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Identification of abnormality from Endoscopic Color Images using Normalized cuts

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Abstract. The normalized cut criterion measures both the total dissimilarity between the different groups as well as the total similarity within the groups. These methods perform segmentation of the images through hierarchical partitioning instead of performing single flat partition. In this paper the normalized cuts method of segmentation is used to perform the segmentation of abnormal region from endoscopic images. The other image features such as image brightness, color and texture are considered while performing segmentation. The experimentation is carried out on 50 images containing tumor. The results of segmentation of tumor from the endoscopic images using the proposed method are very encouraging.

Keywords: Endoscopy, color, Graph partitioning, abnormal, normalized cuts, texture.

1 Introduction

Gastro intestinal endoscopy is a medical procedure which captures the images from esophagus, stomach and duodenum. These images are better than that of the other tests, and in many cases endoscopy is superior to the other imaging techniques such as traditional x-rays and ultrasound images. A physician may use an endoscopy as a tool for diagnosing the disorders in the digestive tract, including disorders of the esophagus, stomach, small intestine, large intestine, anus, rectum and colon. Symptoms that may indicate the need for an endoscopy include swallowing difficulties, nausea, vomiting, reflux, bleeding, indigestion, abdominal pain, chest pain and a change in bowel habits. In some cases, a physician may use the endoscopy to obtain tissue samples for biopsy in a laboratory. A physician may also use the endoscopy to remove abnormal tissue such as polyps and tumors. In the conventional approach for the diagnosis of endoscopic images the visual interpretation by the physician is employed. The process of computerized visualization, interpretation and analysis of endoscopic images will assist the physician for identifying the abnormality in the images [1]. In this direction research is carried out for classifying the abnormal endoscopic images based on their properties like color, texture, structural relationships between the image pixels, etc. The method proposed by P. Wang et.al. [2] classifies the endoscopic images based on texture and neural network, where as the analysis of curvature for the edges obtained from the endoscopic images is proposed by Krishnan et.al.[3]. Hiremath et.al.[4] proposed a method to detect the possible presence of abnormality using color segmentation of the images based on 3σ-interval [5] for obtaining edges followed by curvature analysis. The watershed segmentation approach for classifying abnormal endoscopic images is proposed by Dhandra et.al. [6].

Segmentation of medical images using energy minimization criteria gained popularity in the recent years. Dhandra et. al.[7] proposed the active contours using the level set method with energy minimization approach, which is also known as active contours without edges, for the segmentation and analysis of abnormality in the endoscopic images. This active contour approach segments the image by minimizing the contour energy $E$ as proposed by chan et. al [8]. The graph cuts based active contours (GCBAC) segmented tumors and cancer growth regions from the endoscopic images [9]. This method is a combination of active contours and the optimization tool of graph cuts. It differs fundamentally from traditional active contours in that it uses graph cuts to iteratively deform the contour.

The variations of the minimal spanning tree or limited neighborhood set approaches were used extensively in image segmentation. Although these approaches use efficient computational methods, the segmentation criteria used in most of them are based on local properties of the graph. Since perceptual grouping is about extracting the global impressions of a scene, this partitioning criterion often falls short of the main goal of utilizing local properties.

In this paper normalized cuts based segmentation method proposed by Jianbo Shi et. al. [10] is applied for hierarchically partitioning the image to segment the tumor from endoscopic images. This method employs graph-theoretic criterion for measuring the goodness of an image partition. To achieve better segmentation of the region of interest the other image features such are brightness, color and texture are used while performing hierarchical partitioning. The minimization of this criterion can be formulated as a generalized eigenvalue problem. The eigenvectors can be used to construct good partitions of the image and the process can be continued recursively as desired (Section 2). Section 3 gives a detailed explanation of the steps of grouping algorithm. In Section 4, experimental results are discussed. Section 5 presents the concluding remarks.
2 Graph partitioning by grouping

A graph $G = (V, E)$ can be partitioned into two disjoint sets $A$ and $B$, such that $A \cup B = V$, and $A \cap B = \emptyset$, by simply removing edges connecting the two parts. The degree of dissimilarity between these two pieces can be computed as total weight of the edges that have been removed. This is called as the cut in graph theoretic language:

$$\text{cut}(A, B) = \sum_{u \in A, v \in B} w(u, v)$$  \hspace{1cm} (1)

By minimizing this cut value the optimal bi-partitioning of a graph can be achieved. Although there are an exponential number of such partitions, finding the minimum cut of a graph is a well-studied problem and there exist efficient algorithms for solving it.

Wu and Leahy [11] proposed a clustering method based on this minimum cut criterion. In particular, they seek to partition a graph into $k$-sub graphs such that the maximum cut across the subgroups is minimized. This problem can be efficiently solved by recursively finding the minimum cuts that bisect the existing segments. As shown in Wu and Leahy’s work, this globally optimal criterion can be used to produce good segmentation on some of the images. However, as Wu and Leahy also noticed in their work, the minimum cut criteria favors cutting small sets of isolated nodes in the graph. This is not surprising since the cut defined in eqn. (1) increases with the number of edges going across the two partitioned parts. Fig. 1 illustrates one such case. Assuming the edge weights are inversely proportional to the distance between the two nodes, we see the cut that partitions out node $n_1$ or $n_2$ will have a very small value. In fact, any cut that partitions out individual nodes on the right half will have smaller cut value than the cut that partitions the nodes into the left and right halves.

To avoid this unnatural bias for partitioning out small sets of points, a new measure of disassociation between two groups is introduced. Instead of looking at the value of total edge weight connecting the two partitions, this measure computes the cut cost as a fraction of the total edge connections to all the nodes in the graph. This disassociation measure is called as the normalized cut ($Ncut$):

$$Ncut(A, B) = \frac{\text{cut}(A, B)}{\text{assoc}(A, V)} + \frac{\text{cut}(A, B)}{\text{assoc}(B, V)}$$  \hspace{1cm} (2)

where $\text{assoc}(A, V) = \sum_{u \in A, t \in V} w(u, t)$ is the total connection from nodes in $A$ to all nodes in the graph and $\text{assoc}(B, V)$ is similarly defined.

![Fig. 1. A case where minimum cut gives a bad partition.](image)

With this definition of the disassociation between the groups, the cut that partitions out small isolated points will no longer have small $Ncut$ value, since the cut value will almost certainly be a large percentage of the total connection from that small set to all other nodes. In the case illustrated in Fig. 1, it can be noticed that the cut1 value across node n1 will be 100 percent of the total connection from that node.

In the same way, a measure for total normalized association within groups for a given partition can be described as:

$$Nassoc(A, B) = \frac{\text{assoc}(A, A)}{\text{assoc}(A, V)} + \frac{\text{assoc}(B, B)}{\text{assoc}(B, V)}$$  \hspace{1cm} (3)

where $\text{assoc}(A, A)$ and $\text{assoc}(B, B)$ are total weights of edges connecting nodes within $A$ and $B$, respectively. Again this is an unbiased measure, which reflects how tightly on average nodes within the group are connected to each other.
Let \( d(i) = \sum_j w(i, j) \) be the total connection from the node \( i \) to all other nodes. Let \( D \) be an \( N \times N \) diagonal matrix with \( d \) on its diagonal, \( W \) be an \( N \times N \) symmetric matrix with \( W(i, j) = w(i, j) \). Then it turns out that we can minimize \( Ncut(A, B) \) by

\[
\min_{A, B} Ncut(A, B) = \min_y \frac{y^T (D - W)y}{y^T Dy}
\]

(4)

Note that the above expression is Rayleigh quotient \([12]\). If \( y \) is relaxed to take real values, the above equation can be minimized by solving the generalized eigenvalue system,

\[
(D - W)y = \lambda Dy
\]

(5)

Interestingly, the second smallest eigenvector \( y \) gives the solution of the normalized cut problem.

3 The Grouping Algorithm

The grouping algorithm can be described as follows:

Step 1:
Construct an \( N \times N \) symmetric similarity matrix \( W \) as:

\[
w(i, j) = e^{-\frac{(||F(j) - F(i)||^2)}{\sigma_i^2}} \cdot \beta
\]

(6)

where \( \beta = \begin{cases} e^{-\frac{||x(i) - x(j)||^2}{\sigma_i^2}} & \text{if } ||x(i) - x(j)||^2 < \gamma \\ 0 & \text{otherwise} \end{cases} \)

and \( X(i) \) is the spatial location of node \( i \), i.e., the coordinates in the original image \( I \), and \( F(i) \) is a feature vector defined as:

- \( F(i) = 1 \) for segmenting point sets,
- \( F(i) = I(i) \), the intensity value, for segmenting brightness (gray scale) images,
- \( F(i) = [v, v \cdot s \cdot \sin(h), v \cdot s \cdot \cos(h)](i) \), where \( h, s, v \) are the HSV values, for color segmentation,
- \( F(i) = [I * f_1], ..., [I * f_n](i) \), where the \( f_i \) are DOOG filters at various scales and orientations, as used in \([13]\), for texture segmentation.

Let \( d(i) = \sum_j w(i, j) \) be the total connection from the node \( i \) to all other nodes. Construct an \( N \times N \) diagonal matrix \( D \) with \( d \) on its diagonal.

Step 2
Solve a generalized eigensystem,

\[
(D - W)y = \lambda Dy
\]

and get an eigenvector with the second smallest eigenvalue.

Step 3
Use the eigenvector to bipartition the graph. In the ideal case, the eigenvector should only take on two discrete values, and the signs tell us exactly how to partition the graph \((A = \{Y_i > 0\}, B = \{Y_i <= 0\})\).

However, \( y \) is relaxed to take real values; therefore, a splitting point is needed to be chosen. There are several ways such as:
- Take 0
- Take median
- Search a splitting point which results in that \( Ncut(A, B) \) is minimized.

The splitting point which minimizes \( Ncut \) value also minimizes

\[
\frac{y^T (D - W)y}{y^T Dy}
\]

(8)
where \( y = (1 + X) - b(1 - X) \), \( b = k/(1 - k) \) and \( k = \sum_{i=0}^{\infty} d_i \sum d_i \).

where \( X \) is an \( N \) dimensional indicator vector, \( x_i = 1 \) if node \( i \) is in \( A \) and -1, otherwise.

To find the minimal \( \text{Ncut} \), we need to try different values of splitting points. The optimal splitting point is generally around the mean value of the obtained eigenvector.

**Step 4**
Repeat bipartition recursively. Stop if \( \text{Ncut} \) value is larger than a pre-specified threshold value. Large \( \text{Ncut} \) value means that there is no clear partition point any more. Furthermore, stop if the total number of nodes in the partition (Area) is smaller than a pre-specified threshold value.

### 4 Results

The Olympus V70 endoscopic equipment is used for capturing the image. For the implementation of this paper Matlab software release 7.0 is used. Experimentation is carried out on 50 endoscopic color images with no lumen region.

Figure 2 shows the segmentation process by the proposed method. The original endoscopic color image selected for the segmentation is shown in Fig. 2(a). The edges obtained by the proposed segmentation method are as shown in Fig. 2(b). Fig. 2(c) shows the segmented image. The coefficients used to compute the similarity weight matrix are \( \sigma_I = 5.0 \), \( \sigma_X = 4.0 \) and the coefficient used for computing similarity matrix for the neighbourhood definition is \( \gamma = 1.5 \). The number of segments generated is from the proposed segmentation are limited to five since higher value generates larger number of segments leading to deviation from the tumor region and lower number of segments leads to improper or incomplete segmentation, failing in identifying tumor.

![Fig. 2. Segmentation of image using proposed method. (a) Input image, (b) Grayscale image and (c) image after segmentation](image-url)

Figure 3 shows the segmentation results carried out on three endoscopic images with original color endoscopic images and images after segmentation.

![Fig. 3. Segmentation of tumor from endoscopic color images showing original images and corresponding segmented images](image-url)
5 Conclusion

The segmentation adapted in this paper is based on normalized cuts partitioning method proposed by Jianbo Shi et. al. [10]. The normalized cut criterion measures both the total dissimilarity between different groups as well as the total similarity within the groups. Also the normalized cut is an unbiased measure of disassociation between subgraphs of a graph and it has a nice property that minimizing normalized cuts leads directly to maximizing the normalized association, which is an unbiased measure for total association within the subgroups. The generalized eigenvalue system used in this paper provides a real valued solution in developing an efficient algorithm for computing the minimum normalized cut. The algorithm also utilizes other image features like color, texture and brightness. The segmentation results using the proposed method are very encouraging.

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