Graph Cut Application for Image Segmentation in OpenCV

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***Abstract*—Along development of computer science, computer vison is growing very rapidly. Proof by Snapchat or Instagram filter. image segmentation is some of part of computer vision programming. This paper will discuss about graph cut technique in application for image segmentation. Image segmentation can be use for image classification and image recognizing. Some famous computer vision library that implement graph cut is OpenCV. In this paper we will demonstrate graph cut with the function that built in OpenCV that is GrabCut. The languages that the author use for demonstrate is Python 2.7 and for simpler program author will use some extra library for showing image and do some calculation. That is Matplotlib and Numpy. Numpy is some library to do scientific calculation and the author will use matplotlib for showing the image after applying graph cut with grab cut function.**

***Keywords*— Cut,graph, image,segmentation.**

I. INTRODUCTION

In recent years since 2000, computer vision programming is growing very rapidly. Some of startup use computer vision for product is snapchat, instagram, snow, google, facebook, microsoft. Snapchat can do faceswap between 2 face or face detection for filter, following snapchat now instagram can do that too. This is the application of computer vision programming. It is often needed to separate background image and the object that we want to separate.

Computer vision programming and image processing field provide many methods to do image segmentation. One of that is using graph structure with graph cut method. Graph cut is very useful such as for image segmentation, image restoration, image smoothing, the stereo correspondence problem.

Sometime we need separate object instantly for time efficiency such as we have to process large number of image with limited time or make object tracking video.. This job can't be done fastly if we just manually edit that images one by one.

We will discuss a little about what is graph structure then we jump to what is computer vision programming and the last the method of graph cut algorithm for background separation to get an object that we want. This paper will explain what is min-cut, source node, sink node.

This paper will implement the graph cut method with python demonstration using OpenCV library and using OpenCV API. Image segmentation in this paper using graph-based algorithm and some modifier to simplify for explain.

II. GRAPH, GRAPH TERMINOLOGY, COMPUTER VISION AND GRAPH-CUT

A.Graphs

A graph G = (V,E) consists of V, that is a nonempty set of verrices and E, that is a set of edges. Each edge has one or two vertices that connected with it. It is called endpoints. The set of vertices V of a graph can be infinite and also edges can be infinite. It is called infinite graph. So that for graph with finite vertex or edges is called finite graph. Graph-cut in this paper use finite graph to representate the structure.

A graph which each edge connect to two different vertices and no other edge connect with the same vertice with other edge it is called simple graph. If any other edge connecting to the same vertice as any the other edge it is called multigraph.

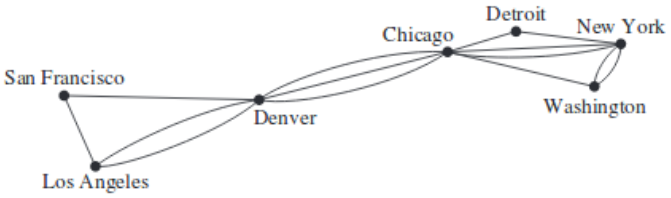


Figure 1. Multigraph, picture from Discrete Mathematics and Its Applications, 7th Ed. - Rosen.

Graph in figure one also an example of undirected graph and then their edge also undirected. There is also a directed graph which definition is a graph called directed graph or digraph (V,E) consists of a nonempty set of V as vertices and a set of directed edges E or (u,v) determine that start from u to v which u and v is vertices.

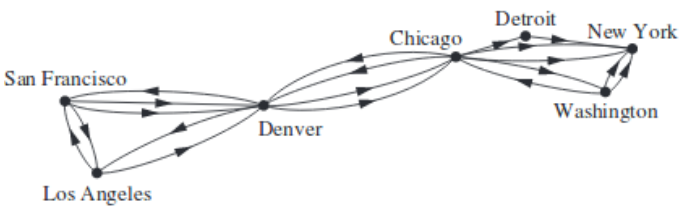


Figure 2. Directed graph, picture from Discrete Mathematics and Its Applications, 7th Ed. - Rosen.

B.GRAPH TERMINOLOGY

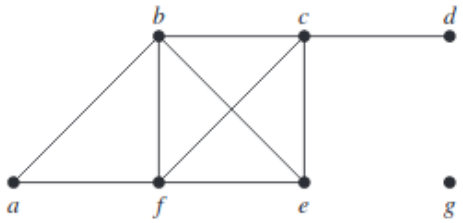


Figure 3. Undirected graph, picture from Discrete Mathematics and Its Applications, 7th Ed. - Rosen.

First is adjacent. Two vertices u and v in an undirected graph G are called adjacent or neighbors if u and v are endpoint of some edge e in G. if that happen then edge e is called incident with vertice u and v. Therefore, u and v is connected. In figure 3 vertices a and b is neighbors. In figure 3 vertices b and f is neighbors. In figure 3 vertices b and e is neighbors. In figure 3 vertices a and f is neighbors. In figure 3 vertices e and c is neighbors. In figure 3 vertices e and f is neighbors. In figure 3 vertices c and d is neighbors. In figure 3 vertices d and g is not neighbors. In figure 3 vertices a and e is not neighbors.

Second is isolated vertex. Isolated vertex is a vertices that no edge incident with that vertices or in other word that vertice doesn't have neighbors. In figure 3 vertice g is a isolated vertex.

Third is null graph or empty graph. A graph G is called null graph or empty graph if there is no edge in G. As examoke in figure 4 that there is no edge incident with vertices A, B, and C.

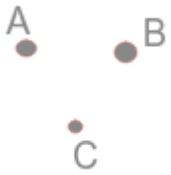


Figure 4 , make by the author

Next terminology is degree. Degree in undirected graph G is the number of degree that incident with the node that we want to know what is the degree. In figure 4, the degree of vertices A, B, and C is zero and in figure 3 the degree of vertices a is two, the degree of vertices b is four, the degree of vertices c is four, the degree of vertices d is one, the degree of vertices e is three, the degree of vertices f is four and the degree of vertices g is zero.

Next terminology is path. Path is collection of vertice and edge that collected from vertices u to vertice v. In figure 5 path from vertice a to c is a e1 b e2 c.

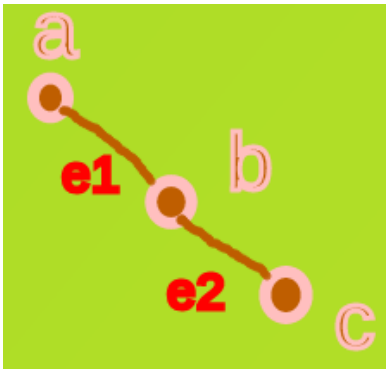
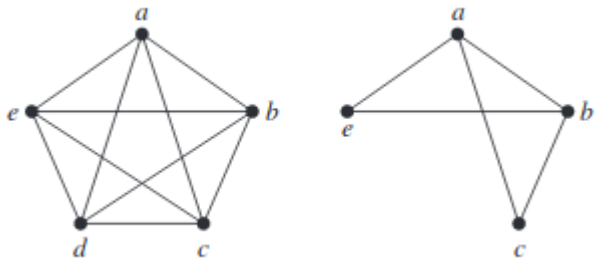


Figure 5
make by the author of this paper

Next terminology is sircuit or cycle. Sircuit or cycle is path that the start vertice and the end vertice is in the same vertice. Graph in figure 3 have sircuit path.

Next terminology is connected. Graph G is connected if each pair of vertices have minimal 1 path. Graph in figure 3 is an example of unconnected graph.

Next terminology for graph is subgraph. If there is graph G = (V,E) then graph G1 = (V1,E1) is subgraph of G if V1⊆V and E1 ⊆ E. In figure 6 graph G1 is a subgraph of graph G.



G G1

Figure 6, G1 is subgraph of G, picture from Discrete Mathematics and Its Applications, 7th Ed. - Rosen.

Last terminology is weighted graph. Weighted graph is a graph where each edges have a value.

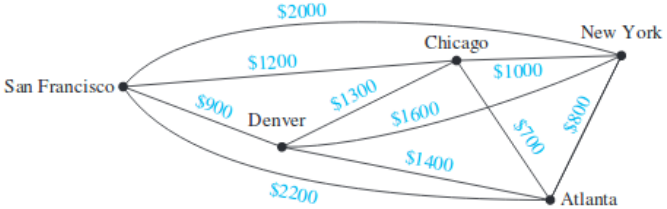


Figure 7, Weighted graph , picture from Discrete Mathematics and Its Applications, 7th Ed. - Rosen.

C. Computer Vision

Computer vision is collection of method to build or construct

meaningful description object from images in explicit form. Computer vision is a field that growing fast in this century. Such as Instagram or snapchat using computer vision as some their products or their services.

Some of application of computer vision are optical character recognition which the function is recognize letter, then the next application is 3D model building or called photogrammetry. Image segmentation, face recognition, smoothing an image and many more.

D. Graph Cut

Graph cut is a technique to separate background and object that we want to separate. Using graph to classificate whether it belong to background or the object that we want to separate.

An image segmentation problem can be have meaning as partitioning into different category such as background and object that we want to separate. Then, the category can become node for graph cut.

A cut of graph is to separate graph G into two disjoint subset of G. In this technique graph cut using weighted graph then after scoring through pixel and classification the we apllied graph cut.

After that, we apply max-flow or min-cut to the graph so that we can separate that iamge.

Figure 8. picture taken from http://www.coe.utah.edu/~cs7640/readings/graph_cuts_intro.pdf 2 December 2017

III. IMAGE SEGMENTATION

A. Idea

The idea was that we consider pixel in reference image as a node in MRF. MRF is Markov Random Field. Idea was that we have 2 nodes that have directed edge to the pixels first is Sink Node and second is source node.

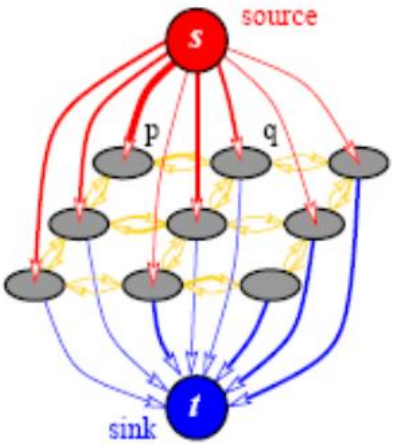


Figure 9 , Picture takenfrom http://www.coe.utah.edu/~cs7640/readings/graph_cuts_intro.pdf 2 December 2017

The goals of this method is to separate between sink and source or in other word is to separate between background and the object that we want to separate.

We use energy function for labelling.

$$A = \{(p, q) \mid p_y = q_y, 0 \leq q_x - p_x < k\}$$

$$E(f) = E_{data}(f) + E_{occ}(f) + E_{smooth}(f)$$

Figure 10 , taken from https://web.stanford.edu/class/ee368/Project_Autumn_1516/Reports/Stevens_Liu.pdf 2 December 2017

- Edata interpreted as the cost of intensity between pixels that correspondence each other
- Eocc is a constant penalty cost
- Esmooth is some constraint keep similarities between neighbors pixel

B.Min-cut Graph

We must construct graph in order to perform graph cut method. The idea was to make source node and sink node or the other word is background node and object node. Then we create directed edge to the pixels from source node or called background node and then create directed graph from sink node or called object node to the pixels. And dont forget to determine its value. Cause we use weighted graph in order to perform minimum cut graph. For node that representate pixel use enery function in figure 10 for labelling This is the rules.

edge	weight	for
(s, a)	$D_{occ}(a)$	$a \in \mathcal{A}^0$
(a, t)	$D_{occ}(a)$	$a \in \mathcal{A}^\alpha$
(a, t)	$D(a) + D_{smooth}(a)$	$a \in \mathcal{A}^0$
(s, a)	$D(a)$	$a \in \mathcal{A}^\alpha$
$(a1,a2)$ $(a2,a1)$	$V_{a1,a2}$	$\{a1,a2\} \in \mathcal{N}$, $a1,a2 \in \tilde{A}$
$(a1, a2)$	∞	$p \in \mathcal{P}, a1 \in \mathcal{A}^0, a2 \in \mathcal{A}^\alpha$ $a1,a2 \in N_p(\tilde{f})$
$(a2, a1)$	C_p	$p \in \mathcal{P}, a1 \in \mathcal{A}^0, a2 \in \mathcal{A}^\alpha$ $a1,a2 \in N_p(\tilde{f})$

Figure 12. Picture taken from https://web.stanford.edu/class/ee368/Project_Autumn_1516/Reports/Stevens_Liu.pdf 2 December 2017

C.Graph Cut in OpenCV Library

In OpenCV there is a function that adopt this method to separate foreground from background. The function is GrabCut. The argument for this function is input image, mask , then the coordinate of rectangular that cover the object that we want to separate, background model array, then foreground model array, interation count and then mode. Furthermore we need numpy library for calculation and matplotlib for showing the result image. This is some simple code below to do graph cut.

```
1 import numpy as np
2 import cv2
3 from matplotlib import pyplot as plt
4 img = cv2.imread('somefiles.jpg')
5 mask = np.zeros(img.shape[:2],np.uint8)
6 bgdModel = np.zeros((1,65),np.float64)
7 fgdModel = np.zeros((1,65),np.float64)
8 rect = (50,50,450,290)
9 cv2.grabCut(img,mask,rect,bgdModel,fgdModel,5,cv2.GC_INIT_WITH_RECT)
10 mask2 = np.where((mask==2)|(mask==0),0,1).astype('uint8')
11 img = img*mask2[:,:,np.newaxis]
12 plt.imshow(img),plt.colorbar(),plt.show()
```

Figure 13, taken by the author at https://docs.opencv.org/trunk/d8/d83/tutorial_py_grabcut.html

First line author import numpy as np object. In the second line import cv2 as cv2 object. Cv2 is a library officially from OpenCV. Numpy library is the basic package for scientific computing with python. Then in the third line, import matplotlib pyplot function from matplotlib library as plt object.

In fourth line author open the image files and store it in img variable. Infifth line, create the mask for grabcut. Then we create background model and foreground model . Then we create array for rectangle. This rectangle cover the object that we want to separate. After that we apply grabcut to img variable.Then we apply mask for img variable . In this code mask will have black color and the last line will show the image that have been processed.

Figure 14 . Before Grab Cut, original messi image from http://www.huffingtonpost.com.au/2017/04/24/lionel-messi-is-still-cool-even-with-a-tarantula-in-his-shorts_a_22052703/

Figure 15. After applying Grab Cut, screenshooted from program by author, original messi image from http://www.huffingtonpost.com.au/2017/04/24/lionel-messi-is-still-cool-even-with-a-tarantula-in-his-shorts_a_22052703/

Looking picture after applying Grab Cut (figure 15) , the hair of our football star Messi from Barcelona is missing. Who like messi without his extraordinary hair? So we need to bring back his hair. But to do that we have to add some touchup line from us. To do that we have to edit again the code and add some extra code and also extra brush to bring back Messi hair. But the code will more complex and the author of this paper will not showing the code cause it is too long.

We will add some touchup line to add information about what is background in the image and what is the object or the foreground.

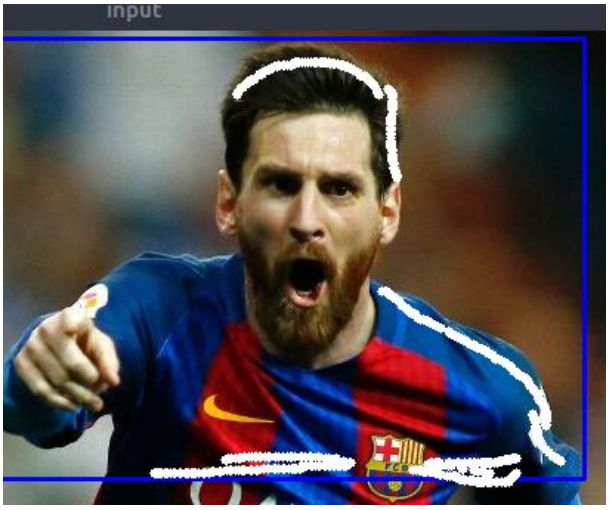


Figure 16 touchup image , original messi image from http://www.huffingtonpost.com.au/2017/04/24/lionel-messi-is-still-cool-even-with-a-tarantula-in-his-shorts_a_22052703/

Figure 17 touchup image after graphcut with grabcut , original image from http://www.huffingtonpost.com.au/2017/04/24/lionel-messi-is-still-cool-even-with-a-tarantula-in-his-shorts_a_22052703/

Now after give some touch up, the hair of Messi can be shown as figure 17.

IV. Some of Application

Image segmentation can useful for many field. Such as image processing, computer vision, Unmanned Aerial Vehicle (UAV) for mapping, Geographic Information System Software, recognizing object, photogrammmetry and many more.

Figure 18 Before and after segmentation UAV-based image , taken from https://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XL-3-W2/261/2015/isprsarchives-XL-3-W2-261-2015.pdf

Figure 18 show before and after segmentation . It can be perform with graph cut but the code will more complex than the code that author shown in figure 13. And will more complex if we perform to classificate and perform 3d modelling. Such as in the Agisoft software or ARCGis.

Many field that use Agisoft software to perform his job such as geological engineering and geodesy and geomatics engineering. In hollywood film, Agisoft can perform 3d face modelling for some actrees or actor.

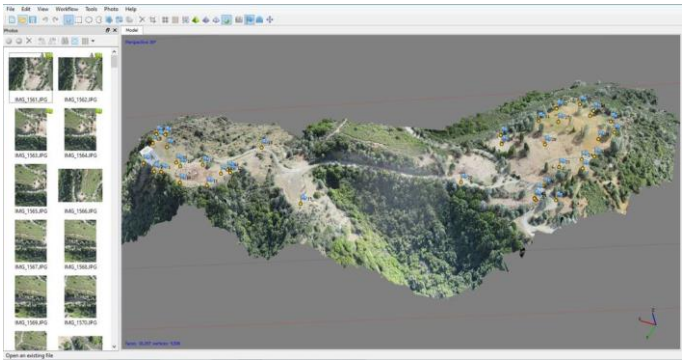


Figure 19 . Agisoft software to reunited image for mapping with Unmanned Aerial Vehicle (UAV), picture taken from https://aerotestra.com/aerialmapping/

Figure 19 show some image combined to make 3D modelling for mapping. At figure 19 many image segmentation performed to build combined and 3D modelling images.

V. Conclusion

Graph cut is a useful technique or algorithm to perform background separation or image segmentation. In many field this algorithm is so useful such as for Unmanned Aerial Vehicle for mapping. Some software use this algorithm to reunited some image to 3d UAV modelling like ARCGis or Agisoft.

VI. Appendix

The author's implementation of some algorithm discussed in this paper can be accessed on https://docs.opencv.org/trunk/d8/d83/tutorial_py_grabcut.html and https://github.com/opencv/opencv/blob/master/samples/python/grabcut.py . It use python programming language and some extra library such as matplotlib, numpy and OpenCV. OpenCV documentation can be accessed on https://docs.opencv.org/trunk/index.html. For numpy documentation library can be accessed on https://docs.scipy.org/doc/ . For matplotlib documentation can be accessed on https://docs.scipy.org/doc/.

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PERNYATAAN

Dengan ini saya menyatakan bahwa makalah yang saya tulis ini adalah tulisan saya sendiri, bukan saduran, atau terjemahan dari makalah orang lain, dan bukan plagiasi.

Bandung, 3 Desember 2017

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