Binary ECG Segmentation from Color ECG Image

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الخلاصة

يظهر هذا البحث تقنية اقتطاع مقطع أو منطقة معينة خاصة من صوره موجة كهربائية كإشارة لضربات القلب ECG مقطوعة من خلفية ملونة تكون فيها تلك الإشارة للموجة موجودة بالعادة ضمن صورة مليئة بالتعقيد وممزوجة بمجاميع لونية سواء كان ضمن الإشارة نفسها أو في الخلفية المخصصة للصورة قيد البحث ، أن تعدد الألوان وعدم تماثلها وتعقيدها سواء كان للإشارة نفسها أو للخلفية الخاصة بها وهو ما زاد من صعوبة العمل الخاص بعملية اقتطاع تلك الإشارة ، أن قطع واستخلاص تلك الإشارة كصورة رقمية ثنائية مستقلة يجعلها قابلة للاستخدام لآجل أجراء التحليل عليها وتمكين استخدامها وتهيئتها لمختلف أنواع التحليل وتمكين تطبيق العديد من تطبيقات استخلاص و تحديد أو استخراج أهم الملامح الموجودة فيها والتي تجعلها قابلة للاستفادة منها للخروج بمختلف النتائج و الاستنتاجات البحثية أو لآي تطبيقات أخرى والتي تتطلب اقتطاع مقطع من صورة ملونة أو رقمية كجزء أولي يساعد على البدء في عمليات المعالجة الخاصة بتلك التطبيقات . أن الخوارزمية المقترحة تم انجازها باستخدام تحليل ألأطياف اللونية ، تحليل عناصر الصورة الرقمية وبالتالي استخلاص العناصر المرغوبة وإهمال العناصر الغير مرغوب بها .

ان عملية الحصول على مقطع اشارة الـ ECG التي يتم الحصول عليها في المستشفيات وعند ذوي التخصصات الطبية المتخصصة من خلال اجهزة تخصصية وباستخدام خلفيات متعددة للصورة لا وبل بعضها يستخدم خلفيات لها نفس الالوان التي من الممكن ان تتكون منها اشارة الـ ECG مما يجعلها متداخلة معها ويزيد من صعوبة تحديدها . ان كافة البحوث الطبية والمتعلقة بهذا المجال تكون معتمدة بشكل اساسي على الطرق الاحصائية والخبرات الطبية لدى مجموعة محددة من الاطباء التخصصيين وبهذا تترك الحاسبات الرقمية فقيرة بهذا المجال الحيوي. ان البحث المعروض امامكم يستخدم مفاهيم معالجة الانماط والصور لتشكيل خوارزمية تكون قادرة لفتح افاق التعامل مع هذا النوع من الصورالطبية لتهيئتها على شكل صورة رقمية ثنائية قابلة للتحليل.

أن نتيجة المعالجة الناتجة هو صورة رقمية ثنائية لإشارة ECG محددة مقطوعة خالية من تأثيرات وتشوهات الخلفية والتي يتطلب للوصول إليها أجراء مجموعة من التجارب ألاختباريه بفعالية للوصول إلى أمثل صورة ثنائية . إن الخوارزمية المقترحة تم اختبارها بأخذ مجموعة متعددة من صور حالات حقيقية متعددة الخلفيات والألوان وقد أعطت الخوارزمية المقترحة نتائج جيدة للوصول إلى الهدف المنشود .

الكلمات المفتاحية رسم تخطيط موجة كهربائية كإشارة لضربات القلب ECG ، قطع مقطع من صورة ، استرجاع الصورة ، الصورة الثنائية ، تحسين معالم الصورة .

Abstract :

This paper presents color ECG image segmentation technique to segment a set of ECG wave region which can be used in ECG wave analyzing and detection applications or any other application which may require color segmentation or binary image preprocessing .

The operation of getting ECG signal which can not be gotten in the hospitals and those of medical specialist by using medical specialist by using medical devices and various backgrounds even though some used the signal with the same color that can be merged with ECG so that it is hard to define, all medical researches concerned with this field of study are basically depending on statistical methods and medical experience by a group of specialist doctors this makes the digital computers poor in this important field . In this research image processing is used for forming algorithm to be able to deal with this kind of medical images then prepared it to a binary digital image to analyzing .

The proposed algorithm is carried out by using wave color detection , color image analyzing , filtering of wave process depending on threshold technique and splitting and merging algorithm .

Then the result is binary ECG with located effective undead of test images . The proposed algorithm was tested under multi ECG images cases and give a good result .

keywords ECG , image segmentation , image restoration , binary image , image enhancement .

1- Introduction :

Image processing is a computer imaging where the application involves a human being in the visual loop. The images are to be examined and acted upon by people . For these types of applications we require some understanding of how the human visual system operates . The major topics with in the field of image processing include image restoration , image enhancement , and image segmentation . The primary distinction between computer vision and image processing is that the output image is to be used a human being , image analysis is often used as preliminary work in the development of image processing algorithms [1],[2] .

1.1- Image Restoration :

Image restoration is process of taking an image with some known , or estimated , degradation , then restoring it to its original appearance . Image restoration is often used in the field of photography or publishing where an image was some show degraded but needs to be improved before it can be printed . For this type of application .

We need to know something about the degradation process in order to develop a model for the distortion . When we have a model for the degradation process , we can apply the inverse process to the image to restore it to original form [1] .

1.2- Image Enhancement :

Image Enhancement involves taking an image and improving it visually , typically by taking advantage of the human visual system's response . One of the simplest and often most dramatic enhancement techniques is to simply stretch the contrast of an image . Enhancement and restoration are similar in aim , to make an look better , but they differ in how they approach the problem . Restoration methods attempt to model the distortion to be image and reverse this degradation whereas enhancement methods use knowledge of human visual system's response to improve an image visually [1] .

1-3 Image Segmentation :

Image segmentation is to find regions that represent objects or meaningful parts of objects . Image segmentation techniques can be divided into three categories :

1- **region growing and shrinking .**
2- **clustering methods .**
3- **boundary detection .**

The region growing and shrinking methods use the row and column . Based on image space , whereas clustering techniques can be applied to any domain such as (spatial domain , color space , feature space , etc) . The boundary detection methods are extensions of edge detection technique [1].

1.4- Electrocardiography :

Electrocardiography (ECG or EKG) is a trans thoracic interpretation of the electrical activity of the heart over time captured and externally recorded by an electrocardiographic device [21]. The etymology of the word is derived from the Greek electro , because it is related to electrical activity , cardio , Greek for heart , and graph , a Greek root meaning "to write" in english speaking countries , medical professionals often write EKG (The German abbreviation) in order to avoid confusion with ECG [4].

1.5- How ECG Works :

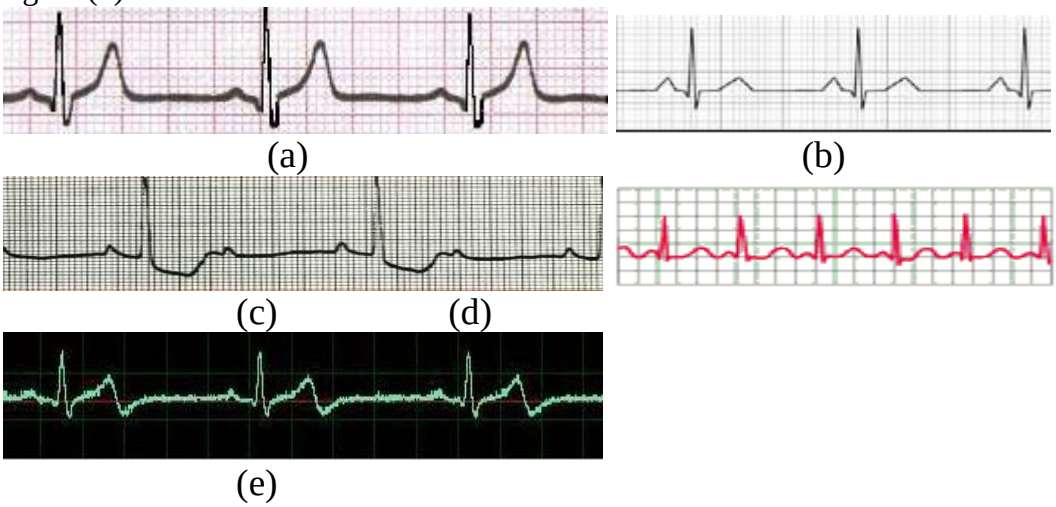
The ECG works mostly by detecting and amplifying the tiny electrical changes on the skin that are caused when the heart muscle "deplolarises" during each heart beat . At rest , each heart muscle cell has a charge across its outer wall , or cell membrane . Reducing this charge towards zero is called de – polarization , which activates the mechanism in the cell that cause it to contract . During each heartbeat a healthy heart will have an orderly progression of a wave of depolarization that is triggered by the cells in the sinoatrial node , spreads out through the atrium , passes through "intrinsic conduction pathways" and then spreads all over the ventricles . This is detected as tiny rises and falls in the voltage between two electrodes placed either on a screen or on paper . This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle [22] .

Usually more than 2 electrodes are used and they can be combined into a number of pairs . (For example: Left arm (LA , right arm (RA) and left leg (LL) electrodes from the pairs : (LA +RA) , (LA + LL) , (RA + LL). The output from each pair is known as a lead . Each lead is said to look at the heart from a different angle . Different types of

ECG , can be the number of leads that are recorded , for example 3-lead , 5-lead or 12-lead ECG's (sometimes simply "a 12-lead") [5] .

1.6- ECG Graph Paper :

The output of an ECG record is a graph (or sometimes several graphs representing each of the leads) with time represented on the X-axis and voltage represented on the Y-axis . A dedicated ECG machine would usually print into graph paper which has a background pattern of 1mm squares (often in red or green) , with bold derisions every 5mm in both vertical and horizontal directions , it is possible to change the output of most ECG devices but it is standard to represent each mV on the Y-axis as 1cm and each second as 25mm on the X-axis (that is paper speed of 25mm/s) . Faster paper speeds can be used – for example to resolve finer detail in the ECG . At a paper speed of 25mm/s, one small block of ECG paper translates into 40ms . Five small blocks make up one large block , which translates into 200ms . Hence , there are five large blocks per second . A calibration signal may be included with record . A standard signal of 1mV must move the stylus vertically 1cm , that is two large squares on ECG paper [6] . See figure (1)



Figure(1) (a,b,c,d,e)Kinds of papers used for ECG

2- Type of Digital Images :

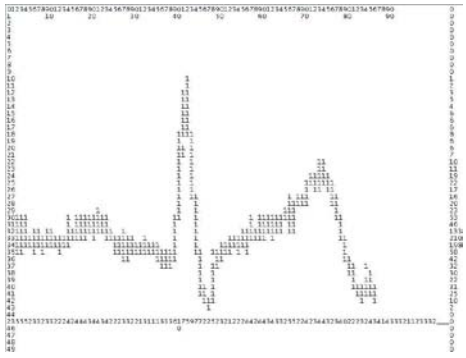
There are three types of images :

1- Binary image .
2- Gray – level image .
3- Color image .

The digital image I(r , c) is analysis as a two – dimensional array of data , each pixel value corresponds to the brightness of the image at the point (r , c) . A two – dimensional array is referred to as a matrix , and one (row or column) is called a vector . There are some type of digital image : [7], [8]

2.1- Binary Image :

Binary image are the simplest type of image analysis and can take on two values black and whit or '0' or '1' see figure (2)



Figure(2) Binary image simulated by 0,1

A binary image is referred to as a (1bit/pixel) image because it takes only on binary digital to represent each pixel [7] .

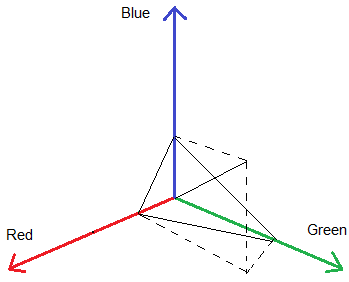
2.2- Gray – Level Image :

Gray – level are referred to as monochrome or one color images . They contain brightness information only, no color information . Typically gray – level image analysis contains 8-bit /pixel data which allow us to have (0-255) different shades [10], [11].

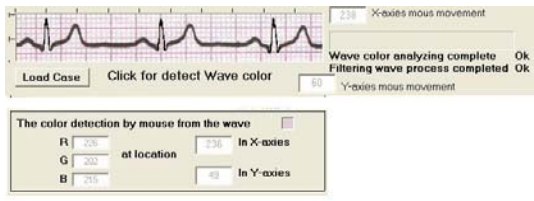
2.3- Color Images :

Color images can be modeled as three – band monochrome image data where each band of data corresponds Red , Green , Blue or RGB images which represent the original thee color . When we use 8-bits monochrome standard as a model , the corresponding color image would have 24-bits / pixel 8-bits for each of the three – color bands (red , green blue) . In 8-bits colored image analysis the palette represents 256 (0—255) colors variation [7],[10],[12].

The proposed study of ECG color image will analyzing each of these three – band monochrome in each pixel in corresponding color ECG image . The values of each pixel will be represented in detail and with it's coordinates (r,c) see figure (3) .



(a) Color triangle



(b) ECG image with it's Color analyzing Figure(3)

Color is the most extensively used visual content for image retrieval . It's three – dimensional values make its discrimination potentiality superior to the single dimensional gray values of image . It's relatively robust to ECG wave and it's background . Before selecting an appropriate color description , color space must be determined first [3],[7]. Humans perceive a color as a combination of three stimuli , R(red) , G(Green) , and B(blue) , which form a color spaces for the ECG color image , represent three form a color spaces for the ECG color image , represent three 2-Dimention arrays represents the color information , corresponding to the richness of background and ECG wave color that represents the type of color such as red , green , and blue widely color used in must color ECG image background and deferent intensity for the ECG wave image from a given color that used to describe that color information in an color ECG image . The additional information contained within these images is often very difficult to determine ECG wave automatically . Therefore , human intervention is usually required to analyze and interpret the ECG wave image and collect important data . Furthermore the ECG wave images obtained often suffer from severe background and noise distortion due to the paper scall condition and ECG device characteristics .

Another difficulty in the analysis of there ECG images is the similarity distance between the ECG wave level color and it's environment , that cases distortion images .

3- Color Image Segmentation :

A central problem with image segmentation is to distinguish object within an image . Many image segmentation methods have been researched in this regard [14] . Most image segmentation methods can be in one of the three categories :

1- Characteristic feature thresholding or clustering (Feature Domain) .
2- Boundary detention (spatial Domain) .
3- Region growing (spatial Domain) .

In this paper it proposed to use characteristic feature thresholding or clustering is a technique to categories the ECG image pixels into the selected feature of the pixel . These could be features such as the pixel gray level values RGB value .

Characteristic feature thresholding is effective in image segmentation when it takes spatial information into consideration [14] . That the boundary or edge detection tacks the intensity of the pixels changes dramatically compared to the pixels of it's surrounding , a decision is made based on this information and the pixel under examination , but these algorithms are suitable for images that are simple and noise – free; however edge detection on noisy , complex images will often produce missing edges , or extra edges . Region growing is a technique where the aim is to group pixels into larger and larger regions . It also uses spatial information and guarantees the formation of closed connected regions but it is not without its problems . It is often not clear at what point the region growing process should be terminated , resulting in under or over segmentation [14] .

3.1- Logical Definition of Segmentation :

A region is defined as an area with homogeneous spatial properties [15]. The level to which this subdivision is carried depends on the problem being solved . That is , segmentation should stop when the objects or regions of interest in an application have been isolated . Segmentation is a form of pixel classification , i.e. , each pixel is assigned to a class of pixels based on some property of the pixel .

As a result of segmentation , the regions should be homogeneous with respect to the segmentation criterion such as uniformity in gray level intensity or texture [15] .

3.2- Mathematical Definition of Segmentation :

The objective of segmentation is to partition an image into regions . Segmentation techniques are based on finding the regions directly . R represents the entire image region . We may view segmentation as process that partitions R into n sub region , R1 , R2 , …. , Rn , with the following property :

a- $R = \bigcup R_i$ $i= 1,2,3, \ldots , n$.
b- R_i is a connected region , $i= 1,2,3, \ldots , n$.
c- $R_i \cap R_j = \emptyset$ for all i and j , $i \neq j$, $\emptyset$ = empty
d- $P(R_i)$ = TRUE for $i= 1,2,3, \ldots , n$.
e- $P(R_i \cup R_j)$ = FALS for $i \neq j$ R_i and R_j .

Condition (a) indicates that the segmentation must be complete ; that is every pixel must be in region .

Condition (b) requires that points in a region must be connected.

Condition (c) refer to the region must be disjoint .

Condition (d) deals with the properties that must be satisfied by the pixels in segment region for P(Ri) = TRUE if all pixel in Ri have the same intensity .

Condition (e) indicates that the region Ri and Rj are different in the sense of predicate P [2] .

4- Thresholding Technique :

The Thresholding technique is very popular in image processing operations , one of which is the segmentation . Thresholding transforms a data set containing values that vary over some range into a new data set containing values that vary a smaller range . The simplest case is when the destination data set contains only two values ; a threshold is applied to the input data so that values falling blow the threshold are replaced by one of the values in the data set ; input values at or above the threshold are replaced by the other output value [16].

In this paper it proposed to use threshold values which are usually selected from the wave (ECG color wave image) .

This can be done by known or determined the gray level ranges of the ECG color wave by click the mouse over it to occupied the color of ECG image area objects and background are well separated [17], [18] .

Thresholding is defined as an operation that involves test against a numeric function T of the from [2] .

$T_0 = T \{ X,Y , P (X , Y) , f (X , Y)\}$ ……. (1)

Where P (X,Y) denotes some local property of the point (X,Y) .

The resulting thresholding images g(X,Y) is then defined as :

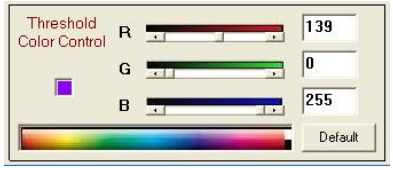
$$g(X,Y) = \begin{cases} 1 & \text{if } f(X,Y) > T_0 \\ 0 & \text{if } f(X,Y) \leq T_0 \end{cases}$$ ------ 4.1 …….. (2)

In general , a signal threshold value is not enough to detect all the objects in a complicated image , such as natural outdoor images . It is more efficient to use multiple thresholds rater than a single threshold [19], [20].

Multiple thresholding is an operation that involves test against a D-dimension function T .

$(T_0 , T_1 , \ldots\ldots T_{D-1}) = T \{(X,Y) , p(X,Y) , f(X,Y)\}$ with $0<D<L$

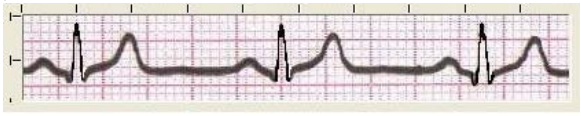
The resulting threshold image g(X,Y) uses D + i values (V_0,V_1 , …. V_D) to map the D+1 classes in the image defined by the D thresholds see figure (4) :



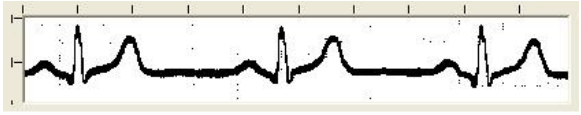
Figure(4) Threshold color control

$$g(X,Y) = \begin{cases} V_0 & \text{if } f(X,Y) \leq T_0 \\ V_1 & \text{if } T_0 < f(X,Y) \leq T_1 \\ \vdots & \\ V_D & \text{if } f(X,Y) > T_{D-1} \end{cases}$$ …….. 4.2

Equation 4.1 and 4.2 can be seen better as mapping gray level f verses the out put as illustrated in figure (5)



(a) Color ECG loaded image



(b) The resulting threshold image

Figure(5)

5- The Proposed Segmentation Method :

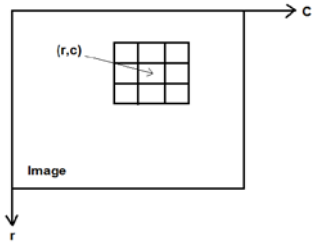
In this section we firstly look into color ECG wave as an color RGB image that need to analyzed and detect it's color space that is suitable for detection based on ECG color distribution in different color space , then take a suitable threshold color based on the analysis of ECG wave color components and finally propose a technical solution for automatic segmentation method to obtain binary ECG segment image . The image segmentation method in this work based on spatial domain techniques only .

5.1- Operation Method :

The term spatial domain refers to the aggregate of pixels composing the image , and spatial domain methods are procedures that operate directly on there pixels . Image processing functions in the spatial domain may be expressed as :

$$Pr(r,c)= T[f(r,c)] \quad \text{---------- } 5.1$$

Where f(r,c) is the input image , pr(r,c) is the processed image , and T is an operator on f , defined over some neighborhood of (r,c) . In addition T can also operate on a set of input images ; such as performing the pixel – by – pixel sum of M images for noise reduction . The principal approach to defining a neighborhood about (r,c) is to use a square or rectangular sub image area centered at (r,c) , as figure (6) shows [2] .



Figure(6) A 3x3 neighborhood about a point (r,c) in an image

The center of the sub image is moved from pixel to pixel starting , say at the top left corner and applying the operator at each location (r,c) to yield g at that location . Although other neighborhood shapes , such as approximation to a circle , sometimes are used , square and rectangular arrays are by for the most predominant because of their ease of implementation .

The simplest form of T is when the neighborhoods is |X| . In this cause g depends only on the value of fat (r,c) , and T becomes a gray level transformation (also called mopping) function of the form :

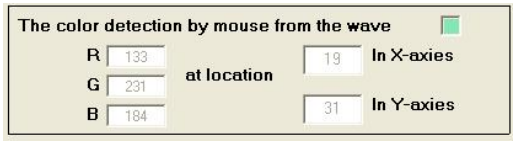
$$S = T(r) \quad \text{……. } 5.2$$

Where , for simplicity in notation , r and s are variables denoting the gray level of f(r,c) and pr(r,c) at any point (r,c) . The effect of this transformation is to produce an image specific contrast than the original image . T(r) produces a two – level (binary) image [2] .

5.2- ECG Region Segmentation :

The proposed region segmentation that represent objects or meaningful parts of objects can be divided into three categories :

1- When the test ECG image is transformed into RGB color space , then its used as a look up table to assign a probability of ECG wave to each pixel see figure (7) .



Figure(7) The R,G,B bands analyzed from location x,y

2- The ECG color probability image is binarized with a thresholding technique ; the regions with proper probability are labeled as a wave color regions .

The basic algorithm is given below :

Procedure
Set the initial values of
T_R is the Red threshold , set of rang 0 – 255
T_G is the Green threshold , set of rang 0 – 255
T_B is the Blow threshold , set of rang 0 – 255
R(x,y)
G(x,y) } are the two dimension arrays satisfied the color space
B(x,y)
Begin
For x=0 : end do
For y=0 : end do
If $R(x,y) \leq T_R$ and $G(x,y) \geq T_G$ and $B(x,y) \leq T_B$ then
Resulting threshold image g(x,y) = 0
else
g(x,y) =1
end if
end for
end for
end

3- The final related approach is to splitting and merging algorithm used to weed out unlikely ECG regions or incorrect aspect ratio the remaining regions are used as a selected regions in the ECG region segmentation .

5.3- Split and Merge Algorithm :

Implemented as shown below:-

The proposed split and merge algorithm is dived – and – conquer ECG wave image method . First of all , it takes the whole image as an area of interest . After that an area of interest is processed based on the following notions :

1- Among the three components of RGB numerical values get an efficient threshold values , see figure (4) .

2- Analyzing the three – band R,G, and B for each pixel in area of interest (color ECG image) .

3- Region merging : Two adjacent regions merge into a single region if satisfy equation 4.3 with R taken as the union of these two regions .

$P(Ri \cup Rk) = P(R) = TRUE$ ……. 4.3

See figure 5(B) :

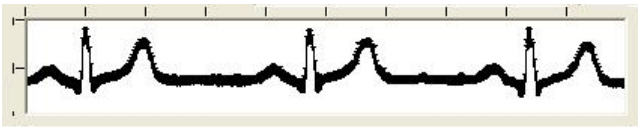
4- Region splitting : A region is subdivided into smaller regions , if it dose not satisfy the similarity equation 3.4 .

$P(R) = FALSE$ …… 4.4

5- The resulting image will be a binary ECG wave image

6-

Note : The behavior of the proposed algorithm is influenced by :
The good choice of initial threshold values see figure (8) :



Figure(8) ECG after splitting smaller regions

6- Experimental Results :

A number of experiment were preformed to test and evaluate the performance of the algorithm . The algorithm has shown the ability to process color ECG wave segmentation of image of size 396 × 60 pixels with in less than 4 seconds on average .

The algorithm was tested on most known recorded color ECG papers or images that taken from ECG monitors see figure 1 (A,B,C,D,E) .

It was found that the acceptable results depend on the experience that the person gut from his frequent use of three RGB threshold detection .

In each ECG – wave in the scall paper (the background of the scall ECG – wave) it is important to know how to set and determined the optimal threshold . The proposed threshold gives the solution by analyzing each pixel to it's RGB – bands see figure (7) , in addition threshold can be selected easily from
comparing ECG wave segment color with the suitable color selected from the combination of colors directly see figure (9) .

Figure(9) Combination of colors that can set threshold directly

For each images were taken at different background the algorithm successfully segment the ECG wave . If the algorithm fails to reach the optimal segment , this is due to a poor lead to a correct estimation of RGB threshold .

By taken the opinion of the doctors they found that , it is a very good stape for automated ECG wave to give a good support to reduce errors and eliminate the ECG papers dependency .

7- Conclusion :

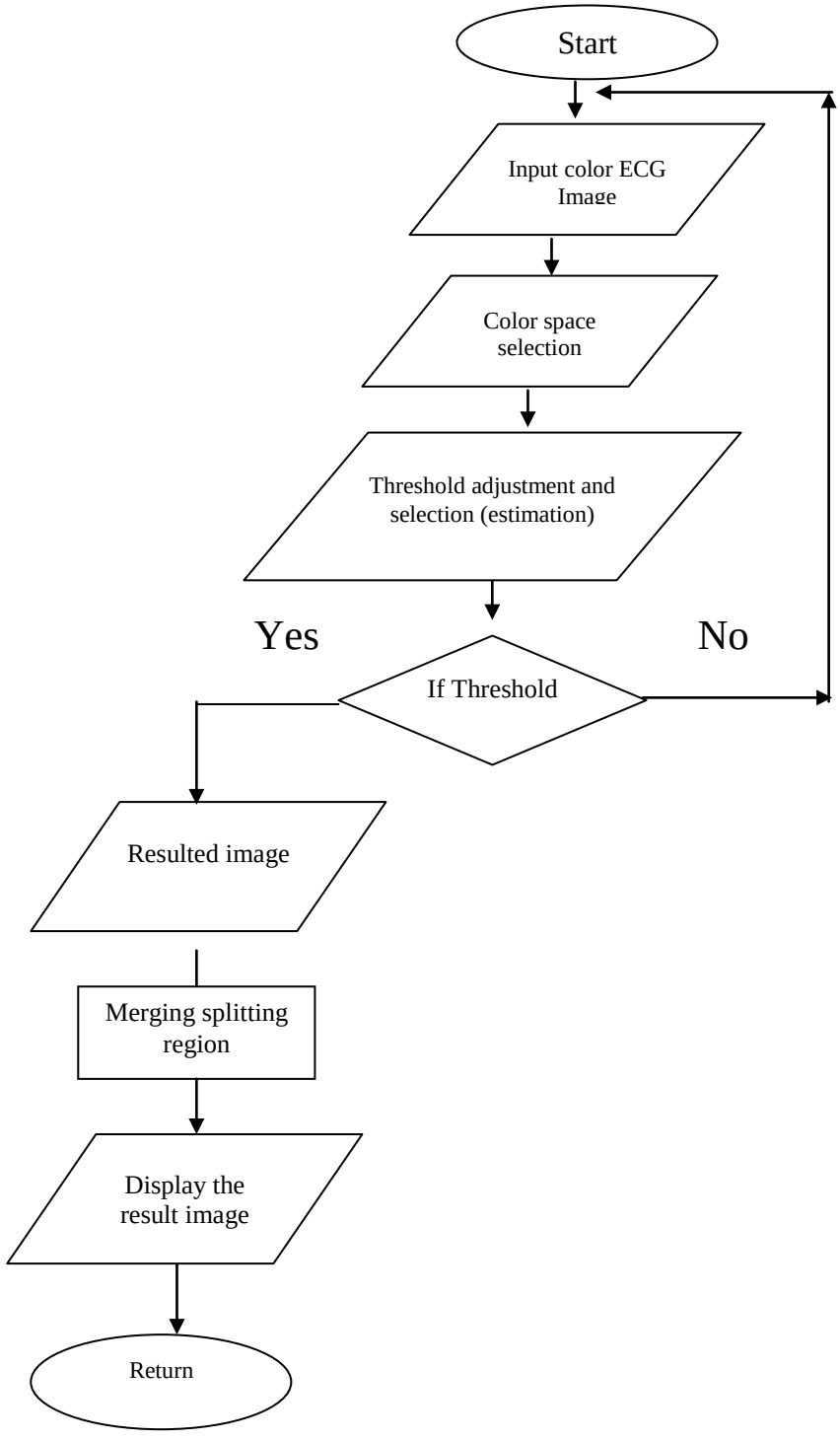
This paper presents a color ECG segmentation method based on the RGB color analyzing , thresholding techniques and region merging , splitting region algorithm . The proposed algorithm based on spatial domain techniques . After investigating a various color ECG image we select RGB color model for analysis . The complexity and difficulty of detecting ECG wave segment from color space has been solved .

Experiment results prove the segmentation of color ECG wave can be detect efficiently after a good estimation of RGB threshold . Binary ECG wave image has been reached .

8- Future Works :

Several suggestions can be recommended for future work my be given as follow :

1- Using other features such as image enhancement , shape and others in the implementation of ECG wave image .
2- ECG image features analyzing can be combined in order to increase the performance of process .
3- Image segmentation can be an integration of both low – level visual features and high – level features in order to manage visual data in more effective ways .



The proposed ECG color segmentation digraph

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