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Hybrid Image Segmentation Method Based on Global Thresholding Method and Edge Detection using Canny Operator

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Abstract

This paper presents a hybrid image segmentation technique based on edge detection and global thresholding methods. The segmentation process is simplified and becomes very fast due to applying the proposed method to discontinuous relationship between image pixels called edge pixels instead of whole pixels. Also, Our method is robust for selecting the initial estimate of threshold value depends on the similar relationship between pixels. The proposed method begins by applying edge-based segmentation by splitting the object using canny operator and merging the lines or edge linking using Hough transform. The resulted image will be binary image and represent the object that was separated from its background. Then intensity-based segmentation method is applied by partitioning the image histogram using global thresholding technique. The performance of the proposed method is illustrated using acquired images from a range of different shapes and compared with proposed methods.
Keywords: Canny Edge detection; Hugh Transform; Global thresholding.

المستخلص:

يعرض هذا البحث تقنية هجينة لتجزئة الصور بالاعتماد على طريقة الكشف عن الحواف وطريقة مستوى العتبة العالمية. اصبحت عملية التجزئة للصور بسيطة وسريعة جدا وذلك بسبب تطبيق الطريقة المقترحة على بكسلات الصورة ذات العلاقة الغير مستمرة بدلا من تطبيقها على كل بكسلات الصورة بدون استثناء. أيضا عرض البحث طريقة قوية لتحديد التقديرات الأولية والنهائية لقيمة العتبة العالمية يعتمد على علاقة التماثل بين بكسلات الصورة. تبدأ الطريقة المقترحة من خلال تنفيذ خوارزمية Canny edge detection لغرض تحديد حواف صورة الاختبار ثم تطبيق تحويل Hough لغرض ربط الحواف المتجاورة والحصول على خط مستقيم. الصورة الناتجة تكون صورة ثنائية وتمثل صورة الكائن الذي تم فصلها عن خلفيتها. المرحلة الاخيرة تتضمن تطبيق خوارزمية مستوى العتبة العالمية بالاعتماد على الرسم البياني للصورة والتي تعتمد على بكسلات الصورة ذات العلاقة المتشابهة . ويتضح أداء الطريقة المقترحة باستخدام صور تم الحصول عليها من مجموعة من الأشكال المختلفة، وبالمقارنة مع الطرق المعمول بها في البحث.

1. Introduction

The objective of image Segmentation in computer vision, is to partition the digital image into its fundamental parts, objects or homogeneous regions. These regions share common characteristics based on color , intensity, texture, etc. Depending on the type of patterns that a task is interested [1].Image segmentation is an essential process for most image analysis algorithms. In particular, many of the existing techniques for image description and recognition, image visualization , and object based image compression [2]. Image Segmentation algorithms can be broadly based on one of the following basic intensity values:

- Discontinuity : partition an image based on a smooth changes in intensity such as boundaries, shape features, textures. Isolated points and lines and edges in an image can therefore be detected..
- Similarity : based on partitioning an image into regions that are similar according to a set of predefined criteria, thresholding, region growing, and region splitting and merging are examples in this category [3].

Some of the practical applications of image segmentation are:

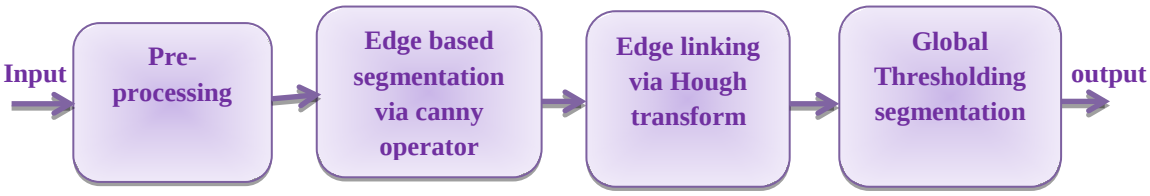
- Medical Imaging.
  - Locate tumors and other pathologies.
  - Computer-guided surgery.

- Diagnosis.
- Locate objects in satellite images (roads, forests, etc.)
- Face recognition
- Fingerprint recognition
- Traffic control systems
- Brake light detection [4]

In this paper hybrid edge detection using canny operator and global thresholding methods are used in gray scale image segmentation. The canny edge detector is first smooth the image to eliminate gradient to highlight regions with high spatial derivatives. The algorithm then tracks along these regions and suppresses any pixel that is not at the maximum (non-maximum suppression) [5]. The gradient array is now further reduce remaining pixels that have not been suppressed. Hysteresis uses two thresholds and if the magnitude is below the first threshold, it is set to zero (made a non-edge). If the magnitude is above the high threshold, it is made an edge. And if the magnitude is between the two thresholds, then it is set to zero unless there is a path from this pixel to a pixel with a gradient above second threshold. Edges linking by using Hough line transformation is necessary to link the edges and identify the locations and orientations of certain types of features in a digital image [6]. A global threshold is applied to robust segmentation technique, Any point which gradient greater than threshold value is called an object point; otherwise, the point is called background point[7]. The contents of this paper is organized as follows: in section 2 the description of the proposed algorithm are provided, in section3 the experimental results are presented and discussed. Finally, conclusion is given in section 4.

2. The Proposed Segmentation Algorithm

In this section, we present an overview of the proposed algorithm. The block diagram of it is depicted in figure(1). The first stage is preprocessing to convert colored image to gray scale image then remove as much noise as possible using Gaussian derivatives. Secondly detect the edges for the gray image using a stable and reliable edge detector called canny operator. Finally, Segmentation methods that combining edge detection with thresholding are presented.



Figure(1) block diagram of proposed image segmentation algorithm

2-1 Convert RGB Image to Grayscale Image

grayscale images are denoted as monochrome or one color images. This means they contain brightness information only. The number of bit used for each pixel determines the number of different brightness level available. The typical image contains 8 bits for each pixel data, which allows us to have 256(0-255) different brightness (gray) levels. Grayscale algorithms utilize the basic three-steps [6].

Step1: Get the red, green, and blue values of a pixel.

Step2: Use fancy math to turn those numbers into a single gray value using equation (1).

Gray = (0.2989 * Red + 0.5870 * Green + 0.1140 * Blue)---------- (1)

Step3: Replace the original red, green, and blue values with the new gray value.

2-2 Edge Based Segmentation Via Canny Operator

Edge detection refers to the process of identifying and locating sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity which characterize boundaries of an object in image. The purpose of edge detection in general is to considerably reduce the amount of data in

an image, while preserving the structural properties to be used for further image processing. There is very large number of edge detection operators available, and this paper focuses on canny method [7]. It is regarded as one of the best edge detectors in computer vision and after 20 years still known to many as the optimal edge detector with regard to the following criteria:

- Minimizing multiple responses to a single edge. It is important that edges occurring in images should not be missed and that there be no responses to non-edges.
- Maximizing the signal-to-noise ratio of the gradient.
- An edge localization factor. In other words, the distance between the edge pixels as found by the detector and the actual edge is to be at a minimum. Based on these criteria, The steps of Canny algorithm depicted in figure(4) and are as follow [11].

Step1 Pre-Smoothing:

Is to decrease the influence of noise in the original image taken by camera before trying to locate and detect any edges. To prevent that noise is mistaken for edges by convolving the image with the Gaussian filter. The convolution mask of a Gaussian filter with a standard deviation of σ = 1.4 is shown in figure(2).

$\frac{1}{115}$

2	4	5	4	2
4	9	12	9	4
5	12	15	12	5
4	9	12	9	4
2	4	5	4	2

figure(2)discrete approximation to Gaussian function

Step2 Finding gradients: After eliminating the noise from grayscale image, the next step is to find gradients has large magnitudes of the image. The Sobel operator performs spatial gradient measurement on an image in both the vertical and horizontal directions by feeding the smoothed image through a convolution operation with Sobel operator that uses a pair of 3x3 convolution masks, one estimating the gradient in the x-direction (columns) and the other estimating the gradient in the y-direction (rows) [10]. They are shown in figure (3).

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gv

figure(3) vertical and horizontal mask of Sobel operator

The gradient magnitudes (also known as the edge strengths) can then be determined as an Euclidean distance measure as shown in Equation (2).

$$G = \sqrt{Gx^2 + Gy^2} \qquad \text{----------(2)}$$

where:

Gx and Gy are the gradients in the x- and y-directions respectively.

Then the direction of the edge(Theta) is computed using the gradient in the x and y directions using equation(3).

Theta = atan (Gy / Gx) ----------(3)

When the edge direction is compute, the next step is to relate the edge direction to a direction that can be traced in an image. So if the pixels of a [5 X 5] image are aligned as follows:

x x x x x
x x x x x
x x a x x
x x x x x

Then, by looking at the center pixel "a", there are four possible directions when describing the surrounding pixels - 0 degrees (in the horizontal direction), 45 degrees (along the positive diagonal), 90 degrees (in the vertical direction), or 135 degrees (along the negative diagonal), 180 degrees region is just an mirror region of 0 degrees region. Therefore, any edge direction falling within the yellow range (0 to 22.5 & 157.5 to 180 degrees) is set to 0 degrees [9]. Any edge direction falling in the green range (22.5 to 67.5 degrees) is set to 45 degrees. Any edge direction falling in the blue range (67.5 to 112.5 degrees) is set to 90 degrees. And finally, any edge direction falling within the red range (112.5 to 157.5 degrees) is set to 135 degrees [11].

Step3 Non-maximum suppression:

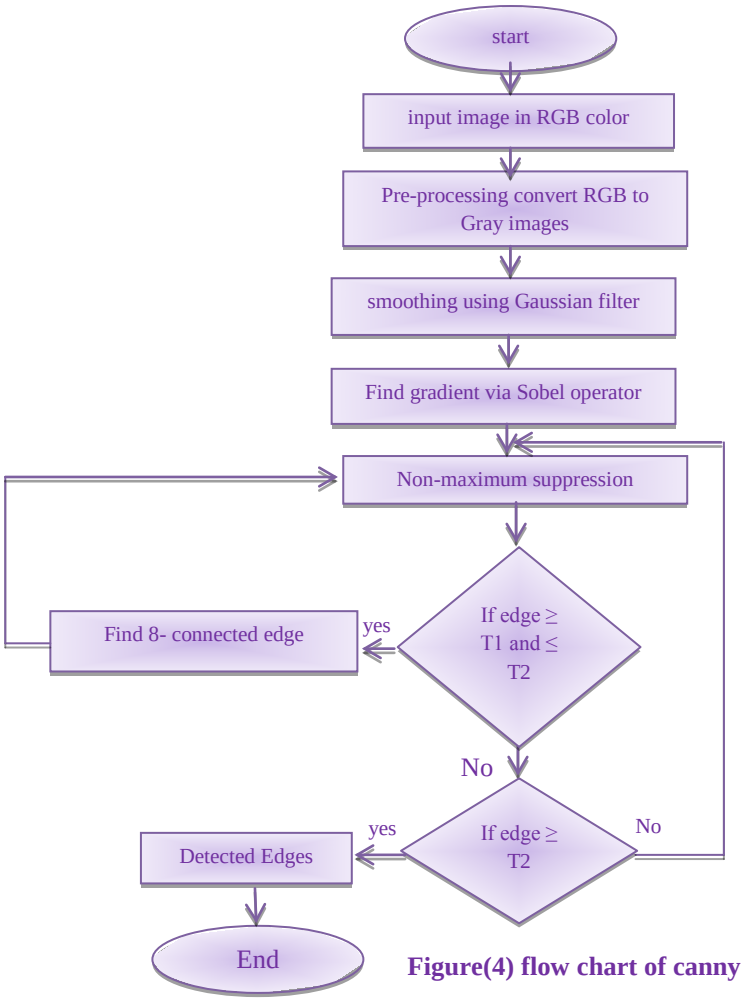
The purpose of this step is to convert the coarse edges in the image of the gradient magnitudes to sharp edges trace along the edge in the edge direction and suppress any pixel value (sets it equal to 0) that is not considered to be an edge. This will give a thin line in the output image[12].

Non-maximum suppression algorithm

1. The edge direction is grouped into 8 directions: [(0, 45), (45, 90), (90, 135), (135,180), (180, 225), (225, 270), (270, 315), (315, 360)].
2. Compare the edge strength of the current pixel with the edge strength of the pixel in the positive and negative gradient direction. I.e. if the gradient direction is north (theta = 90◦), compare with the pixels to the north and south.
3. If the edge strength of the current pixel is largest; preserve the value of the edge [13].

Step4 Hysteresis Threshold:

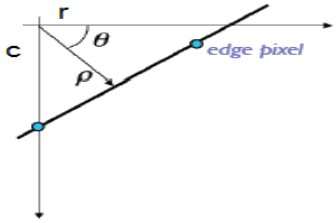
Used as a means of eliminating the breaking up of an edge contour caused by the operator output fluctuating above and below the threshold. Canny operator preserve Potential edges by using Double thresholding technique[14]. The output of step3 is compared to both high threshold T1 and low threshold T2. Pixels with gray values greater than T1 is marked as strong and immediately be included in the final edge image. while pixels are set as background if their values are lower than T2. Finally, edge pixels between the two thresholds are marked as Weak edges and can be included in the final edge if and only if they are connected to strong edges and that have a value greater than T2[15].



Figure(4) flow chart of canny edge detection

2.3 Edge linking via Hough Transform

Is one of the most frequently used algorithms in image analysis and computer vision. The Hough transform algorithm used to detect and estimate parameters of multiple lines that are presented in the image that is firstly edge-detected and the resulting data serve as input to the Hough algorithm. In order to understand the Hough transform, we understand the normal representation of a line: If we have a line in our row and column (rc)-based image space [8], we can define that line by ρ, the distance from the origin to the line along a perpendicular to the line, and θ represent the angle between the r-axis and the ρ-line as shown in figure(5).



Figure(5) representation of straight line

Hough Transform for Straight Lines Algorithm is depicted in figure (6).
Step1: Define the desired increments on ρ and θ, Δρ and Δθ, and quantize the Hough space accordingly.
Step2: Generate an accumulator array A(r, q); set all values to zero
Step3: For all edge points (r, c) in the image

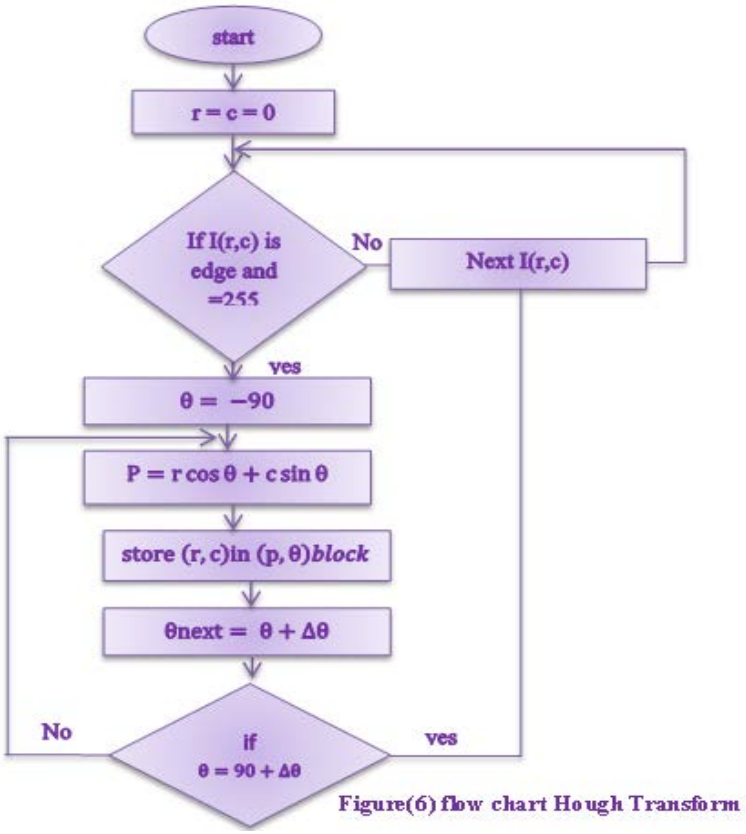
1. Use gradient direction for q.
2. Compute r from the equation.
3. Increment A(r, q) by one.

Step4: For all cells in A(r, q).

1. Search for the maximum value of A(r, q).
2. Calculate the equation of the line using equation(4).

$$P = r\cos\theta + c\sin\theta \text{----------(4).}$$

Step5:To reduce the effect of noise more than one in the accumulator array are increased [10].
The flow chart of Hough transform shown in figure(6).



Figure(6) flow chart Hough Transform

2-4 Global Thresholding Segmentation

The fundamental principle of thresholding techniques is based on the characteristics of the image. Global thresholding method is an image segmentation technique based on intensity of image pixels. All the pixels brighter than a specified brightness level are taken as 255 and the rest are left 0[16]. In this way we get a binary image with useful objects image as 255 and unwanted as background. The basic global thresholding algorithm which depicted in figure(7) is shown below:

Step1: Select an initial estimate for the global threshold, T is the average grayscale

Step2: Segment the image using T. It will produce two groups of pixels:
G1consisting of all pixels with intensity values > T and G2 consisting of pixels with values T.

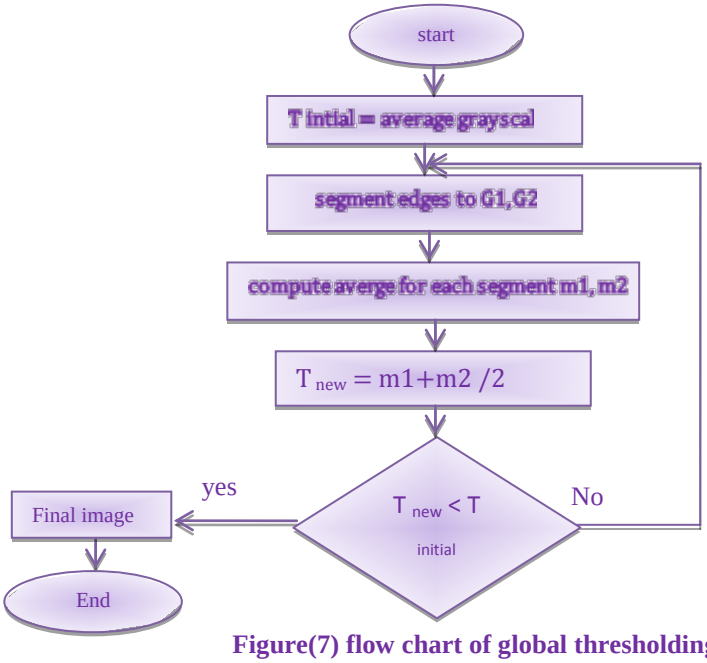
step3: Compute the average intensity values M1 and M2 for the pixels in G1 and G2, respectively.

Step4: Compute a new threshold value T as equation(5).

$$T = \frac{M1+M2}{2} \text{----------(5)}$$

Step5: Repeat Steps 2 through 4 until the difference between values of T in successive iterations is smaller than initial parameter T [17].

The success of this method depends entirely on how well the histogram can be partitioned.



Figure(7) flow chart of global thresholding

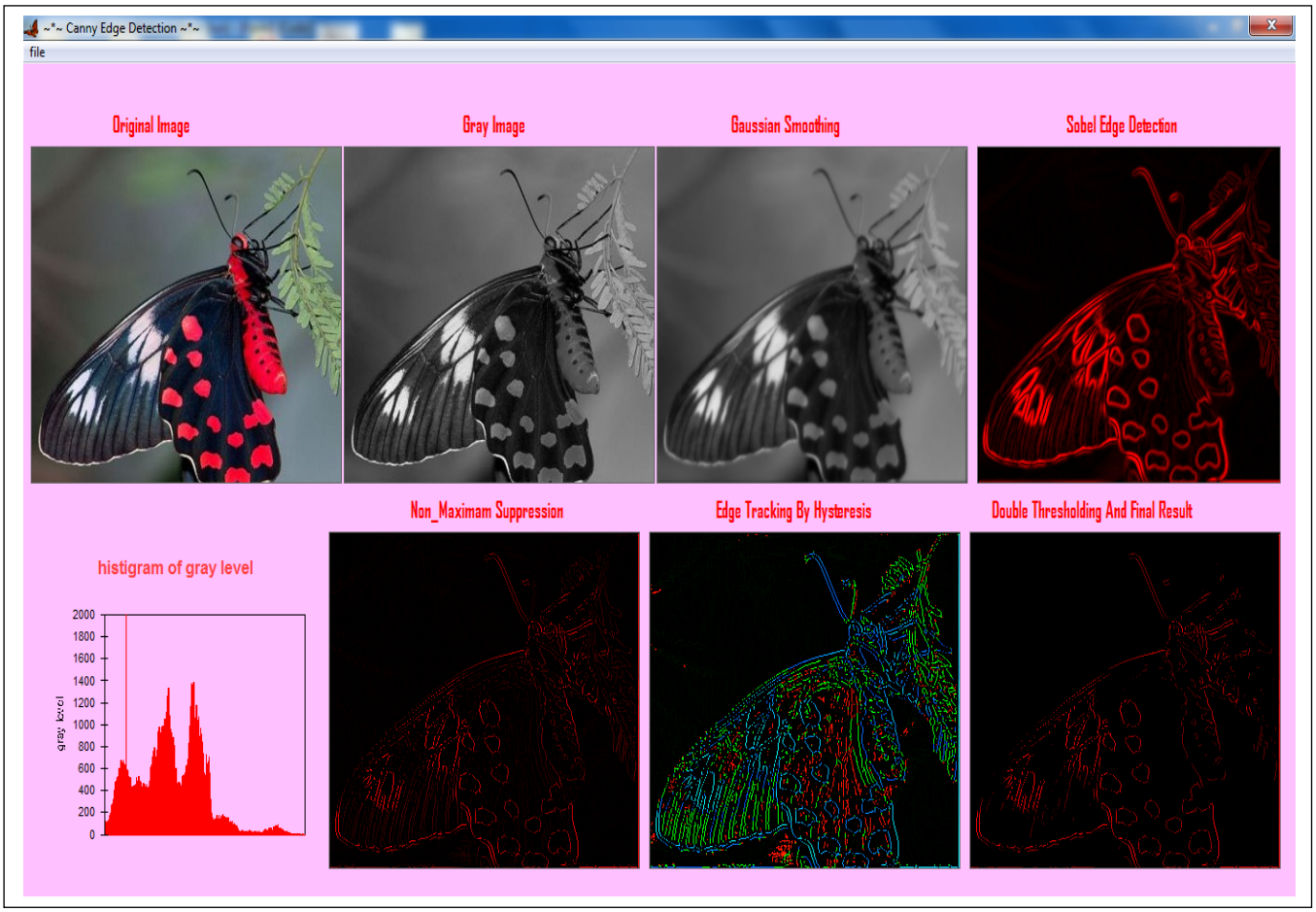
3. Experimental Results

The paper presents two techniques of image segmentation, Canny edge detection and Global thresholding, they are tested with a variety of representing natural images and their corresponding segmentation using the proposed system. An examples of experimental on colored images and their segmentation, results are given in figure(8a, 8b,8c).

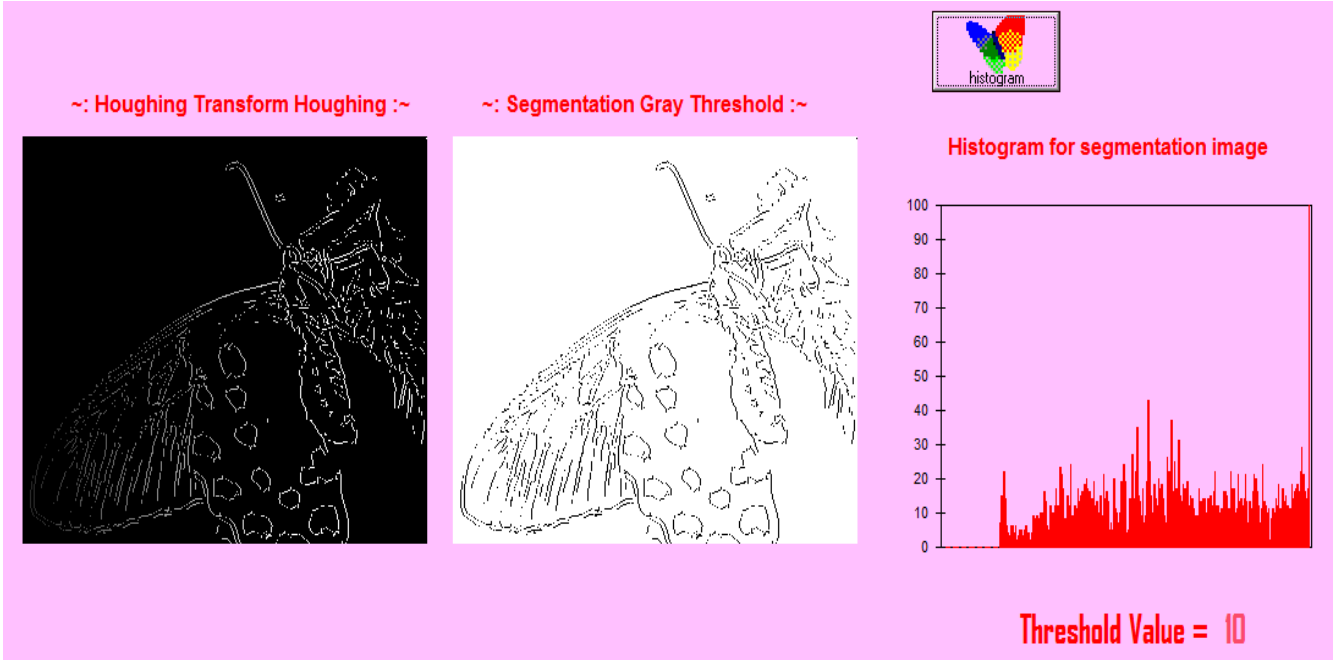
We can see from the implementation of proposed segmentation algorithm. Firstly, all edges that values between the two thresholding (30,65) in Non-suppression step are scanned for neighbor edges and joined into groups. At the same time it is marked which groups are adjacent. Then all of these markings are examined to determine which groups of edges are connected to actual image edges (directly or indirectly) and marked as final image edges . The rest of the edges that not connected are suppressed. Secondly, final output shows image edges in blue, edges connected to image edges in green, and other suppressed edges in red.

a. first image

a1. Edge detection algorithm result in first image



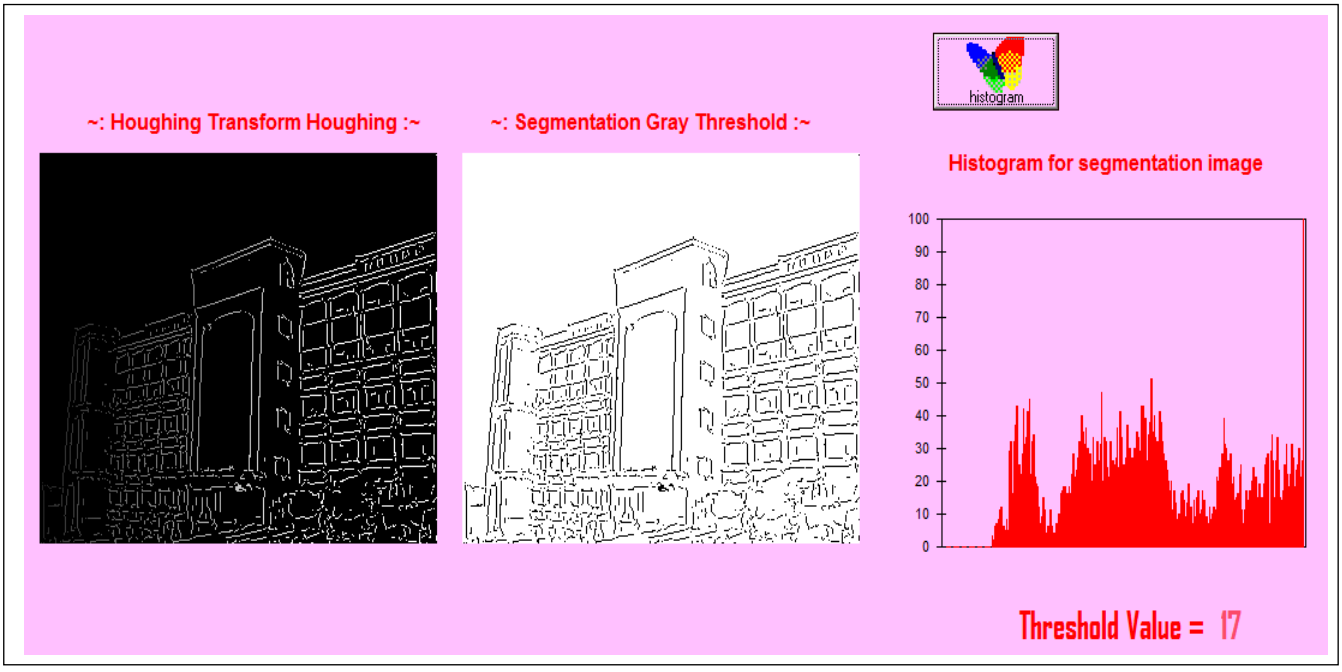
a2. Compartment result between Hough transform and Global thresholding algorithms on first image



b. Second image

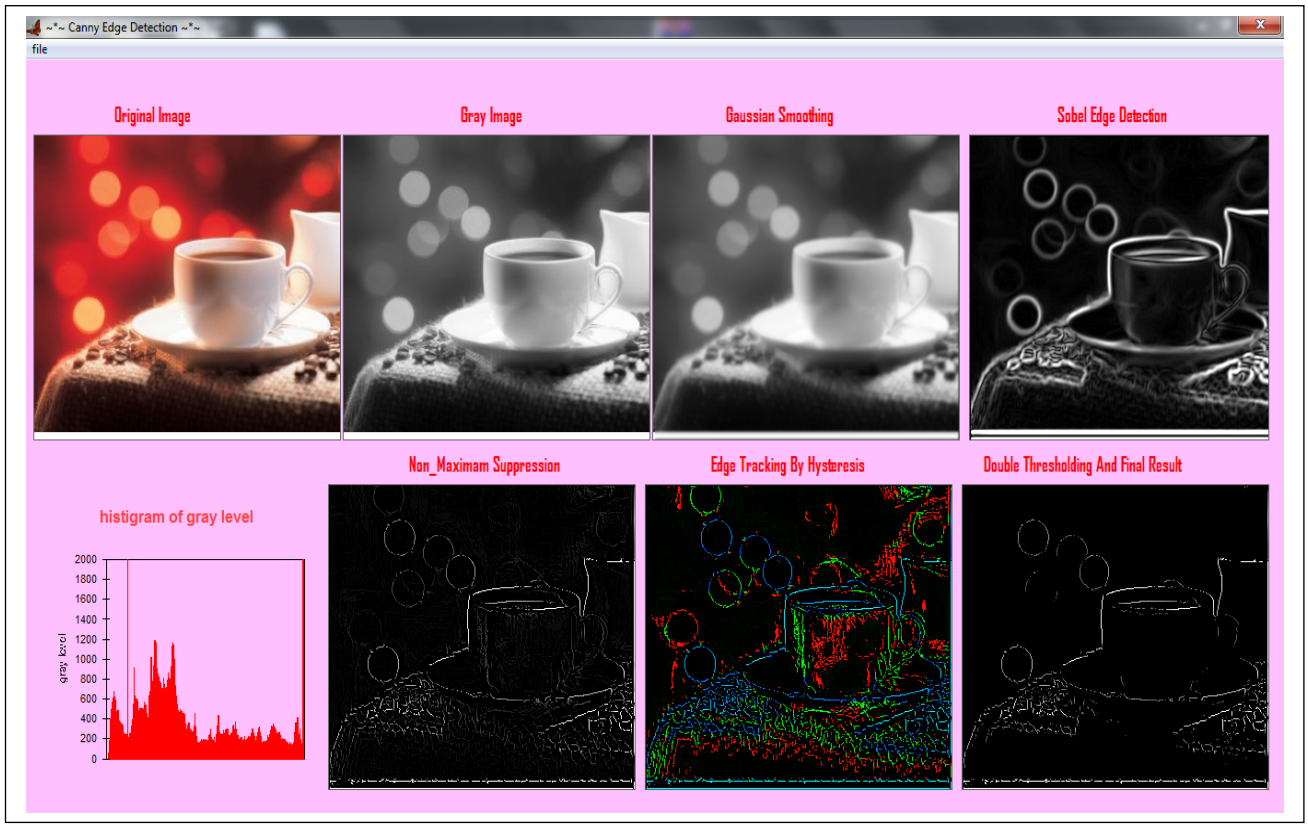
b1. Edge detection algorithm result on second image

b2. Compartment result between Hough transform and Global thresholding algorithms on second image



c. Third image

c1. Edge detection algorithm result on third image



c2. Compartment result between Hough transform and Global thresholding algorithms on third image

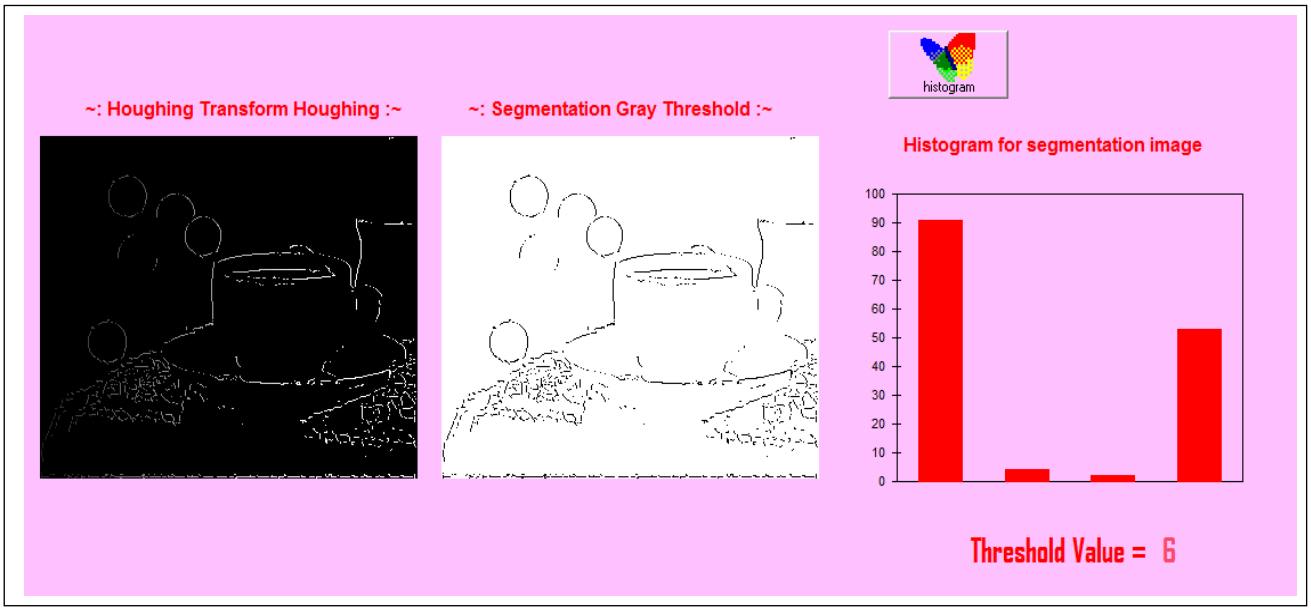


Figure (8) shows the complete image segmentation process on the test images including all intermediate results.

4. Conclusion

1. A pre-processing is important step in image segmentation, because any noise during the image acquisition can cause many problems in the result of segmentation. The results show the efficiency of the algorithms are dependable on shape of an image histogram.
2. Canny operator is suitable in image segmentation especially when there is no clear distinction of the objects from the backgrounds.
3. Values of T1,T2 in canny edge detection are determine by try and error manner.
4. This paper introduced the concept of Hough line Transform, and how is used in object detection the HT in general has several limitations making it challenging to detect anything other than lines and circles, because more parameters are needed to describe shapes and add more complexity.
5. Global thresholding is an effective tool in image segmentation especially when object in the foreground has quite different gray levels than the surrounding background.
6. Hybrid canny operator and global thresholding for image segmentation gives better result than using only Canny, because it produces too many no needed edges.

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