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Satellite Image Segmentation based on YCbCr Color Space

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Abstract

Segmentation is one of the most important processes in the satellite image processing to retrieve most useful information from the satellite images. This paper proposed an effective fuzzy based method of segmentation of satellite images in YCbCr color space. The YCbCr Color space represents color as intensity and exploits the characteristics of human eye. Our eye is more sensitive to intensity than hue. The intensity component can be stored with greater accuracy as the amount of information to be minimized. The JPEG file format mostly uses this color space to discard the unwanted or unimportant information. In the proposed approach, the satellite image in RGB color space is transform into YCbCr color space and then the transformed satellite image is split into three different components (channels or images) based on luminance and chrominance. Subsequently Fuzzy based segmentation is applied separately for all three components for efficient segmentation. Finally the threshold is applied to extract the foreground (object) from the background. The experimental result reveals that the proposed fuzzy based segmentation method is efficient and accurate for extracting the necessary information from the satellite images.

Keywords: Color Space, FCM, Image Segmentation, RGB, Satellite Image, Threshold, YCbCr

1. Introduction

The satellite images contains huge amount of information for analysis and processing. But human eye is insensitive to realize small changes in the characteristics such as intensity, color, and/or texture. So the manual human processing is not successful to retrieve the hidden treasures of information in the satellite image. The optimal solution is the processing of satellite images with digital computers. To retrieve the information or extract region of interest (ROI) from images, we need a segmentation method which is the most important and difficult task in the image analysis[15]. The segmentation in image processing can be defined as the process of grouping or dividing image pixels according to the characteristics of the image[7]. The goal of the segmentation process is to simplify and change the representation of an image into more meaningful and make easier to analyze[14]. The processed satellite images are usually in RGB color space. However this RGB color space is not preferred for image segmentation because this space is not perceptually uniform and all components should be quantized with the same precision[8]. In this paper, an efficient and accurate segmentation of satellite images using YCbCr color model, FCM and threshold is proposed. First the satellite image in RGB color space is transform into YCBCR color space and then segmented using the FCM Clustering. The threshold is the final step to retrieve the information from the segmented image. The subsequent sections of this paper are organized as follows. The section 2 briefly describes the concept behind the color space. The section 3 gives details about RGB and YCbCr color space. The Fuzzy based clustering, FCM, is given in the section 4. The proposed approach for satellite image segmentation is explained in the section 5. The section 6

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describes different experiments and finally the section 7 concludes the paper.

2. Color Space

Color space is a mathematical model to represent color information as three or four different color components[3]. Color space explains how the colors are represented and specifies the components of color space accurately to learn how each color spectrum looks like[1]. Different color models are used for different applications such as computer graphics, image processing, TV broadcasting, and computer vision[10].

2.1 Device Dependent Color Space

In this color space, the color produced on the monitor or other display purely depends on the equipment used for display and the set of parameters. For example, in RGB color space, different devices reproduce a given RGB value differently i.e., the color produced will be different from one device to others. This is due to composition of the color elements and their response to the individual Red, Green and Blue levels vary from one company to others. In RGB based monitors, while changing the brightness or contrast, the pixel values of RGB also altered. Example for device dependent color model includes RGB, CMY, CMYK, YIQ, YUV, and YCbCr. These models are not intuitive and not related to the concepts of hue, saturation and brightness. This hardware oriented color models are widely used in many applications where the color be consistent with the hardware used such as TV and Video systems[12].

2.2 Device Independent Color Space

In the device independent color space, a set of parameters will produce the same color on whatever equipment they are used irrespective of manufacturer or company. This means that the color model is not affected by the system or device properties. So in this space, the coordinate used to specify the color will produce the same color wherever they applied. These models are well suited for the applications where the information is transmitted through different hardware devices. CIE XYZ, CIE $L^*U^*V^*$, CIE $L^*a^*b^*$ are example for device independent color models.

3. RGB and YCbCr Color Space

3.1 RGB Color Space

RGB color space representation shown in Figure 1 is additive in nature. In this additive color space, other colors are produced by adding the primary colors red, green and blue. The combination of all three primary colors produces white color and the absence of all primary color makes black. The RGB color model is represented by a unit cube and the axes are labeled as R, G and B. The origin (0, 0, 0) is considered black and the diagonally opposite corner (1, 1, 1) is considered as pure white. This color space is widely used in television and computer monitors. Any other color space can be obtained from a linear or non-linear transformation from RGB. This color space is device dependent which means that the same signal or image can look different on different devices. This RGB color space is not suited for color analysis and color based segmentation algorithm because of chrominance and luminance component are mixed.

3.2 YCbCr Color Space

According to ITU (International Telecommunication Union) standards ITU-R BT.601-5 and ITU-R BT.709-5, YCbCr defined as a color space for digital television systems and also defines the transformation of coefficients between YCbCr and RGB color spaces. YCbCr color space is represented in terms of one luminance component (Y) and two chrominance components (Cb and Cr). In this color space, the intensity of the light is represented by 'Y' component. The intensities of the blue and red components relative to the green component are represented by 'Cb' and 'Cr' components respectively. YCbCr color space imitates the human vision i.e., exploits the properties of the human eye. Our human eye is more sensitive to light intensity changes and less sensitive to hue

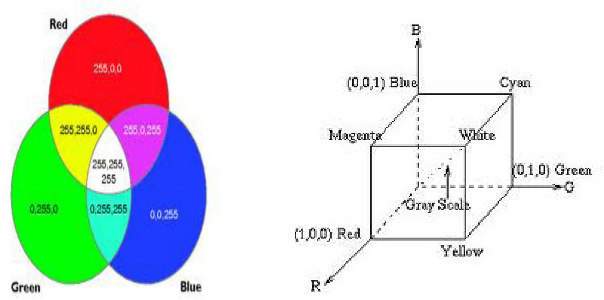

Figure 1. RGB color space representation.

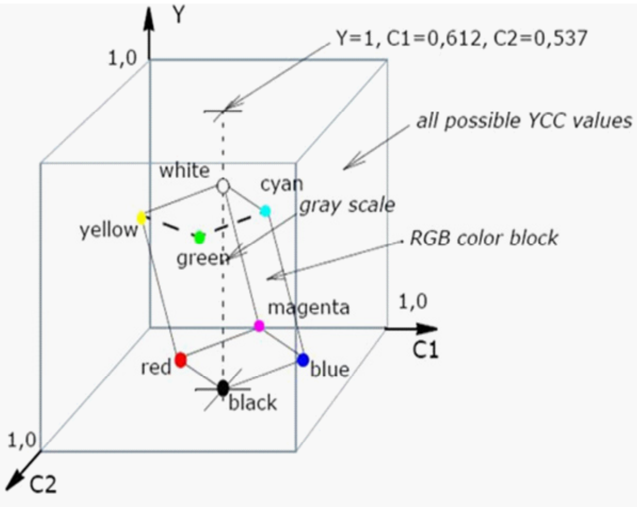

Figure 2. YCbCr color space representation.

changes. So it is very easy to our eyes to perceive more information from luminance than any other components. YCbCr color space makes use of this property to achieve an efficient representation of images. YCbCr color space is widely used in image compression standards like Joint Photographic Experts Group (JPEG) and digital encoding of color information in computing systems. As per the definition of ITU-R BT.601 definition, for 8-bit unsigned integer images, the range for luminance (Y) component is [16,235] and the range for chrominance (Cb and Cr) components is [16,240].

3.3 Transformation between RGB and YCbCr

According to ITU-R BT.601, for standard definition television applications, the conversion between RGB color space and YCbCr color space is described by the following equations[6]:

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 0.279 & 0.504 & 0.098 \\ -0.148 & -0.291 & 0.439 \\ 0.439 & -0.368 & -0.071 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.164 & 0.000 & 1.596 \\ 1.164 & -0.392 & -0.813 \\ 1.164 & 2.017 & 0.000 \end{bmatrix} \begin{bmatrix} Y-16 \\ Cb-128 \\ Cr-128 \end{bmatrix} \quad (2)$$

In computer based applications, the full range of 8-bit is used, without providing space for header and footer. This full-range color format is used for JPEG images. The conversion between RGB color space and YCbCr color space is described by the following equations:

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.500 \\ 0.500 & -0.419 & -0.081 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.000 & 0.000 & 1.400 \\ 1.000 & -0.343 & -0.711 \\ 1.000 & 1.765 & 0.000 \end{bmatrix} \begin{bmatrix} Y \\ Cb-128 \\ Cr-128 \end{bmatrix} \quad (4)$$

3.4 YCbCr Color Space for Satellite Image Segmentation

The reasons for selecting the YCbCr Color space for Satellite Image Segmentation are as follows:

1. The YCbCr color space is commonly used in image processing as it separates the luminance, in Y component, from the chrominance described through Cb and Cr components. The luminance component can be used separately for storage in high resolution and the two other chrominance components can separately be considered for improving the performance[11].
2. This YCbCr Color space is widely used in digital encoding of color information and image compression[16].
3. The illumination variations in the image can easily be solved because the illumination component is independent of the color.
4. It has the minimum overlap between the segmented (desire) and the non-segmented (undesired) regions even under various illumination conditions[17].
5. The YCbCr color space represents color as intensity (brightness) and two color difference signals, while RGB represents color as three different components red, green and blue. YCbCr color space exploits the properties of the human eye. The intensity component can be stored with greater accuracy as the amount of information is to be minimized. So the JPEG file format mostly uses this color space to discard the unwanted or important information[12].

4. Fuzzy-C-Means Clustering Algorithm

The FCM clustering is the modified and fuzzified version of the hard c-means or k-means clustering algorithm.

Unlike k-means clustering, in the FCM clustering, data member i.e., image pixel can belong to more than one cluster[2]. This iterative clustering procedure generates an optimal partition by minimizing the objective function given in (5).

$$J = \sum_{j=1}^{N} \sum_{i=1}^{c} U_{ij}^{m} \left\| X_j - V_i \right\|^2 \tag{5}$$

The FCM algorithm is based on minimizing its cost function or objective function[6]. Consider a two dimensional satellite image f(x,y) which has N number of pixels (image elements). The objective is N partitioned into C number of clusters. $X = \{x1, x2 \ldots xn\}$ is the data set and C is the number of clusters with $2 \le c \le n - 1$. The c centers can be represented by $V = \{v1, v2, \ldots, vc\}$, V_i is the center of the cluster i. The fuzzy partition matrix U_{ij} can be represented as $U_{ij} = U_i(X_j)$ is the degree of membership of X_j in the i^{th} cluster. The parameter m is used to determine the amount of fuzziness of the classification[13]. In all cases m > 1.

$$U_{ij} = \sum_{k=1}^{c} \left\{ \frac{\left\| X_j - V_i \right\|}{\left\| X_j - V_k \right\|} \right\}^{-2/m-1} \tag{6}$$

$$V_i = \frac{\sum_{j=1}^{n} \left(U_{ij}\right)^m X_j}{\sum_{j=1}^{n} \left(U_{ij}\right)^m} \tag{7}$$

for i = 1, 2…c and for j = 1, 2…n

The standard FCM clustering algorithm is given below[4]

1. Receive the image in the form of data matrix *X*.
2. Fix the number of clusters, c ($2 \le c \le n$), n is the length of the image data.
3. Assume the partition matrix, *U*.
4. Calculate the cluster centers, V_i, i = 1… c using equation (7).
5. Calculate the Euclidean distance matrix, *d*, using following equation (8).

$$d_{ij} = \left\| X_j - V_i \right\| \tag{8}$$

6. Compute the cost or objective function according to Equation (9). Stop if either it is below a certain tolerance value or its improvement over previous iteration is below a certain threshold.

$$J(\mathrm{U}, \mathrm{c}_1, \ldots, \mathrm{c}_c) = \sum_{i=1}^{c} \sum_{j=1}^{n} \mathrm{u}_{ij}^{m} \mathrm{d}_{ij}^{2} \tag{9}$$

7. Compute a new U using equation (10). Go to step 2.

$$U_{ij} = \sum_{k=1}^{c} \left\{ \frac{\left\| X_j - V_i \right\|}{\left\| X_j - V_k \right\|} \right\}^{-2/m-1} \tag{10}$$

5. The Proposed Approach for Satellite Image Segmentation

The Proposed method for segmentation of satellite images using YCbCr color space and FCM threshold is shown in Figure 3. For simulation of the proposed approach, a database was created which consists of 25 GeoEye-1 multispectral satellite images. Generally Geoeye-1 collected a multispectral image at 1.65 meter resolution and then sharpened in the panchromatic mode so that the final image is full color with 0.50 mete resolution. The image shown in the result is the image of Ferrari World Abu Dhabi, United Arab Emirates which was taken in October 17, 2009. In RGB color space, chrominance and luminance component are mixed that is why RGB is not widely used for color image segmentation problem. So the original RGB image is converted into YCbCr color image by using the transformations and the components are separated for an efficient segmentation to gather huge amount of hidden information. Our eye is very sensitive to intensity (luminance) variation. So it is very easy for our eyes to perceive more information from luminance than any other components. YCbCr color space makes use of this property to achieve an efficient representation of images. But it is difficult to collect all the information from the luminance component alone. So the segmentation is also applied to the chrominance components to gather complete information from the

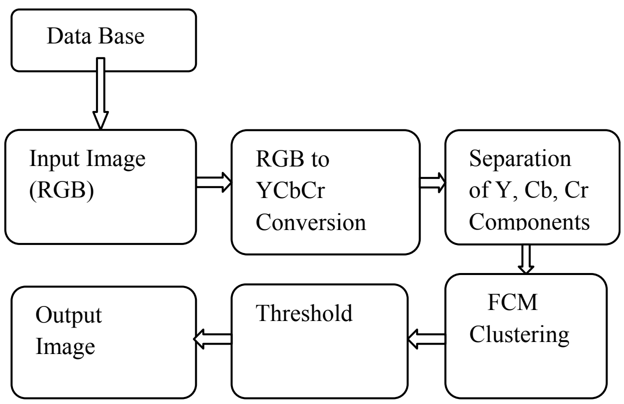

Figure 3. The proposed system architecture.

satellite image. To retrieve the object (foreground) from the background, threshold is applied on the segmented images[9].

5.1 The Proposed Algorithm for YCbCr and FCM Threshold based Segmentation

The algorithm for YCbCr color space and threshold based satellite image segmentation is given below.

Step 1: Select the satellite color image in any format or size as test image. If the size is too large, it is convenient to make it into smaller size. Other it will take very long time for processing.

Step 2: Usually the image is in RGB color space. In RGB color space, chrominance and luminance component are mixed that is why RGB color space is not choose for color analysis and color based segmentation algorithm. Any other color space can be obtained from a linear or non-linear transformation from RGB color space. So we can easily transform test image in RGB color space into YCbCr one.

Step 3: In this YCbCr color space, Y is the luminance which is very similar to the gray scale version of the given original image. The component 'Cb' is the chrominance dominated by the blue color and the component 'Cr' is the chrominance dominated by red color. Generally, the luminance is associated with green and both Cb and Cr are weak in the case of color like green. The component 'Cb' is strong in places of occurrence of bluish colors and the component 'Cr' is strong in the places of occurrences of reddish colors.

Step 4: Apply FCM clustering based segmentation to all the three components separately.

Step 5: Threshold is applied on the segmented images. The selection of the optimal threshold value increases the effectiveness of this proposed approach.

Step 6: The result is the segmented output image.

6. Experimental Result and Discussion

The Figure 4 shows the test image in RGB as well as YCbCr. The image shown in the result is the Geoeye-1 satellite image of Ferrari World Abu Dhabi, United Arab Emirates which was taken in October 17, 2009.

The RGB image and YCbCr image is splitted into three different channels or components as shown in Figure 5 and 6 respectively. Figure 7 shows the intensity (gray scale) version of Figure 6.

The segmentation result of luminance component for different threshold values shown in Figure 8. The segmentation result of chrominance components has shown in Figures 9 and 10. The value of threshold is different for all three components.

Table 1 shows segmentation result for the various components in terms of number of iteration and the execution time. For all the segmentation of all three components number cluster is fixed as four.

Figure 4. Test Image in (a) RGB color space. (b) YCbCr color space (Satellite image courtesy of GeoEye).

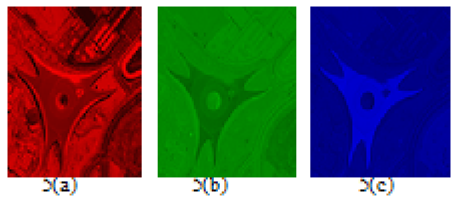

Figure 5. Color images formed by R, G and B components.

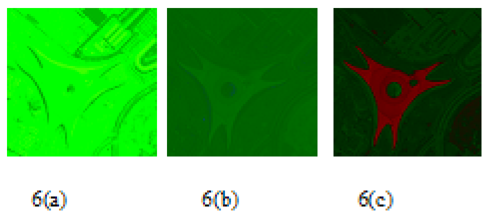

Figure 6. Color images formed by Y, Cb and Cr components.

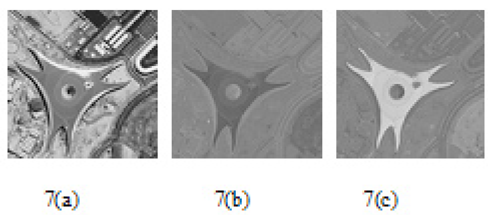

Figure 7. Intensity images formed by Y, Cb and Cr components.

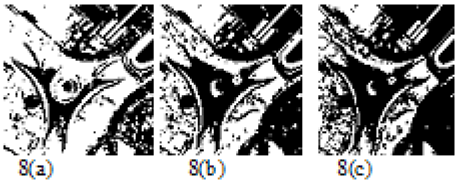

Figure 8. Segmented images for Y = 120, 140 and 160.

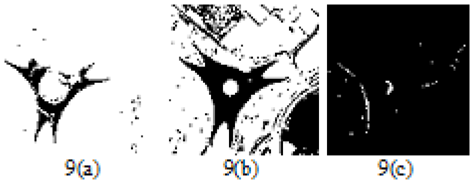

Figure 9. Segmented images for Cb = 100, 120 and 140.

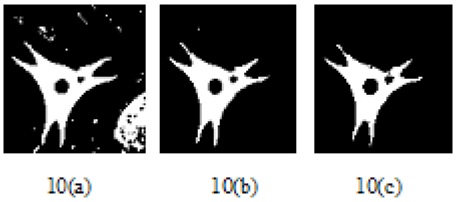

Figure 10. Segmented images for Cr = 120, 140 and 160.

Table 1. Segmentation results for the various components

Sl. No	Component	No. of iteration	No. of cluster	Execution time in seconds
1	Luminance (Y)	42	4	1.5116
2	Chrominance (Cb)	31	4	1.1648
3	Chrominance (Cr)	36	4	1.3576

7. Conclusion

In the satellite image processing, segmentation is the most important but difficult process to gather enormous amount of information. There is no unique system or method for processing the satellite images. Usually all the multispectral images are in RGB color space. But the RGB color space is not efficient for object specification and recognition of colors. Moreover the chrominance and the luminance component are mixed and it is difficult to determine specific color in RGB space. So there is a need for transformation of image in RGB color space into other color space. The YCbCr color space exploits the properties of the human eye. In this space, the intensity component can be stored with greater accuracy and the illumination variations in the image can easily be solved because the illumination component is independent of the color. So we have opted this color space for satellite image segmentation. The optimal choice for segmentation to retrieve more meaningful information is FCM clustering because this is very simple and faster as compared to other segmentation methods. From the simulation result, we can easily conclude that the output binary image is based on the threshold value. The numbers of satellite images are segmented using the proposed algorithm and the experimental result shows the efficiency of the proposed approach.

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