IMAGE SEGMENTATION BASED ON GRAPH CUT TECHNIQUE

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CERTIFICATE

This is to certify that the work in the thesis entitled study of “Image Segmentation Based on Graph cut technique” by S.Vamsi (108CS079) is a record of an original research work carried out by him under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Computer Science and Engineering during the session 2011-2012 in the department of Computer Science and Engineering, National Institute of Technology Rourkela. Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

NIT Rourkela
14 May 2012

Prof. R.Baliarsingh
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CONTENTS

List of Figures

ABSTRACT

Image segmentation is an important image processing technique which is used to analyze what is inside the image. Image segmentation is used to separate an image into several “meaningful” parts. It is an old research topic, which started around 1970, but there is still no robust solution toward it. There are two main reasons, the first is that the content variety of images is too large, and the second one is that there is no benchmark standard to judge the performance. In this project we develop a novel based approach to segment the image in a more better way.in this project we use the Ohta color model instead of RGB color model to get a better segmented image.

Graph cut algorithms are successfully applied to a wide range of problems in vision and graphics. Here we used this graph cut technique to solve the image segmentation problem. And we got successful results in partitioning an in image. In this project we use the normalized cut technique to do the segmentation of an image .in this method we use an efficient computational technique based on the eigenvalues and eigenvectors to get an optimized segmented image. We have applied this approach to segment the static images.

1. INTRODUCTION:

1.1 SEGMENTATION

We all know that every image is a set of pixels. And partitioning those pixels on the basis of the similar characteristics they have is called segmentation dividing an image into sub partitions on the basis of some similar characteristics like color, intensity and texture is called image segmentation. The goal of segmentation is to change the representation of an image into something more meaningful and easier to analyze. Image segmentation is normally used to locate objects and boundaries that is lines, curves, etc. in images.

In image segmentation image is divided into some regions and in that region each pixel is similar with respect to some of the characteristic such as the color, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristic(s).

Segmentation can be done by detecting edges or points or line in the image. When we detect the points in an image then on the basis of similarities between any two points we can make them into separate regions. And in the case of the line detection technique we use to detect all the lines and the similarities in between those lines then on the basis of the dissimilarities between the lines or curves in the image we can divide the image into two regions. And in the case of edge detection we detect the edges in the image and after finding the edges in the image we can easily divide the image and here we can easily analyze what is inside the image and we can get a better segmented image. even it is the old technique to segment the image now a days these segmentation technique is used to segment the image.

We can segment the image by using many techniques but only some techniques gives the better results in image segmentation. Some of the image segmentation techniques won't work for all the images. So till now there are many methods to solve

these image segmentation problem. This image segmentation started in 1970 and till now there is no robust and efficient segmentation technique to solve the image segmentation problem.

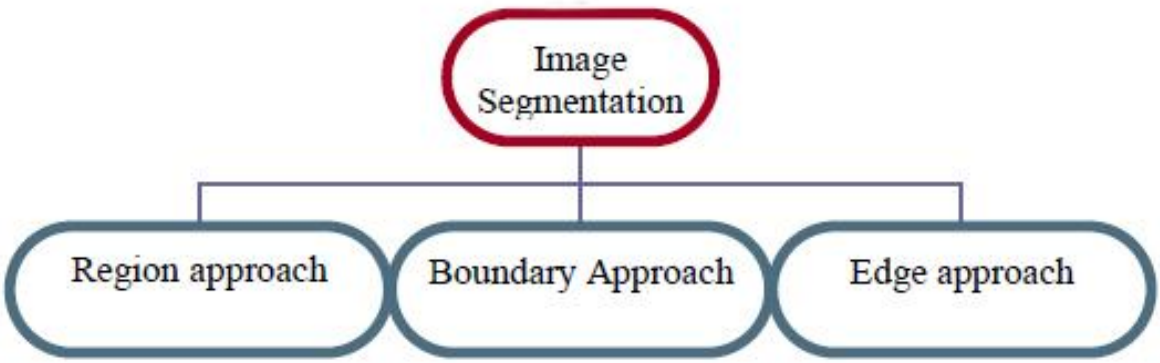
In this project we use the graph cut technique to solve the segmentation problem. here we represent the image in the format of the graph that means it will contain the vertices and the edges like a graph .and here each vertices or a node can be taken as the pixels of the image and the color or intensity difference between any two pixels can be taken as the edge. And whenever there is a week edge in between the graph or the image then we cut that part. if the cutting the part of the graph is more than it is called maximum cut and we can call it minimum cut if the cut is small when compared to other cuts in the image. Here we use the minimum cut method to solve the segmentation problem and we didn't get the better segmented image. Because there are some of the discontinuities are there in the case of the minimum cut technique. Because it cuts all the pixels even if there are similarities in the image. So here we go for the normalized cut method in which we use the eigenvalues and the eigenvectors to solve the image segmentation problem. In this normalized cut method we use the eigenvector of the second smallest eigenvalue. And on the basis of the eigenvector we divide the image into two parts and if it is necessary we can cut the graph which divided into two parts by taking any part of the above divided image. we apply the same technique above applied and by this we can get a more segmented image.

Why we use segmentation?

Image segmentation is to segment the image into multiple parts. It is useful everywhere whenever we want to analyze what is inside an image. For example, if we want to find if there is a chair or dog inside an indoor image, we need image segmentation technique to separate the objects in the image and analyze each object individually to check what it is…as we already know that because of image

segmentation we can identify the diseases in medical imaging and also in many applications like face detection, iris detection, fingerprint recognition and also in brake light detection technique also we used this image segmentation technique.

In image segmentation each technique has its own advantages and also disadvantages, so it's hard to tell which one is better in all the techniques. There are many previous works about the image segmentation, great survey resources could be found from these surveys, we can separate the image segmentation techniques into three different classes. They are,



There are many no of image segmentation techniques that are developed to segment the image in a better way.

- Image segmentation algorithms are developed based on two basic properties of intensity values:

- Discontinuity based
- Similarity based

- **Discontinuity based**

  In **discontinuity** based approach the partition is done based on some abrupt changes in gray level intensity of the image.

  - Detection of Isolated Points
  - Detection of Lines
  - Edge Detection

- **Similarity based**

  In **similarity** based approach segmentation is done based on grouping of pixels based on some features.

  - Thresholding
  - Region growing
  - Region Splitting and Merging
  - Clustering
  - K–Means Clustering
  - Fuzzy C Means Clustering

1.1.1 DISCONTINUITY BASED SEGMENTATION:

The focus of this section is on segmentation methods that are based on detecting sharp, local changes in intensity. The three types of image features in which we are interested are points, edges and lines. Pixels at which the intensity of an image function changes suddenly are called edge pixels, and edges (or edge segments) are sets of connected edge pixels. Edge detectors are like local image processing methods and are used to designed in detecting edge pixels. A line may be viewed as an edge segment in which the intensity of the background on either side of the line is either much higher or much lower than the intensity of the line pixels

In discontinuity based segmentation there are 3 types of discontinuity…

- **Points**

  An isolated point may be viewed as a line whose length and width are equal to one pixel. Isolated points in an image are those points which have abruptly different gray values than those of its surrounding pixels. A mask is utilized for point detection and involves highlighting the gray value difference.

- **Lines**

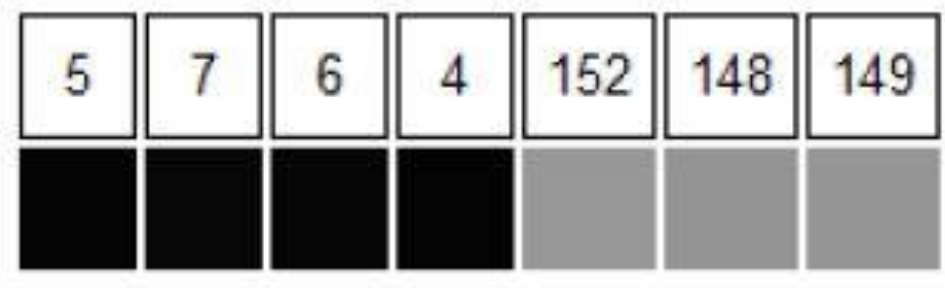
  Line may be embedded inside a single uniformly homogeneous region.
  In the lines we can segment the image on the basis of lines in the image.

- **Edge**

  Pixels at which the intensity of an image changes abruptly are called edge pixels. Edges are set of connected edge pixels. An edge essentially demarcates between two distinctly different regions.

- It is the most common approach for detection of gray level discontinuity in an image.

- We can find out the edge in an image if there is any large intensity difference between any two pixels.



Large intensity difference between the 4th and 5th pixel indicates an edge

Image discontinuities are mostly measured by using a squared mask. And here the mask is moved over the entire image and it will find out the discontinuities in the image so here by using this we can easily segment the image into multiple segments There are many edge detection techniques to segment an image.

Three types were presented:

- Based on the first-order derivative
    - Prewitt and Sobel
- Based on the second-order derivative
    - Laplacian of Gaussian
- Based on the groups of edges
    - Canny

In the above stated all edge detection techniques Canny edge detection technique is widely used technique and it gives better segmented image when compared to the other edge detection techniques. In this method first we remove the noise from the image and then we will apply Thresholding and non-maximum suppression to suppress the pixels in the image which are not edges.

1.1.2 SIMILARITY BASED SEGMENTATION

In **similarity** based approach segmentation is done based on grouping of pixels based on some features.

Thresholding:

This is the simplest method in all the segmentation methods. the method is based on a threshold value to turn a gray scale image into binary image.

Histogram based method:

When compared to other image segmentation methods histogram-based methods typically require only one pass through the pixels so we can tell these are very efficient because they. In this technique, a histogram is computed from all of the pixels in the image,

Clustering method:

The k-means algorithm is an iterative technique that is used to partition the image into *K* clusters. Clustering based image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics. In cluster oriented segmentation partition the image pixels into clusters. It uses the multi-dimensional data to do this. Cluster-oriented technique is a better technique than histogram-oriented one in segmenting an image, where each pixel has several attributes and is represented by a vector.

Region Based Segmentation

Homogeneity property of the image regions are used to segment the image in the segmentation process. The concept of region based image segmentation is to maximize homogeneity in each segmented regions. Homogeneity criteria can be based

on the gray level and color texture of the image. Selection of proper homogeneity criteria is most important and influence segmentation performance. Region based image segmentation can be classified as,

- Region Growing
- Region Splitting and Merging

1.2 Applications of segmentation:

- Image segmentation is mainly used in Medical imaging
  - In locating tumors and other pathologies
  - In measuring tissue volumes
  - In computer-guided surgery
  - In diagnosing a disease
  - In treatment planning
  - In study of anatomical structure
- To locate objects in the satellite images.
- Face recognition

  A facial recognition system is a computer application for identifying or verifying a person from a digital image or a video frame from a video source automatically. We can use this technique by comparing the selected facial features from the image and a facial database.

  In security systems we can use this face recognition technique to identify the thieves or any security related work. And can be compared to other biometrics such as fingerprint or eye iris recognition systems

- Iris recognition

  Iris recognition is method of biometric identification that uses the mathematical pattern-recognition techniques on video images of the iris of an individual's eyes, whose complex random patterns are unique and can be seen from some distance.

- Fingerprint recognition

  It refers to an automated method of verifying a match between two or more human fingerprints. Fingerprints are mainly used in identifying individuals and verify their identify .

- Traffic control systems
- Brake light detection
- Machine vision

  Image segmentation is a prerequisite for most of the machine vision application or for image analysis. Success of the machine vision applications is highly dependent on the success of the autonomous segmentation of images. Every machine vision application should have a support of robust segmentation algorithm.

- Agricultural imaging – in detecting the crop disease

2. COLOR MODELS

Several color models have been developed for specifying color. A few of the more important color systems are described below. In this project we used the RGB color model and Ohta color model.

2.1 RGB COLOR SPACES

It is one of the color space that is most commonly used in the many ways to represent an image. It is normally represented in a 3 dimensional cube. The coordinates of each point inside the cube represent the values of red, green and blue. Choosing the RGB color space is the most prevalent choice for computer graphics because by using the colors Red, Green and Blue we can get any desired color of our own so it is mostly used in the computer graphics to represent any type of images. The RGB color space simplifies any type of architecture or design of the system. But as far as we concerned about image segmentation this RGB color space couldn't give the better segmented image because of the correlation property it has. And also it is impossible to find out the similarities between two colors from their distance in the RGB space. And in this RGB color space there is another disadvantage is that non uniform perception in the three color panes

2.2 OHTA COLOR SPACE

This color space also known as I1, I2, I3. This Ohta color space derived from the color planes of the RGB color space. We can get the values of the I1, I2, I3 values from the R,G,B values. In ohta color space there is no correlation in between the three color planes so when we segment the image which is in the format of ohta color space the we can get a better segmented image.

When we compare the Ohta color space with other color space it has been found that Ohta color space is more effective than the other color spaces in the terms of quality of segmentation and the time taken to complete the complexity.

2.3 LIMITATIONS OF RGB COLOR MODEL

1. There is a high correlation among the three color planes. That means there is a high dependency in between the three planes of the rgb color model . if we reduce the dependency in between the three color planes then we can get a better segmented image.
2. Perceptual non-uniformity is there in the RGB color model.

2.4 RGB COLOR TO OHTA COLOR SPACE

To overcome the above problems Ohta *et al* (1979) developed a model called Ohta color model. It reduces the amount of correlation between three planes Here we are converting RGB color to Ohta color model to overcome the limitations in the RGB color model. To convert the attributes of image pixel from RGB to Ohta conversion we need to use the following formulae.

$$I_1 = \frac{R+G+B}{3}$$
$$I_2 = R-B$$
$$I_3 = \frac{2G-R-B}{2}$$

In this Ohta color model we can overcome the limitations of the RGB model and there is no such correlation in between the three color planes.so here we can get a more and better segmented image

3. GRAPH CUT

By applying the graph cut technique we can easily and efficiently solve a wide variety of low-level computer vision problems, such as image smoothing and many other computer vision problems and and the stereo correspondence problem, can be solved in terms of energy minimization. We can solve binary problems exactly using this approach; here problems where pixels can be labeled with more than two different labels (such as stereo correspondence, of a grayscale image) cannot be solved exactly, but here we can get the optimum solution to the problem.

In the graph cut technique we represent the image in the form of graphs. That means containing nodes and vertices like a graph. So here we represent the each pixel as a node and the distance between those nodes as the edges. We can calculate the distance between the nodes by using the attributes of the Ohta color model.

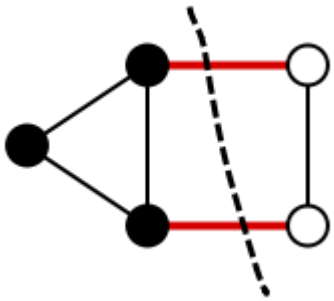
In graph theory, a cut is a partition of the nodes that divides the graph into two disjoint subsets. The set of cuts of the cut is the set of edges whose ending points are in different subsets of the divided region. If edges are in its cut-set then they are said to be crossing the cut.

In an un-weighted undirected graph, we can say that the weight or size of a cut is the number of edges that are crossing the cut in an image. And in the case of a weighted graph, it is defined as the sum of the weights of all the edges crossing the cut.

The basic cuts in the graph theory are minimum cut and maximum cut.

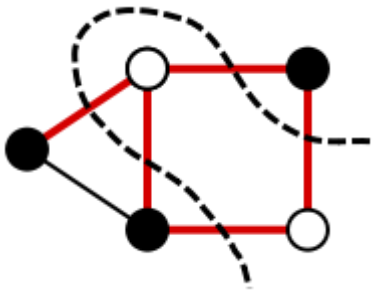
3.1 MINIMUM CUT

In the minimum cut technique the size of the cut is not larger than the size of the any other cut. The figure showed in the below shows a minimum cut: Here the cut size is 2, and there is no cut of size 1 because the graph is bridgeless.



3.2 MAXIMUM CUT

A cut is maximum if the size of the cut is not smaller than the size of any other cut in the image. In the below figure that shows a maximum cut: the size of the cut is equal to 5. In general, finding a maximum cut in an image is computationally hard.

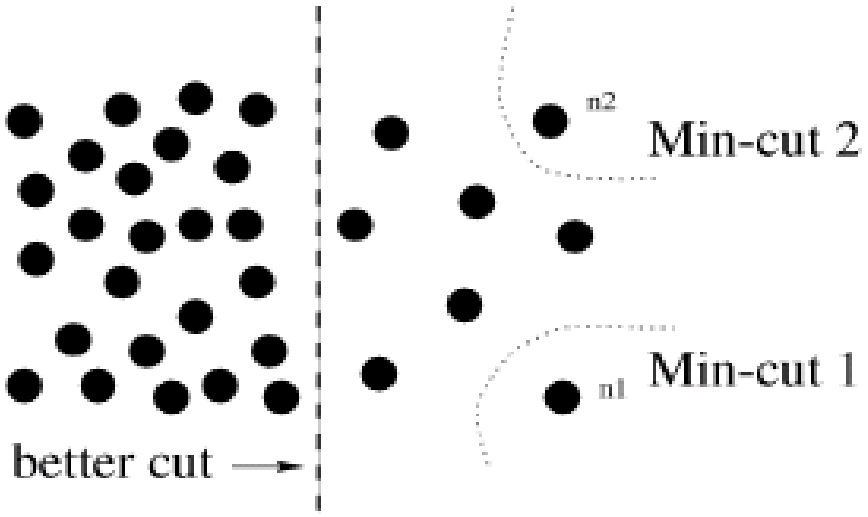


3.3 LIMITATIONS IN MINIMUM CUT

Wu and Leahy proposed a clustering method based on this minimum cut criterion. In the minimum curt technique we need to segment each and every pixel of an image. That means in this technique we need to cut each pixel in an image even if those

pixels are similar with respect to color or intensity or texture. So in this minimum cut technique we couldn't get a better segmented image when compared to the other techniques so here we use the normalized cut method to segment the image. In particular, they want 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.

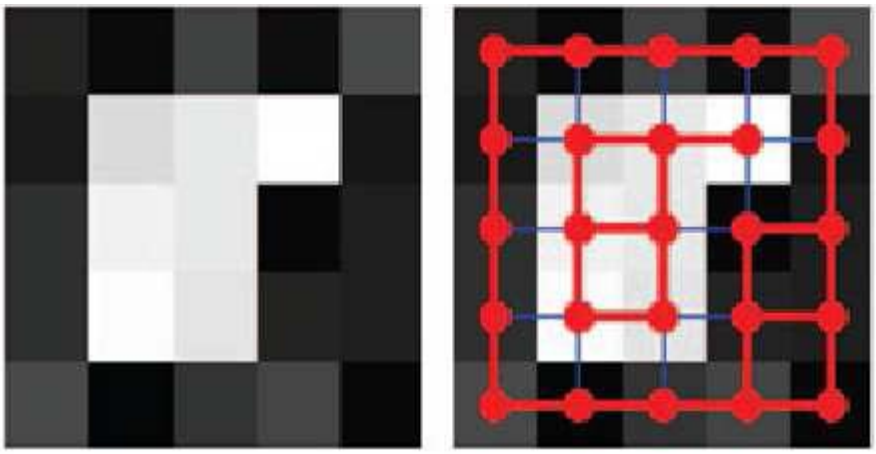
the minimum cut criteria favors cutting small sets of isolated nodes in the graph Assuming the edge weights are inversely proportional to the distance between the two nodes, we see the cut that partitions out node n1 or n2 will have a very small value. In fact, any cut that partitions out individual nodes on the right half will have smaller cut value than the cut that partitions the nodes into the left and right halves. In minimized cut technique we couldn't avoid the unnatural bias for cutting small set of points. To avoid this unnatural bias for partitioning out small sets of points, we propose a new measure of disassociation



A case where minimum cut gives a bad partition.

3.4 NORMALIZED CUT

The normalized cut method was proposed by J. Malik and J. Shi. In their view, the image segmentation problem can be seen as a graph theory problem. Graph theory is an interesting math topic which models math problems into edges and vertexes. Here we represent the each pixel as a vertex or node and the distance between those nodes as the edges. This model could be used for coloring problems (give each county a color, while connected county should have different colors. Each edge in the model could contain a value (weight), which could be used as flow or importance of it. This kind of graph is called “weighted graph.



In the above two images first image is the original image and the second one is represented in the form of graph. Here images in the pixels are represented as the as the nodes and the difference between the I1, I2, I3 are called the edges of the image. In the above image thick edges represent the strong similarities between two pixels and thin edges represent the week similarities between two pixels. And in graph cut technique we cut the image where there are week similarities in between two pixels.

This is a connected graph because each pixel could go through the edges to reach all other pixels else. The term “cut” refers to eliminating a set of edges in an image to make the graph “unconnected”, and the value of the cut is the total weights on this set of edges. For example, if we eliminate all the thick edges in the above figure, then the nodes with white color will be “unconnected” to the nodes with dark color, and now we say the graph has been separate into two connected graph So, from the graph theory, the image segmentation problem is modeled as graph cut problem. The weights on edges have the similarity meaning between pixels, so if we want to divide two pixels into two different regions, their similarity is expected to be very small.

4. IMPLEMENTATION

4.1 Formula for Finding Normalized Cut

A graph G= (V, E) can be partitioned into two disjoint sets, A, B, A U B = V, A ∩B =Φ, by simply removing edges connecting the two parts. Weight of an edge can be calculated as the similarities between two nodes in a graph so, if there are no similarities in between two nodes then we can cut that edge this is called graph cut.

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

The ***normalized cut*** then could be defined as:

$$N_{cut}(A, B) = \frac{\text{cut}(A,B)}{\text{asso}(A,V)} + \frac{\text{cut}(A,B)}{\text{asso}(B,V)}$$

Here,

$cut(A, B)$ Sum of all the edge weights associated with the cut

$assoc(A, V)$ sum of all the edge weights associated with the cut and all the points in the graph.

Where asso(B, V)=$\Sigma_{u \epsilon A, t \epsilon V}$ W(u, t) is the total connection from nodes in B to all nodes in the graph, and asso(A, V) is similarly defined. In the same way, we can define a value for the total normalized association within groups (a measure for similarities inside each group) for a given partition of the image.

Assume now we want to separate an image V with size M-by-N into two parts, we need to define two matrices: ***W*** and ***D***, both of size (MN)-by-(MN). The matrix ***W*** is the similarity matrix with element $w_{i,j}$ as the similarity between the i^{th} pixel and the j^{th} pixel. The matrix ***D*** is a diagonal matrix and each diagonal element d_i contains the sum of all the elements in the i th row in ***W***. With these two matrices, finding the minimum normalized cut of image V into two parts A and B is equal to solve the equation as followed:

$$\min N_{cut} = \min_y \frac{y^T(D-W)y}{y^T D y}$$

where y is an (M by N) vector with each element indicating the attribute of each pixel into the two groups. In the above equation if y has all the real values then above equation is further simplified into a general eigenvector problem solved.

$$(D - W)y = \lambda D y$$

The eigenvector y with the second smallest eigenvalue is selected for the image segmentation. If the element values in y has all real numbers, On the basis of the eigenvector by taking the signs into consideration we can divide the image into segments.

Here we are taking the eigenvector of the second smallest eigenvalue because in the above equation while solving the equation we will get

$$y_1 = arg.min_{y^T D 1 = 0} \frac{y^T(D - W)y}{y^T D y}.$$

So here if we want to minimize the value of y1 then we can automatically minimize the value of N-cut. and if we want to minimize the y1 value we need to minimize the value of ($y^t y / y^t Dy$). for that we need to use the second minimized eigenvalue then on the basis of that second smallest eigenvalue we need to take the eigenvector.

4.2 WEIGHT MATRIX

We need to find the weight matrix to find out the eigenvalues and eigenvectors. We can find out the weight matrix by using the attributes of the ohta color model. That is we need to use the I1, I2, I3 values.

Here is the formula for the weight function:

$$W(i,j) = e^{\frac{-\left\| X_{(i)} - X_{(j)} \right\|_2^2}{\sigma_X^2}}$$

Where X_i and X_j are the Ohta attributes of two pixels.

If $I_{11,}$ I_{12} ,I_{13} are the three attribute of the first pixel and $I_{21,}$ $I_{22,}$ I_{23} are the three attributes of the second pixel then we can find out the weight between by finding the norm of the Xi-Xj that is ..

$$X_i - X_j = (I_{11} - I_{21})^2 + (I_{12} - I_{22})^2 + (I_{13} - I_{23})^2$$

And we already know that we can find the norm of the x1 ,x2,x3 as sqrt(x12+x22+x32)

Here, σ Is the scaling factor, that determines the sensitivity of the weight function

After finding the weight matrices for all the edges in an image we need to represent all the weights of the image into a matrix. And that is called the weight matrix.

4.3 DIAGONAL MATRIX:

After find out the weight matrix we need to find the diagonal matrix. For that we need to add each row in the weight matrix and then by presenting them in a single column we can get the diagonal values. These values are presented in a diagonal form of a matrix with remaining all elements as zeros. Then we can get a diagonal matrix. The formula for this is

$$D(i) = \sum_{j} w(i, j)$$

Then by using matrices D and W we can find the eigenvalues and eigenvectors. By using the following formula we can find out those eigenvalues and eigenvectors.

$$(\mathrm{D} - \mathrm{W})\mathrm{y} = \lambda \mathrm{D}\mathrm{y}$$

Then, after find out the eigenvectors we need to take the eigenvector of the second smallest eigenvalue to divide the region. On the basis of the eigenvectors based on the sign we can divide it into two regions. That means the pixels containing the same sign need to be in the same region and all the pixels with different signs (-ve) need to be in different region.

4.3 ALGORITHM

1. **Conversion of RGB color space to OHTA color space.**

   When we convert the image from RGB to Ohta color model we can get a better segmented image.

2. **Compute matrices Weight & Diagonal (W & D)**

   In the normalized cut method we use eigenvalues and eigenvectors to find out the cut in the graph that means to find out the week edges in the image.

3. **Solve the equation for getting eigenvectors and smallest eigenvalues.**

   From the equation above stated we can find out the eigenvalues and eigenvectors.

4. **Use the eigenvector with the second smallest eigenvalue to bipartition the graph.**

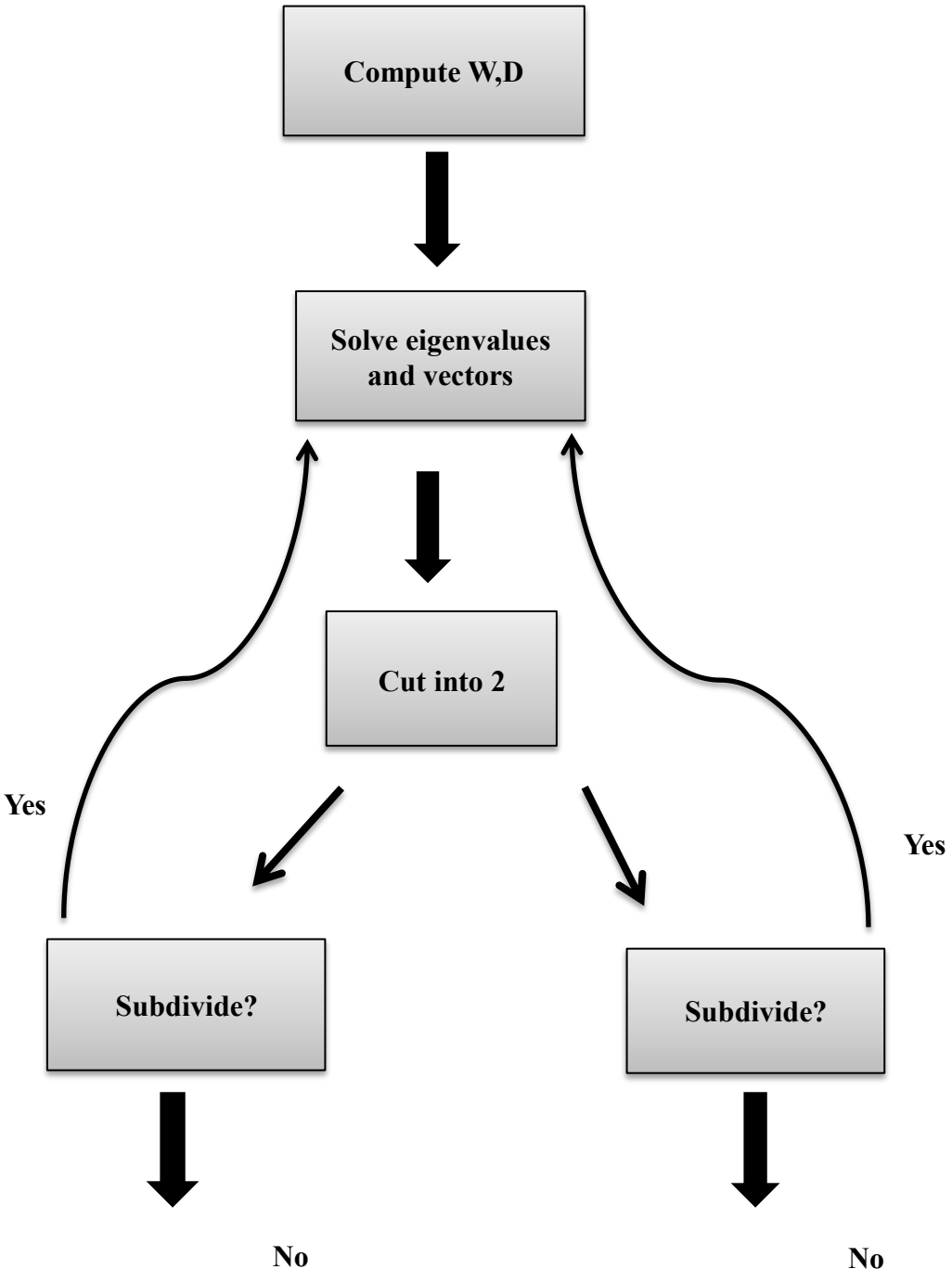
   Here to bipartition the image we need to use the eigenvector of the second smallest eigenvalue. The reason for this to use the second smallest is we need to minimize the Rayleigh quotient so that we can minimize the normalized cut.

5. **Recursively partition the segmented parts if it is necessary.**

   After we cut the graph by using normalized cut method we need to cut the two parts of the image if it is necessary to cut.

4.4 FLOW DIAGRAM

Here is the pipeline for the image segmentation steps carried out in this project

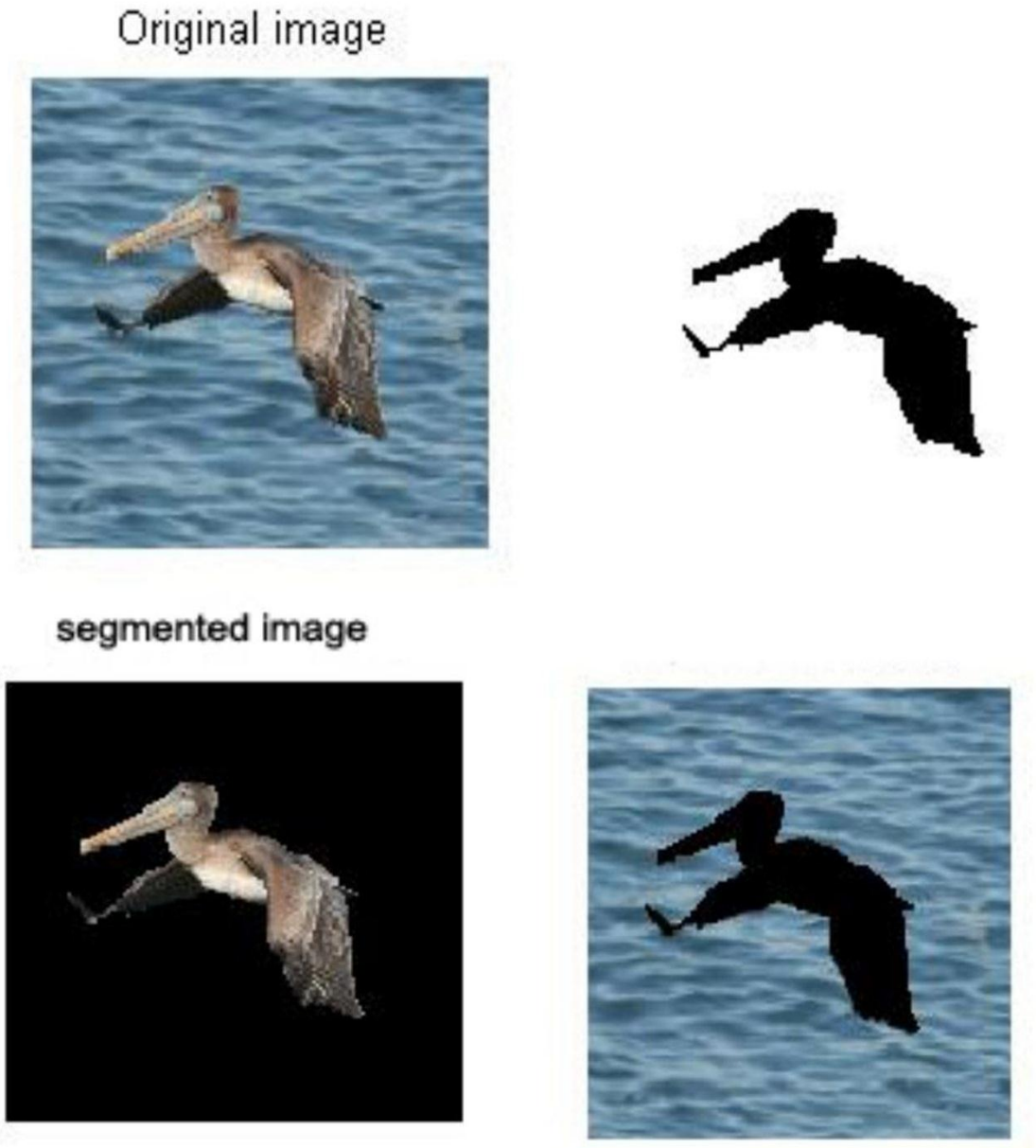


Form the above pipeline it is clear that first we need to find out the weight between all the pixels in the image then from that weight functions we need to create a weight matrix. From that weight matrix we can calculate the diagonal elements of the diagonal matrix by just simply adding the each row in the weight matrix. And then we need to enter those elements in the diagonal position then we can get the diagonal matrix. Then from the weight matrix and the diagonal matrix we need to find out the laplacian matrix just by doing W-D.

For that laplacian matrix we need to find out the eigenvalues and eigenvectors. And then by taking the eigenvector values of the second smallest eigenvalues we can divide the image into two parts, on the basis of the sign this eigenvector contains. Then after dividing the image into two parts we can apply the same procedure to the segmented part. Then we can get a better segmented image.

5 RESULTS

5.1 Segmented image -1



5.2 Segmented image-2

Original image

segmented image

CONCLUSION:

- Here we used the Graph cut technique to segment the image. here we represent the image in the form of graph. taking the advantage of the Ohta (I_1,I_2,I_3) feature space we segmented the image using N cut method. Here, we overcome the correlation property of the image so, we got a better segmented image.

FUTURE WORK:

- Here in the N-cut method of pixel based technique time complexity is more.so it will take more time to compute the segmentation. To overcome this problem we can work on normalized cut method using region based technique. In this N-cut method applying to the resulting segments rather than directly to the image pixels, yields better image segmentation performance. Region based N-cut requires lower computational complexity compared to pixel based Normalized cut. And also it gives a better segmented image when compared to the pixel based normalized cut method.

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