5.1 INTRODUCTION

An elaborate literature review has been presented in Chapter 2. The goal of image segmentation is to identify homogeneous regions in an image. The homogeneity can be based on one or more of several properties, such as texture, colour, and distribution of the densities of the image elements etc. The result of the segmentation is an image of labels identifying each homogeneous region.

This chapter explains the usefulness of features, used to characterize textures. The proposed colour fuzzy texture spectrum as the global texture representation has been highlighted for performing texture segmentation. Rigorous experiments with many target images have been performed and the results are presented. The work has also been compared with texture number scheme.

5.2 TEXTURE SPECTRUM BASED APPROACH

The steps involved in texture segmentation are shown in Figure 5.1.
Texture images of size N x N are considered for experimentation and sub images of size 15 x 15 are used for the analysis. Each sub image, taken from top left corner of the original image, computes the texture features using formulae given in equations (3.4) and (3.6). Then texture segmentation is carried out by comparing the features by overlapping (Sliding window) 15 x 15 sub image blocks, both horizontally and vertically as shown in Figure 5.2.

Figure 5.1 Texture Segmentation Stage

Figure 5.2 Texture Feature Extraction with a sliding window
Each successive block differs from the previous one in its spatial location by one column or one row. The difference in feature values is less, the successive blocks belong to same texture region. The difference increases in the border region, while it is high, when the successive blocks are from two different texture regions. By using suitable threshold technique, the image is segmented. Then, skeletonizing algorithm is applied to get segmented regions of one pixel thick boundaries. The texture segmentation algorithm is given as follows.

**Algorithm**

**Input:** Colour Texture image of Size N x N.

**Output:** Colour Texture Segmented image

1. Read colour texture image.
2. Obtain 15 x 15 sub image blocks, starting from top left corner.
3. Derive the colour fuzzy texture spectrum for original sub image block.
4. Calculate the difference between the colour fuzzy texture spectrum of adjacent sub image blocks.
5. Apply Thresholding techniques and conclude about the same region or different region.
6. Apply skeletonizing algorithm to get thinned or segmented line of one pixel thickness.

The difference in feature values is less, when successive blocks belong to the same texture region and it increases in the texture border region.
5.2.1 EXPERIMENTAL RESULTS AND DISCUSSIONS

Collecting portions of regions from many texture images have resulted in various target texture images. The images are shown effectively segmented. The experiments performed and the results are presented in this section.

The segmented images, obtained by applying segmentation algorithm, are shown in this section. Since, the image windows of larger width are considered for computation of features from the texture, the localization of segmentation is poor. The thinning algorithm proposed by Dyer and Rosenfield(1979) is used for thinning to get the perfect thinned boundaries of segmented images.

The performance evaluation of the Colour fuzzy texture spectrum is experimented with various colour images in Brodatz, Vistex, Outex and Sowerby Colour texture image databases. The Colour Texture Images from Vistex and Brodatz database are selected and discussed in section 5.3.1. The Outdoor colour texture images from Outex and Sowerby are discussed and experimental results are presented in section 5.3.2.

5.2.1.1 Brodatz and Vistex databases

The Segmentation algorithm is applied for five Colour texture images. The first one is formed by the images of Sand 000113, Fabric 00069, DocCageCity and Fabric00058 and at the center circular shape Carpet image is placed and the test image is shown in Figure 5.3 (a) and the segmented output by the proposed approach is shown in Figure 5.3 (b). To differentiate each segmented region, pseudo color is assigned.
Figure 5.3  Texture Segmentation results for Colour texture image consisting of Sand 000113, Fabric 00069, DocCageCity and Fabric00058 and at the center circular shape Carpet image
(a) Original Image (b) Segmented output image

The proposed approach is compared with Segmentation of Color textures by Majid Mirmehdi, Maria Petrou 2000 and Fuzzy clustering of color and texture features for image segmentation: a study on satellite image retrieval by Ooi, Lim, 2006. The output results are shown in Figure 5.4 (b) and 5.5(b).

Figure 5.4  Texture Segmentation results for Colour texture image consisting of Sand 000113, Fabric 00069, DocCageCity and Fabric00058 and at the center circular shape Carpet image by Majid Mirmehdi, Maria Petrou 2000
(a) Original Image (b) Segmented output image
Figure 5.5  Texture Segmentation results for Colour texture image consisting of Sand 000113, Fabric 00069, DocCageCity and Fabric00058 and at the center circular shape Carpet image by Ooi, Lim 2006  
(a) Original Image (b) Segmented output image

The second set of input image is formed by the combination of images of Metal00030, Food, deepgrass, Fabric00058 in square shape and the test image is shown in Figure 5.6 (a) and the segmented output by the proposed approach is shown in Figure 5.6 (b). To differentiate each segmented region, pseudo color is assigned.

Figure 5.6  Texture Segmentation results for Colour texture image consisting of Metal00030, Food, deepgrass, Fabric00058  
(a) Original Image  (b) Segmented output image
The proposed approach is compared with Segmentation of Color textures by Majid Mirmehdi, Maria Petrou 2000 and Fuzzy clustering of color and texture features for image segmentation: a study on satellite image retrieval by Ooi, Lim, 2006. The output results are shown in Figure 5.7 (b) and 5.8 (b).

Figure 5.7  Texture Segmentation results for Colour texture image consisting of Metal00030, Food, deepgrass, Fabric00058 by Majid Mirmehdi, Maria Petrou 2000
(a) Original Image (b) Segmented output image

Figure 5.8  Texture Segmentation results for Colour texture image consisting of Metal00030, Food, deepgrass, Fabric00058 Ooi, Lim 2006
(a) Original Image (b) Segmented output image
The third set of input image is formed by the combination of images of particleboard1, cloth05 and a square shape texture image deepgrass is placed at the center. The input image is shown in Figure 5.9 (a) and the segmented output by the proposed approach is shown in Figure 5.9 (b).

![Figure 5.9](image)

**Figure 5.9** Texture Segmentation results for Colour texture image consisting of particleboard1, cloth05 and a square shape texture image deepgrass

(a) Original Image  (b) Segmented output image

The proposed approach is compared with Segmentation of Color textures by Majid Mirmehdi, Maria Petrou 2000 and Fuzzy clustering of color and texture features for image segmentation: a study on satellite image retrieval by Ooi, Lim 2006. The output results are shown in Figure 5.10 (b) and 5.11 (b).
Figure 5.10 Texture Segmentation results for Colour texture image consisting of particleboard1, cloth05 and a square shape texture image deepgrass by Majid Mirmehdi, Maria Petrou 2000
(a) Original Image (b) Segmented output image

Figure 5.11 Texture Segmentation results for Colour texture image consisting of particleboard1, cloth05 and a square shape texture image deepgrass by Ooi, Lim 2006
(a) Original Image (b) Segmented output image

The fourth set of input image is formed by the combination of images of Fabric 00069, Bark00080 and triangular shape image Flowers00040. The input image is shown in Figure 5.12 (a) and the segmented output by the proposed approach is shown in Figure 5.12 (b).
Figure 5.12 Texture Segmentation results for Colour texture image consisting of Fabric 00069, Bark00080 and Flowers00040
(a) Original Image (b) Segmented output image

The proposed approach is compared with Segmentation of Color textures by Majid Mirmehdi, Maria Petrou 2000 and Fuzzy clustering of color and texture features for image segmentation: a study on satellite image retrieval by Ooi, Lim 2006. The output results are shown in Figure 5.13 (b) and 5.14(b).

Figure 5.13 Texture Segmentation results for Colour texture image consisting of Fabric 00069, Bark00080 and Flowers00040 by Majid Mirmehdi, Maria Petrou 2000
(a) Original Image (b) Segmented output image
5.2.1.2 Outex and Sowerby databases

In this section, we discuss the segmentation of colour texture images for natural outdoor images taken from Outex and Sowerby Databases. The target test image is as shown in Figure 5.15(a) and the segmented output by the proposed approach is shown in Figure 5.15 (b). To differentiate each segmented region, each pixel is painted with the average colour of the pixel in its neighborhood that belongs to the same class.
The proposed approach is compared with Segmentation of Color textures by Majid Mirmehdi, Maria Petrou 2000 and Fuzzy clustering of color and texture features for image segmentation: a study on satellite image retrieval by Ooi, Lim, 2006. The output results are shown in Figure 5.16 (b) and 5.17 (b).

Figure 5.16  Texture Segmentation results for Outdoor Scene Image by Majid Mirmehdi, Maria Petrou 2000
(a) Original Image (b) Segmented output image

Figure 5.17  Texture Segmentation results for Outdoor Scene Image by Ooi, Lim 2006
(a) Original Image (b) Segmented output image by Segmented output image
The second test outdoor colour textured image is shown in Figure 5.18(a) and the segmented output by the proposed approach is shown in Figure 5.18 (b).

![Image of outdoor scene](image1)

(a) 
(b)

**Figure 5.18  Texture Segmentation results for outdoor Scene image**
(a) Original Image (b) Segmented output image

The proposed approach is compared with Segmentation of Color textures by Majid Mirmehdi, Maria Petrou 2000 and Fuzzy clustering of color and texture features for image segmentation: a study on satellite image retrieval by Ooi, Lim 2006. The output results are shown in Figure 5.19 (b) and 5.20 (b).

![Image of outdoor scene](image2)

(a) 
(b)

**Figure 5.19  Texture Segmentation results for outdoor Scene image by Majid Mirmehdi, Maria Petrou 2000**
(a) Original Image (b) Segmented output image
5.2.2 Conclusion

In this section, texture segmentation is proposed by clustering concept with colour fuzzy texture spectrum. From the experimental result, obtained for texture segmentation from Brodatz, Vistex, Outex and Sowerby Databases, it is concluded that the proposed approach yields good segmentation result when compared to Segmentation of Color textures by Majid Mirmehdi, Maria Petrou 2000 and Fuzzy clustering of color and texture features for image segmentation: a study on satellite image retrieval by Ooi, Lim 2006.

The usage of the proposed colour fuzzy texture spectrum is shown effectively by performing textured edge detection, which is discussed in the following section.
5.3 TEXTURED EDGE DETECTION

This section explains the usefulness of features, used to characterize and perform edge detection operations. Here, a method is proposed for combining the traditional edge detection techniques (Roberts’s operator) with newly proposed Colour fuzzy texture descriptor to detect the presence of edges present between different texture regions of Colour texture images.

5.3.1 Texture Edge Detection System

The steps involved in texture segmentation are shown in Figure 5.8.

Figure 5.21 Texture edge detection stage

The idea of obtaining edges present in Colour texture images is to apply conventional edge detection on the texture features rather than on mere intensities. Roberts’s operator was used as the edge detection operator. Colour Texture spectra were calculated considering a moving window. The integrated absolute difference between two Colour texture spectra centered in two windows has been taken as the difference between two elements of the edge
detection operator. Then, the edge value, R is computed by equations (5.1, 5.2 and 5.3).

\[ R_{(Roberts)} = \sqrt{D_1^2 + D_2^2} \]  

(5.1)

where

\[ D_1 = \sum_{K=1}^{N^k} |S_{i,j}(K) - S_{i-1,j-1}(K)| \]  

(5.2)

\[ D_2 = \sum_{K=1}^{N^k} |S_{i,j-1}(K) - S_{i-1,j}(K)| \]  

(5.3)

where \( S_{i,j}(k) \) denotes \( K^{th} \) element of the Colour fuzzy texture spectrum calculated from the window located at the position \( i, j \). Thus, \( D_1 \) and \( D_2 \) give the absolute difference between two Colour textures spectra located in diagonal positions.

The convolution using the above operator was carried out for the entire image, with a step of one position sliding on a square grid. The proposed method can effectively extract boundaries between these textures.

5.3.2 Experimental Results and Discussions

The boundary-detected images are obtained by applying edge detection algorithm, in this section. The proposed edge detection algorithm distinguishes texture boundaries between different texture regions. Thus, edges inside the same texture (micro-edges) and texture boundaries between different texture regions are distinguished by the proposed method. Due to the geometric effects of moving window, four exterior portions are not processed and the derived boundaries may be easily improved by using suitable post processing algorithms. For example, thinning algorithm.
To evaluate the performance of the Colour fuzzy texture spectrum, several experimental studies have been carried out on for Brodatz, Vistex, Outex and Sowerby Colour texture images. The Colour Texture Images from Vistex and Brodatz database are selected and discussed in section 5.5.1. The Outdoor colour texture images from Outex and Sowerby are discussed and experimental results are presented in section 5.5.2.

5.3.2.1 Brodatz and Vistex databases

The first set of input image is formed by the combination of images of Carpet, Fabric00058 placed in irregular shape. The input image is shown in Figure 5.22 (a) and the edge detected output result by the proposed approach is shown in Figure 5.22 (b).

![Figure 5.22](image)

*Figure 5.22 Colour texture edge detection results for texture images consisting of Carpet, Fabric00058*

(a) Input colour texture image (b) Output edgemap showing edges

The proposed approach is compared with the Colour edge detection in RGB using jointly Euclidean distance and vector angle by Wesolkowski and Jernigan 1999 and the edge detected output result is shown in Figure 5.23 (b).
Figure 5.23 Colour Texture Edge Detection results for texture images consisting of carpet, fabric00058 by Wesolkowski and Jernigan 1999

(a) Input Colour Texture Image (b) Output edgemap showing edges

The second set of input image is formed by the Texture images of a square shape in clockwise direction combination of images of Cloth, reddeepcarpet, Granite and mud. The input image is shown in Figure 5.24 (a) and the edge detected output result by the proposed approach is shown in Figure 5.24 (b).

Figure 5.24 Colour Texture Edge Detection results for texture images consisting of cloth, reddeepcarpet, granite and mud

(a) Input image with four natural colour texture regions
(b) Output edgemap showing edges
The proposed approach is compared with Colour edge detection in RGB using jointly Euclidean distance and vector angle by Wesolkowski and Jernigan 1999 and the edge detected output result is shown in Figure 5.25 (b).

![Figure 5.25](image)

**Figure 5.25** Colour Texture Edge Detection results for texture images consisting of cloth, reddeepcarpet, granite and mud by Wesolkowski and Jernigan 1999
(a) Input image with four natural colour texture regions
(b) Output edgemap showing edges

The third set of input image is formed by the Texture images of fallen leaves and cloth image is placed at the center. The input image is shown in Figure 5.26 (a) and the edge detected output result by the proposed approach is shown in Figure 5.26 (b).

![Figure 5.26](image)

**Figure 5.26** Colour Texture Edge Detection results for texture images consisting of fallen leaves and cloth image
(a) Input image with colour texture regions
(b) Output edgemap showing edges
The proposed approach is compared with Colour edge detection in RGB using jointly Euclidean distance and vector angle by Wesolkowski and Jernigan 1999 and the edge detected output result is shown in Figure 5.27 (b).

![Image](a) ![Image](b)

**Figure 5.27** Colour Texture Edge Detection results for texture images consisting of fallen leaves and cloth image by Wesolkowski and Jernigan 1999

(a) Input image with colour texture regions
(b) Output edge map showing edges

5.3.2.2 Outex and Sowerby databases

The proposed method is experimented with natural outdoor images taken from Outex and Sowerby Databases. The first test input image is shown in Figure 5.28(a) and the edge detected output result by the proposed approach is shown in Figure 5.28(b).

![Image](a) ![Image](b)

**Figure 5.28** Colour Texture Edge Detection results for outdoor scene image (a) Original Image (b) Output edge map showing edges
The proposed approach is compared with Colour edge detection in RGB using jointly Euclidean distance and vector angle by Wesolkowski and Jernigan 1999 and the edge detected output result is shown in Figure 5.29 (b).

![Original Image](a) ![Segmented Output Image](b)

Figure 5.29 Colour Texture Edge Detection results for outdoor scene image by Wesolkowski and Jernigan 1999
(a) Original Image (b) Segmented Output Image

5.3.3 Conclusion

The idea behind this proposed method is to exhibit the usage of colour fuzzy texture spectrum features for texture edge detection. The features are approximately the same, when the windows or sub images considered are from the same texture and different, if they are from different textures. Varieties of textures collected from standard albums are stitched to form target images, which are used for edge detection. It is found that the proposed method yield better results. Texture segmentation results obtained using colour fuzzy texture spectrum as features are found to be better, when compared with Colour edge detection in RGB using jointly Euclidean distance and vector angle attempted by Wesolkowski and Jernigan 1999. This fact has been experimentally established with a number of target images collected from standard Benchmark database images namely Brodatz and Vistex, Outex and Sowerby Databases.

The usage of the proposed colour texture descriptor in few medical images is discussed in the next chapter.