Jurnal
Teknologi

Full Paper

# GRAPH CUT SEGMENTATION METHOD AND ITS APPLICATION IN MEDICAL IMAGES

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**Article history**
Received
*3 December 2013*
Received in revised form
*2 July 2014*
Accepted
*25 November 2014*

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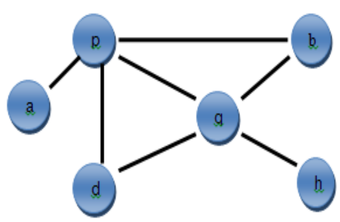
**Graphical abstract**




**Abstract**

Graph cut is an interactive segmentation method. It works based on preparing graph from image and finds the minimum cut for the graph. The edges value is calculated based on belonging a pixel to object or background. The advantage of this method is using the cost function. If the cost function is clearly described, graph cut is presents a generally optimum result. In this paper graph concepts and preparing graph according to image pixels is described. Preparing different edges and performing min cut/max flow is explained. Finally, the method is applied on some medical images.

*Keywords*: Graph cut, segmentation, image processing



## 1.0 INTRODUCTION

Some segmentation methods need some initialization values to start the process like region growing which known as interactive segmentation methods. These kinds of segmentation methods are becoming more popular to solve difficult problems. These methods try to separate image into two sections "object" and "background". User enforce specific constraints for segmentation by selecting some pixels as seed points which are certainly are a part of the object and some pixels which are belong to the background. Thus, segmentation method will separate image into two parts by satisfying constraint which enforce by user.

Graph cut segmentation presents a novel interaction method which is the region and boundary detection technique. This method perform the segmentation by applying min cut algorithm to find minimum cut on graph which is generated from image pixels [1]. Recently this method has been used widely in different area. Some segmentation methods has been generated based on graph cut like grab cut [2] and lazy snapping [3].

The advantage of graph cut methods is to present a general optimum result for an N-dimensional segmentation if the cost function is clearly described. "Some earlier techniques (snakes, deformable templates, shortest path, ratio regions, and other) can do that only in 2D applications when a segmentation boundary is a 1D curve" [1]. In this method the cost function is declared in terms of boundary and region characteristics of the segments. Despite some methods which don't have cost function, graph cut segmentation can be managed more consistently using cost function.

## 2.0 BACKGROUND AND CONCEPTS

Some terminology will be introduced in this section. A graph G=(V,E) is consisted a set of nodes or vertices V and a set of edges E. Each edge explained by two connected nodes. For example e={p,q} represent an edge between p and q which e∈E. In undirected graph the order of two pair of nodes are not important. Figure 1 shows an undirected graph.

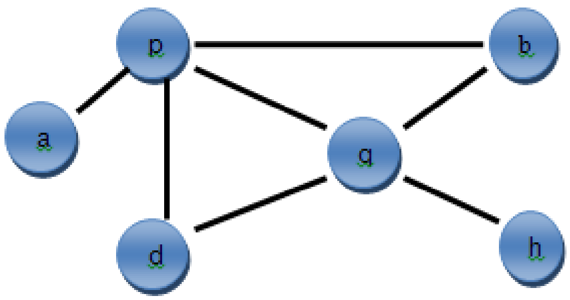



**Figure 1** A graph with 6 nodes

In this work we make graph based on image pixels or voxels. So we assign one node in the graph to each image. In other word number of node is equal to number of pixels.

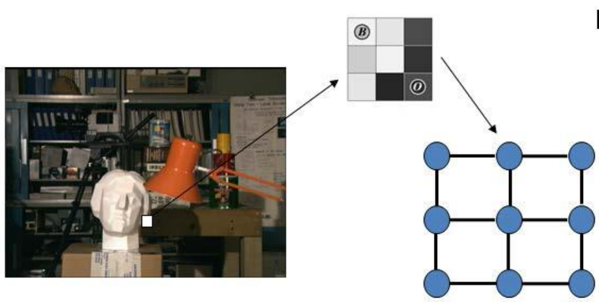


**Figure 2** Making graph from a part of image

As can be seen in Figure 2, a part of image has been selected and a graph has been generated from it with nodes and edges. Neighbouring pixels has been connected to gather. In the following, two special terminal nodes which are known as source and sink are added. The source node represents by S and distinct "object" and the sink represent by T and distinct "background". Edges between pixels called neighbouring links and represent by t-link which connect each two node in 8 or 26 neighbouring system.

Special extra nodes are connected with some edges which called terminal links and represent by t-link. The set E is included all edges which are n-links, t-links that are assigned with some weights (Figure 3).

A subset of edges like C which C ⊂E called an s-t cut if it can divide main graph in two disjoint parts and make two sub graphs for S and T. This cut is represented with g(C)=(V,E/C) and and divide nodes between two terminals which has been illustrated in Figure 4.

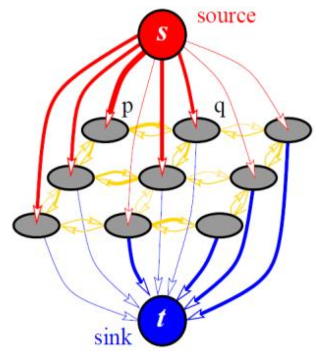



**Figure 3** Sample graph with source and sink nodes

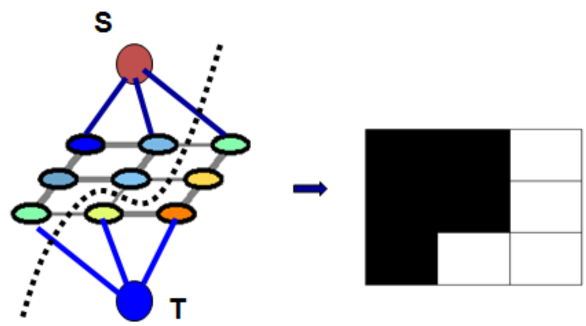



**Figure 4** Cutting the graph and separate the object from background

As can be seen in this Figure 4, cut has been made a binary segmentation and assign object or background two each node. The aim of s-t cut is to find the best cut which gives an optimal segmentation. This cut has a cost value which gets by

$$|C| = \sum_{e \epsilon C} w_e$$

This formula makes a summary on disconnected edges by cut. The minimum cost cut may correspond to segmentation with a desirable balance of boundary and region properties [4].

## 3.0 SEGMENTATION ALGORITHM

In this section the details of graph cut algorithm will be explained. Primary object and background area are gotten from operator and represent by "O" and "B". Thus O ⊂P , B ⊂P and P is a set of sites or pixels as we declared before. Therefore O ∩ B and we know

$$\forall\, p \in O, A_p = \text{"obj"}$$

$$\forall\, p \in B, A_p = \text{"bkg"}$$

We create graph based on image pixels with two extra nodes. The edge weights are calculated based on region and boundary. A cut is calculated to perform the segmentation. This segmentation method is a binary segmentation which divides pixels into two part object and background. We define a graph to apply a min cut algorithm on it. Graph G=(V,E) in which V is set of nodes that include images pixels with two extra nodes, source terminal for objects which is shown by S and sink terminal for background which is shown by T. Therefore,

$$v = P \cup \{S, T\}$$

Set E consists of edges that included two set of undirected edges which are n-links and t-links. The first one is neighbouring links that include edges between pixels of the images which represent by N and the second one is edges between pixels and source (S) and edges between pixels and Sink (T) which represent by {p,S},{p,T}. Therefore

$$E = N \bigcup_{p \epsilon P} \{\{p, S\}, \{p, T\}\}$$

Calculating edges weights govern soft constraints to assign weight to unmarked pixel. Assigning appropriate value is done according to probability of pixels which selected by operator. Hard constraints govern on pixels which selected by user that declaring node belongs to which side of cut. The weights which can be assigned to edges are described in Table 1.

**Table 1** Edges and weights of graph in graph cut segmentation method

| Edge | Weight | For |
|---|---|---|
| $\{p, q\}$ | $B\{p,q\}$ | $\{p, q\} \in N$ |
| $\{p, S\}$ | $\lambda.\ Rp(\text{"}bkg\text{"})$ | $p \in P, p \notin O \cup B$ |
| | K | $p \in O$ |
| | 0 | $p \in B$ |
| $\{p, T\}$ | $\lambda.\ Rp(\text{"}obj\text{"})$ | $p \in P, p \notin O \cup B$ |
| | 0 | $p \in O$ |
| | K | $p \in B$ |

where

$$K = 1 + \max_{p \epsilon P} \sum_{q:\{p,q\} \epsilon N} B_{\{p,q\}}$$

This constant is enough large to not be in the cut set. This formula set the value which is more than all soft constraints. The constant » controls the relative importance of region and boundary energy. Because the results of this segmentation method is depend on selecting on this parameter, some research has been done on this parameter to get better results and reduce the sensitivity of method to » [5, 6].

By applying these steps the graph G will be completed. The min cut algorithm can achieve a minimum cut on graph edges and separate graph in two different parts. The image object can be extract from graph cut algorithm.

The minimum cut problem on a graph is to achieve a minimum cut between all cuts cost. One of the solution of solving minimum s-t cut problem is finding a maximum flow from the source s to the sink t. suppose that amount of water want to send from the source to sink using pipes as graph edges which capacities are equal to weights. A maximum flow from s to t uses a series of edges which separate the nodes into two disconnect parts {S, T} according to a minimum cut [7] In other world min-cut and max-flow problem wants to achieve same solution. Finding Max-flow or min-cut is a problem in graph theory and many algorithms have been presented for it and fast implementation can be an issue in practice. For graph cut algorithms two most directed presentations are max-flow [7] or push-relabel [8], which can be slow. In this work we use the latest work based on the new graph cut algorithm from [4].

## 4.0 EXPERIMENTAL RESULT

In this work the graph cut segmentation method has been applied on verity of images. In this process some seed points were selected from foreground (object) and some seed points were selected from the background. The method segments the image accurately. As can be seen in Figure 5, user should select two groups of seed points: foreground and background. Foreground is shown by red color and background is shown by blue color. When seed points selected, the graph is prepared for the image and edge weights are calculated for it. It followed by calculating min cut/max flow for graph and the foreground is separated from background.

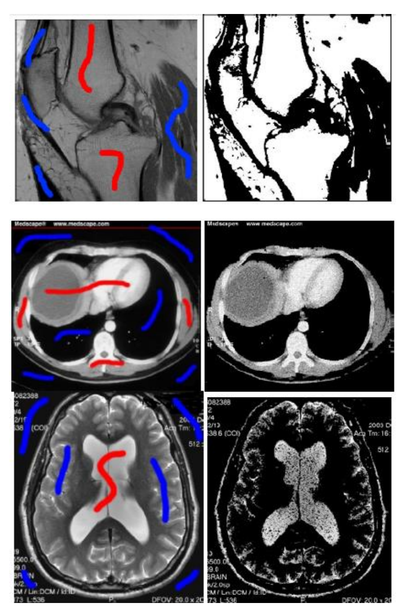


**Figure 5** Graph cut segmentation results

## Acknowledgement

This research was funded by the Universiti Teknologi Malaysia through Research University Grant and manage by Research Management Centre under Vot No. Q.J130000.2528.09H17.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