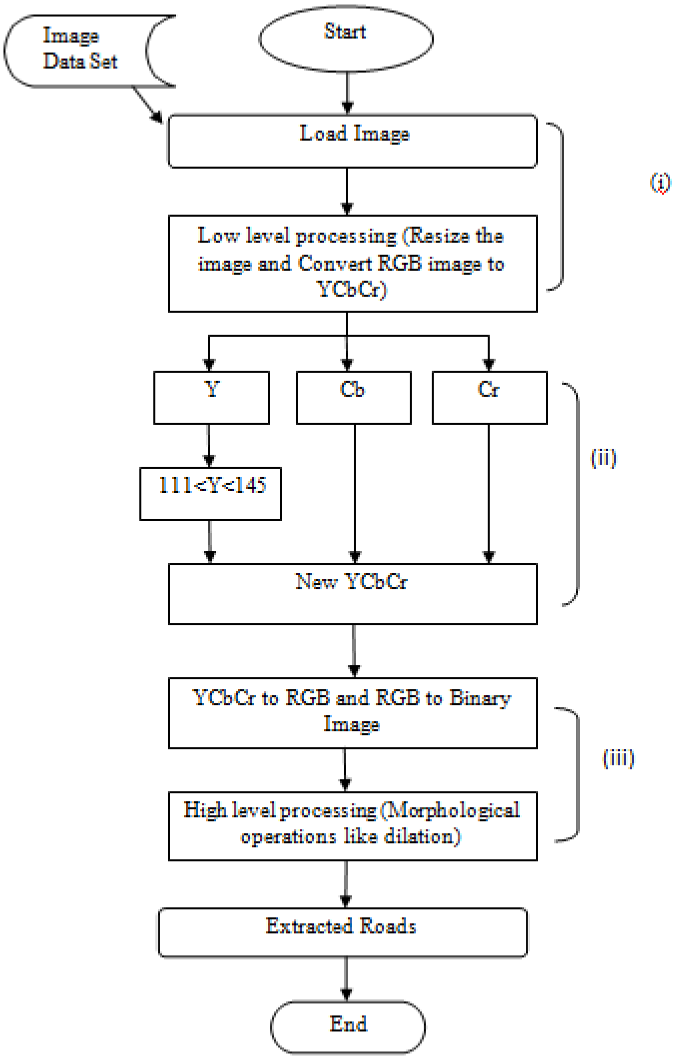

Fig.2. Flowchart of Road Extraction

where (i), (ii) and (iii) represent the low, medium and high level processing respectively. Detailed explanation of these processing as follows:

A) *Low Level Processing:* Google Earth satellite images are used as input in this project. Elementary step of road extraction is to preprocess the input image by resizing it to 512*512 or according to the requirement. R, G, B components are extracted from the input image and image is converted to YCbCr components using the equations (7), (8) and (9) and shown in fig 3(a).

B) *Medium Level Processing:* As at this point we have Y, Cb and Cr components, so now adjust the value of luminance(Y) to achieve the desired results. We concentrate only on Luminance(Y) value because it has great impact on the result. The luminance value of the roads lies between the 111 and 145 [8][9].
Adjust the value of Y:

$$111 < Y(i, j) < 145 \quad (10)$$

where $Y(i, j)$ is the luminance image.

There is no need to change in Cb and Cr as it has very less effect or can say no effect on the road extraction. Now concatenate the three components i.e. new Y, Cb and C and new YCbCr image shown in fig 3(b). Convert new YCbCr image into RGB Color Space again and we obtain new RGB image shown in fig 3(c).

C) *High Level Processing:* Convert the result of medium level processing i.e. new RGB image into gray image shown in fig 3(d). And conversion of this gray image into black and white image shown in fig 3(e) .

Now apply the morphological operations to remove the noise. In our case Opening and dilation are performed to achieve better results and these results shown in fig 3(f).

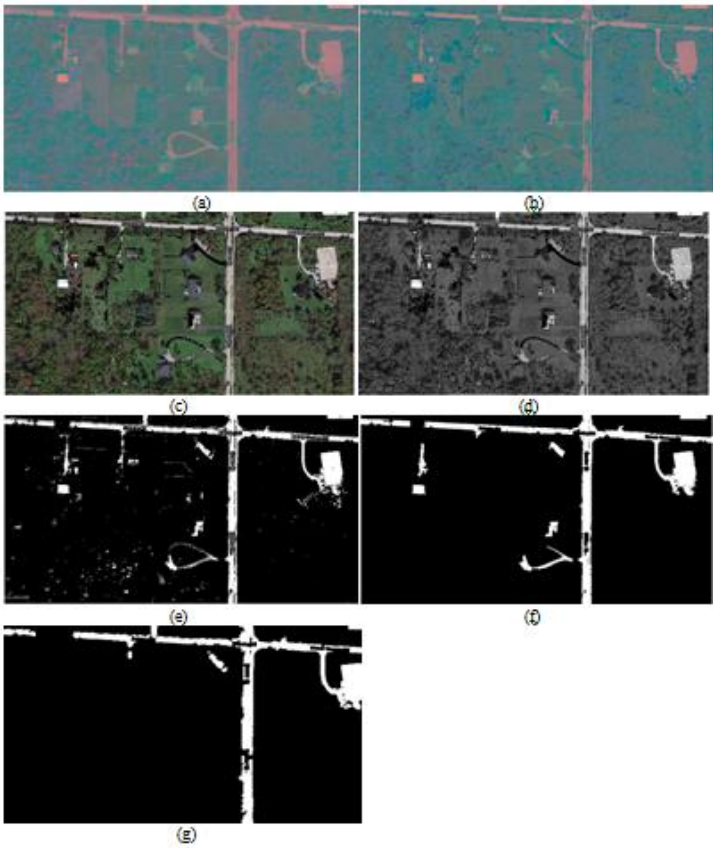

Fig. 3. Experiment Results of Proposed Methodolgy. a)RGB to YCbCr Conversion, b)New YCbCr image after thresholding, c)New RGB image, d)Gray image of new RGB, e)Binary image, f)Binary Image after opening and dilation(Resulted Image), g) Resulted Image of USM technique.

Another example of curve road extraction (surrounded by bushes and sandy regions). These results prove that the algorithm used in this work has a very good finishing and accurate performance in extracting the simple road regions.

Fig.4. Original image 2

Following figures 5 & 6 shows extraction of road using the unsharp masking method and proposed method respectively.

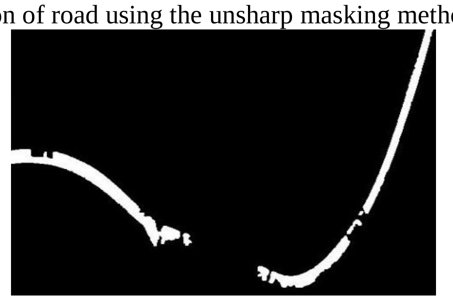

Fig.5. Extraction using USM

Fig.6. Extraction using Color Space method

IV. EVALUATION AND ERFORMANCE MEASURES

Now to evaluate the results we have 3 parameters: Completeness, Correctness and Quality [7].

Table1: Confusion Matrix

Predicted Class → **Actual Class ↓**	**C1 (YES)**	**C2 (NO)**
C1 (YES)	TP	FN
C2 (NO)	FP	TN

Correctness is the ability of an algorithm to detect the correct roads from an image and is defined as:

$$correctness = \frac{\sum TP}{\sum TP + \sum FP} * 100 \quad (11)$$

where TP represent the True positive means count of actual road region pixels in a resulted image and FP represent the False positive means count of Non-Road region pixels that are incorrectly identified as road region pixels in a resulted image.

Completeness the ability of an algorithm to get the all road pixels in extracting image as road pixels in the actual image and is defined as:

$$Completeness = \frac{\sum TP}{\sum TP + \sum FN} * 100 \quad (12)$$

where FN represent the False negative means count of Road region pixels that are identified as non- road region pixels in a resulted image.

Quality is defined as the excellence of the road extraction. It considers both the completeness and correctness of the extracted data and is expressed as:

$$Quality = \frac{\sum TP}{\sum TP + \sum FP + \sum FN} * 100 \quad (13)$$

TN not used in these equations but represent as True negative means count of Non-Road region pixels that are correctly identified as non-roads region pixels in a resulted image.

Now to compute the values of TP, FP, TN and FN, there should be ground truth value of the roads i.e. actual road region pixels in an original image and this ground truth value can be computed manually using GIMP software. To understand this process following criteria is followed:

A = Total number of white pixels i.e. road region pixels in original roads generated through GIMP software and

R = Total number of white pixels in resulted image; white pixels in this case can be road region pixels or non-road region pixels in an resulted image because some noise remains in the resulted image in the form of non-road region pixels.

Mathematically it represent as:

$$TP = A \cap R \quad (14)$$

$$FP = R - TP \quad (15)$$

$$FN = A - R \quad (16)$$

In our research work the values of completeness, correctness and quality of two images shown in the table:

Table2: Performance measurement

Image	**Methods**	**Completeness**	**Correctness**	**Quality**
1	USM	73.23%	80.90%	59%

1	Proposed	79.95%	75.84%	63.7%
2	USM	79.26%	82.12%	67.59%
2	Proposed	84.07%	80.62%	69.94%

Graphical Comparison of the results:

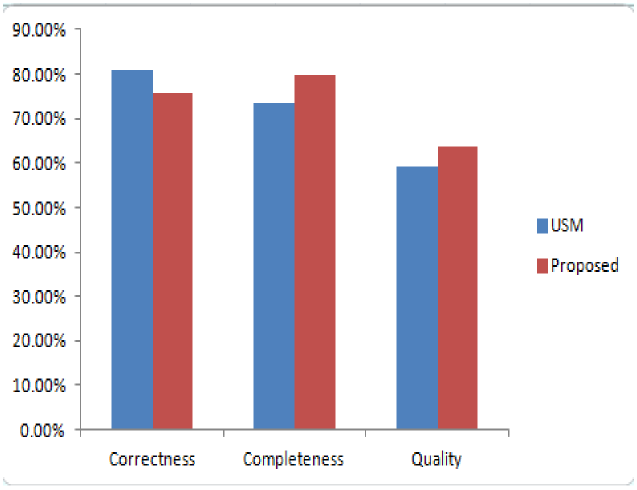

Fig.7. Comparison Chart of Image1

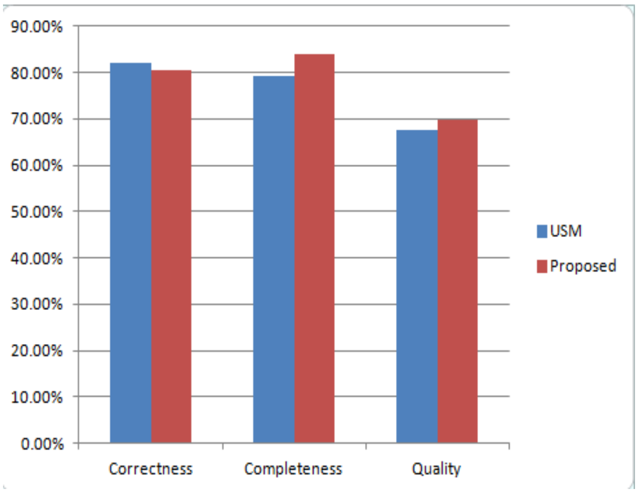

Fig.8. Comparison Chart of Image 2

V. CONCLUSION

The fundamental idea of research work to use color space YCbCr in which value of Luminance(Y) component is set to remove trees or bushes and morphological operations are used to enhance the result. This method applied on the images taken from google and Appolo Mapping in March, 2015. The completeness, correctness and quality of USM is 76.25%, 81.5% and 63.30% and that of Color space model has 82.01%, 78.23 and 66.82% respectively. The results of the comparative analysis shows that Color space model is better than Unsharp masking method and also provides better real time results. Advantage of this method is that there is no need to know about the road width, any other shape characteristics or can say no need of prior knowledge about road conditions. But Color space method has problem of disconnection of the roads and in future this disconnection can be removed using an improved technique.

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