Chapter 2

Detection of esophageal cancer (necrosis) in endoscopic images using color image segmentation

2.1 Introduction

Conventional diagnosis of cancer based on endoscopic images employs visual interpretation of the images by the medical experts. For an automatic visual system to “understand a scene”, it is necessary to extract regions of special interest by proper segmentation [P. Wang et al. 2001]. Computerized image comprehension of endoscopic images offers a powerful tool for enhancing images and rendering them easier for the physician to point out abnormality. A wide variety of image segmentation techniques have been developed, viz., edge detection, region growing, histogram thresholding and clustering. Among them, the methods of clustering and histogram thresholding are extensively used for color image segmentation. For color image segmentation, there exist two basic problems. The first is uncertainty that most segmentation results are not always crisp or correct due to the grayness ambiguity and spatial ambiguity in an image. The second is that the definition of efficient quality measure is difficult and the segmentation methods using various parameters rely on image characteristic and environment. Therefore, the technique developed may not be applicable to other applications. Another difficulty is due to the lumen region which is the area of lowest intensity in an endoscopic image. As the endoscope uses several light sources at its tip and the

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illuminating distances of these sources are limited, the surface lying near the light source will be brighter than that lying further away. The objective of the present study in this chapter is detection of (abnormal regions) esophageal cancer (necrosis) in endoscopic images using color image segmentation. The following diagram (Figure 2.1) depicts the different stages of image processing for detection of the levels of cancer growth.

![Figure 2.1 Processing of images for detection of the levels of cancerous growth](image)

### 2.2 Pre-processing and feature extraction

The endoscopic images of the lower section of esophagus are considered as input images which are of size 128x128 pixels and are assumed to be free from lumen region and are preprocessed. The preprocessing involves smoothening of color images using average filter [Rafael C. Gonzalez 2002]. The RGB color image contains three times more data than a gray-scale image. However, the three maps should not be processed independently because it appears that strong spatial and chromatic correlations exist. We have considered average filter for smoothening on the multi image \([R(x,y), G(x,y), B(x,y)]\). Let \(P_{xy}\) denote the set of coordinates defining a neighborhood centered at \((x,y)\) in an RGB color image. The average \(\overline{c}(x,y)\) of the RGB component vectors in this neighborhood is given by
where $K$ is total number of pixels in $P_{xy}$. We recognize the components of this vector as the scale images that would be obtained by independently smoothing each plane of the starting RGB image using conventional gray-scale neighborhood processing. Thus, the smoothing by neighborhood averaging can be carried out on a per-color-plane basis.

From 25 sample images, the mean, standard deviation, skewness and kurtosis of RGB values, for the regions classified as initial stage or advanced stage of cancer, are determined using the moment based statistical techniques given below [R.S.N.Pillai and V.Bagavathi 1993].

\[
\overline{V}_j = \frac{1}{N} \sum_{(x,y) \in C} V_j(x,y) \quad \text{(Mean)} \tag{2.2}
\]

where $V_j(x,y)$ is the value of the $j^{th}$ color component of the pixel at $(x,y)$ in the cancerous region $C$.

\[
\mu_{2j} = \frac{1}{N} \sum_{(x,y) \in C} \left[ V_j(x,y) - \overline{V}_j \right]^2 \quad \text{(Second moment about the mean)} \tag{2.3}
\]

\[
\mu_{3j} = \frac{1}{N} \sum_{(x,y) \in C} \left[ V_j(x,y) - \overline{V}_j \right]^3 \quad \text{(Third moment about the mean)} \tag{2.4}
\]

\[
\mu_{4j} = \frac{1}{N} \sum_{(x,y) \in C} \left[ V_j(x,y) - \overline{V}_j \right]^4 \quad \text{(Fourth moment about the mean)} \tag{2.5}
\]

Standard deviation $\sigma_j = \sqrt{\mu_{2j}}$ (Measure of dispersion) \tag{2.6}

Skewness $S_j = \frac{\mu_{3j}}{\sigma_j^3}$ (Measure of asymmetry) \tag{2.7}

Kurtosis $K_j = \frac{\mu_{4j}}{\mu_{2j}^2}$ (Measure of peakedness) \tag{2.8}
This information is stored as the knowledge base for automatic segmentation of any given input image. The Table 2.1 shows the estimated mean, standard deviation, skewness and kurtosis of RGB values of regions of interest, namely, regions showing initial and advanced stage of cancer growth.

Table 2.1 The statistical moments of RGB values for the disease class

<table>
<thead>
<tr>
<th>Disease Class</th>
<th>Initial stage</th>
<th>Advanced stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
<td>R</td>
<td>G</td>
</tr>
<tr>
<td>Mean</td>
<td>177.12</td>
<td>56.45</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>17.43</td>
<td>12.48</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.05</td>
<td>0.93</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>3.02</td>
<td>5.35</td>
</tr>
</tbody>
</table>

Histograms of one sample endoscopic image containing initial stage cancerous region and that containing advanced stage cancerous region are shown in Figure 2.2 and Figure 2.3, respectively.

Figure 2.2 (a) Sample endoscopic image containing initial stage cancerous region; (b), (c) and (d) Red, Green and Blue components of sample image (a), respectively; (e), (f) and (g) Histograms of Red, Green and Blue components in (b), (c) and (d), respectively.
Surface plots of one sample endoscopic image containing initial stage cancerous region and that containing advanced stage cancerous region are shown in Figure 2.4 and Figure 2.5, respectively.
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Figure 2.4 (a) Sample endoscopic image containing initial stage cancerous region; (b), (c) and (d) Red, Green and Blue components of sample image (a), respectively; (e), (f) and (g) Surface plot of Red, Green and Blue components in (b), (c) and (d), respectively; (h) Surface plot of gray image of (a).

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

Figure 2.5 (a) Sample endoscopic image containing advanced stage cancerous region; (b), (c) and (d) Red, Green and Blue components of sample image (a), respectively; (e), (f) and (g) Surface plot of Red, Green and Blue components in (b), (c) and (d), respectively; (h) Surface plot of gray image of (a).
2.3 Detection of cancer growth stages

For a given input image, the segmentation is carried out using the $3\sigma$-intervals [William W. Hines 1990] around mean RGB values stored in the knowledge base. The pixels of the input image are classified as belonging to initial stage or advanced stage cancer growth and thus the detection of different stages of esophageal cancer in endoscopic images is achieved.

These images may contain the bright spots which are due to the reflection from the light source. The RGB values of the pixels belonging to these bright spots are replaced by the mean RGB values. This process eliminates the bright spots and thus minimizes the misdetection of cancerous region as normal region. The Figure 2.6 shows the different stages of processing of an endoscopic image.

2.4 Experimental results

For experimentation, the 160 color endoscopic test images of size 128x128 pixels (Appendix III) obtained from a medical expert are subjected to the above proposed segmentation process. The resulting images are shown in Figure 2.7 for five test images. The corresponding images obtained after manual segmentation done by medical expert are shown in Figure 2.8. The comparison of Figure 2.7 and Figure 2.8 indicates that the proposed color image segmentation is in good agreement with the manual segmentation done by a medical expert.
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Figure 2.6 (a) A color endoscopic image, (b) Image obtained after smoothing, (c) Image showing initial stage of cancer, (d) Image showing advanced stage of cancer, (e) and (f) Images with bright spots, (g) and (h) Images after filling bright spots.
Figure 2.7 (a) Original color endoscopic image, (b) Initial stage cancerous region and (c) Advanced stage cancerous region
Figure 2.8 (a) Original endoscopic image, (b) Manual segmentation done by medical expert for initial stage cancerous region and (c) Manual segmentation done by medical expert for advanced stage cancerous region.
2.5 Summary

In this chapter, a color image segmentation method for detection of (abnormal regions) esophageal cancer (necrosis) in endoscopic images is presented. The proposed method is based on \(3\sigma\)-interval around mean RGB values and is experimented with 160 test images. The experimental results show good agreement with the manual segmentation. Thus, the proposed segmentation method can be used for automatic detection of cancerous region (abnormal regions) in endoscopic images, which assists the physician for faster, proper diagnosis and treatment of the disease.