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A Modified Segmentation Approach for Real World Images Based on Edge Density Associated with Image Contrast Stretching

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Abstract

Segmentation of real world images considered as one of the most challenging tasks in the computer vision field due to several issues that associated with this kind of images such as high interference between object foreground and background, complicated objects and the pixels intensities of the object and background are almost similar in some cases. This research has introduced a modified adaptive segmentation process with image contrast stretching namely Gamma Stretching to improve the segmentation problem. The iterative segmentation process based on the proposed criteria has given the flexibility to the segmentation process in finding the suitable region of interest. As well as, the using of Gamma stretching will help in separating the pixels of the objects and background through making the dark intensity pixels darker and the light intensity pixels lighter. The first 20 classes of Caltech 101 dataset have been utilized to demonstrate the performance of the proposed segmentation approach. Also, the Saliency Cut method has been adopted as a benchmark segmentation method. In summary, the proposed method improved some of the segmentation problems and outperforms the current segmentation method namely Saliency Cut method with segmentation accuracy 77.368%, as well as it can be used as a very useful step in improving the performance of visual object categorization system because the region of interest is mostly available.

Keyword: Segmentation, first order derivative, Sobel edge detector, Gamma Stretching, Saliency Cut method, Caltech 101 Dataset.

طريقة تجزئة معدلة لصور العالم الحقيقي بناءا على كثافة الحافة وتمدد تباين الصورة

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الخلاصة

تجزئة صور العالم الحقيقي تعتبر واحدة من أكثر المهام تحديا في مجال الرؤية الحاسوبية بسبب العديد من المشاكل التي ترتبط مع هذا النوع من الصور مثل التداخل العالي بين المقدمة والخلفية للكائن البصري وكائنات بصرية معقدة وكثافة حافة البكسل في الكائن والخلفية تتشابه تقريبا في بعض الحالات. وقد قدم هذا البحث عملية تجزئة معدله ومتكيفة بالاعتماد على تمدد تباين الصور وهي "Gamma Stretching" لتحسين مشكلة التجزئة. إن عملية التجزئة المتكررة على أساس المعايير المقترحة اعطت مرونة عالية لعملية التجزئة في العثور على الكائن في الصورة. وكذلك، فإن استخدام "Gamma Stretching" سيساعد في فصل بكسل الذي ينتمي للكائن من البكسل الذي ينتمي للخلفية من خلال جعل البكسل المظلم أكثر قتامة والبكسل المضيء اكثر اضائة. وقد استخدمت اول عشرين صنف من قاعدة بينات "Caltech 101" للتدليل على فعالية أداء طريقة التجزئة المقترحة.أيضا، وقد استخدمت طريقة "Saliency Cut" كمعيار لقياس كفائة

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الطريقة المقترحة.وباختصار، فان الطريقة المقترحة عالجت بعض مشاكل التجزئة وتفوقت على طريقة التقطيع الحالي وهي طريقة ال "Saliency Cut" بدقة تقسيم 77.368٪ وبالاضافه الى ذلك يمكن استخدام طريقة التجزئه كخطوة اساسيه في تحسين أداء تميز الكائن البصري لأن المنطقة ذات الاهتمام تتوفر في الغالب.

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Introduction

Recently, the segmentation process for various kinds of images such as real world images considered one of the most challenging issues that the researchers have addressed in the last two decades. Therefore, the computer vision committee mentioned this task as an open area for research [1]. The segmentation process means splitting the image into a set of regions which shares the same characteristics. Fundamentally, several types of research have been presented to enhance the segmentation problem such as using pixels intensities, colors, and textures.

Obviously, the literature shows that the segmentation process can be divided into two main approaches, i.e., boundary based segmentation and regionally based segmentation. The former approach deals with the edges pixels which mean using the edge density detector to find the connected border of the region of interest, while the second method deals with the homogeneity which means collect the pixels that have similar characteristics such as colors or texture [2-3].

In fact, still there is a shortcoming in isolating the region of interest due to the high interference between the object foreground and background, week boundary object intensities and complicated objects [4]. However, the edge density has been widely used by different applications for different purposes such as boundary detection and object segmentation. In fact, the segmentation based edge density gives accurate results in detecting the boundary pixels and isolating the regions of interest with some kinds of images such as artificial images and industrial Images. On the other hand, image contrast stretching has also been used by several applications to make an adjustment to the image contrast.

The main purpose of using contrast adjustment is to give inestimable value to the pixels with low intensities which may have sufficient information about the object. As a result, the contrast adjustment process adds some value to the low-intensity pixels and make extracting this kind of pixels are possible by the edge detector operator or any other algorithms[5-6].Therefore, in this research, an iterative segmentation approach based edge density and Gamma stretching have been proposed to improve the segmentation problem. The proposed method will have the ability to isolate the region of interest even when there are images with interference between object foreground and background.

The rest of this paper is organized as follows: In Section 2, the theoretical background related to the state-of-the-art methods has been illustrated briefly. Besides, Section 3, covers the whole steps of the proposed segmentation methods implementations, while section 4 held the experimental results and performance comparison. Lastly, in section 5, the conclusion and the summary of the fact-finding are presented.

Related Work

Edge Density Operator

Edges define the boundaries between the object and background, which could help the segmentation and object recognition applications to improve their performance. The edge is mainly based on the change of the intensities in the image and good edges are imperative for higher level processing.

The edge detector paramount in the area of computer vision. Certainly, different methods have been proposed to extract strong edges including first and second order derivative [7]. Mainly, with both ways the edge detector fail to be adaptive in different situations, this is because the edge detection was mainly base on the lighting conditions which means the intensities of various image regions. The basic idea of the edge detection is by taking the relationship of the neighboring pixels into its account. Essentially, if there is no change in the gray level between the pixel and its neighbors, then there is no edge, otherwise, if there is widely change in the gray level, the current pixel considered as an edge point [8].

Apart from that, the Sobel edge detector considered as a first order derivative which has been widely used in several applications for different purposes such as segmentation because it captures the thicker edges. Clearly, the Sobel operator has two convolution masks, horizontal and vertical. By convolving the image with these convolution masks, the magnitude of gradient and edge orientation would be achieved [9]. Figure- 1 illustrates Sobel operator masks.

Gx=

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

(a)

Gy=

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

(b)

Figure 1-Convolution Masks of Sobel Operator,**(a)** Horizontal mask, **(b)**Vertical mask [9].

The following equations are applied to calculate the magnitude of gradient and the edge orientation. Besides, Figure- 2 gives an example of the Sobel edge detection with real world image.

$G(x,y) = \sqrt{Gx^2 + Gy^2}$ Or $G(x,y) = Max(G_x, G_y)$
(1)

$\theta = \tan^{-1}\frac{Gx}{Gy}$ (2)

(a) (b)

Figure 2- Edge detection by using Sobel edge detection with anchor category of Caltech 101 dataset, **(a)** Original anchor image,**(b)** Edge map through applying vertical and horizontal masks of Sobel operator.

Linear Contrast Adjustment Method:

The method that used to redistribute the intensities values of the image pixels into different ranges called contrast stretching. This method uses linear stretching to make the images with high contrast or low contrast intensities to have a normal distribution of difference values. This process happens through extending the dynamic range of the intensities across the whole image spectrum from 0 to (L-1). This method is considered as an important process in computer vision because it preserves the edge information whereas it is manipulating the intensities values [10]. The literature shows that there are three primary methods employed as a linear contrast stretching operation which is Min-Max linear contrast stretching, Percentage linear contrast stretching and Piecewise linear contrast stretching [5]. When using the Min-Max method, the minimum, and maximum intensities values are mapped to a new full range of available brightness values. For example if an image is with minimum brightness value equal to 60 and maximum brightness value equal to 190, when this image is viewed without enhancement, the values from 0 to 60 and from 190 to 255 are not displayed. Therefore, a contrast stretching is crucial to view the excluded intensities pixels. Equation (3) illustrates this method [6]:-

$Image\ (x,y) = 255 * \left(\frac{Image(i,j) - Min}{Max - Min}\right)$ (3)

where $Image\ (x,y)$ is the pixel intensity, Max represents the maximum brightness value in the image and Min represents the minimum brightness value in the image.

Proposed Segmentation Methods

The proposed segmentation methods will find the region of interest based on the edge density distribution. Fundamentality, the Sobel based edge detection has been proposed, and this operator needs a threshold to verify the pixels are edges or not. Therefore, in this research the edge threshold has been optimized and adaptively set based on the proposed criteria. Apparently, the proposed criteria are dealing with, first the standard deviation of the extracted region of interest about the standard deviation of the whole image. This criterion considered quite effectively especially with homogenate objects because the region of interest will get smaller standard deviation about the standard deviation of the entire image.

Besides, another important criterion has been stated which is the number of pixels that laying out of the boundary box. The boundary box has been calculated based on these equations:

$$Height_{Ratio} = Height * 0.1 \quad (4)$$
$$Width_{Ratio} = Width * 0.1 \quad (5)$$
$$New_{Height} = Old_{height} - Height_{Ratio} \quad (6)$$
$$New_{Width} = Old_{Width} - Width_{Ratio} \quad (7)$$

This criterion also shows very useful results because it reveals how many pixels near the border of the images. In some cases, may some parts of the object near or touch the boundary of the image. Therefore, this criterion will explain how much the object touches the border of the image and then based on specific threshold it will decide if there are much background pixels with the object or not. Based on these criteria, the edge threshold are optimized and adaptively set and the object automatically extracted.

However, after finding the boundary of the object, the seed filling algorithm is used to find the connected regions which are later will be used as the region of interest, gaps filling and noise removal which remove the small regions. Figure-3 illustrates the main methodology of the proposed segmentation process. Besides, the following section explains the proposed segmentation method based on edge density with Gamma stretching.

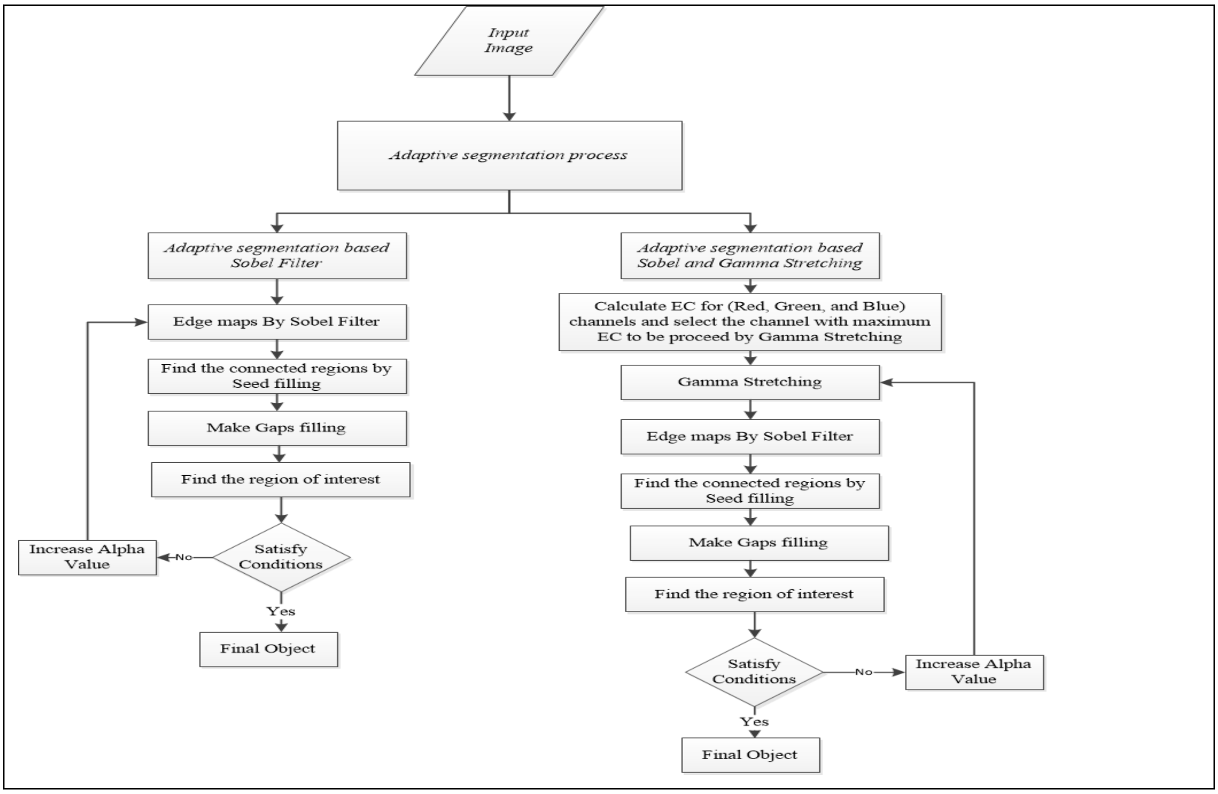

Figure 3- The proposed segmentation process flowchart.

1. Segmentation based Sobel Edge Detection

In this method, the images are directly processed by the proposed Sobel based segmentation. The most remarkable point is the edge threshold automatically optimizes until finding the proper object. In other words, the proposed method starts with an initial threshold and then it tunes the threshold based on the proposed criteria. Algorithm (2) will explain the proposed iterative isolation process and the proposed Sobel based segmentation will be illustrated in algorithm (1).

Algorithm (1): Sobel Based Segmentation
Input: - $Gray_{Img}, Initial_{thre}$
Output: - $Isolated_{object}$

Begin
Step1:- Find the Region of interest through applying Sobel edge detector
$\boldsymbol{Do}$
{
//Apply the Sobel filter to get the $Edge_{map}$.
$Edge_{map} = get\ the\ edges\ maps\ based\ on\ \ initial_{thre}$
//Apply Morphological operations to fill the gaps along the boundaries on $Edge_{map}$
$Edge_{map} = Apply\ dilation\ and\ smudging\ Morphological\ operations\ on\ the\ edge_{map}.$
//Find regions of connected pixels and remove the small regions that are considered outliers.
$Mask_{boundaries} = Apply\ the\ seed\ filling\ algorithm\ on\ the\ edge_{map}$
// Find the holes in the object to make gaps filling.
$Mask_{holes} = Apply\ the\ seed\ filling\ algorithm\ on\ the\ edge_{map}$
$Mask_{connected\ regions} = Combine\ (\ Mask_{boundaries}\ , Mask_{holes}).$

$Isolated_{object} = map\ the\ pixels\ of\ the\ Mask_{connected\ regions}\ to\ the\ original\ image\ pixels$
//Check the isolated object has successfully satisfied the requirements.
$Success = Call\ algorithm\ 2\ to\ the\ isolated_{object}$
$Increament\ Edge_{threshold}\ by\ one$
}$\boldsymbol{While}$ $(Success == false)$
End

This method has been run over the dataset with different thresholds to set the initial threshold. The winning optimal threshold is the threshold that records high accurate isolation to the objects. However, Figure-4 gives an example of Sobel based segmentation of the accordion sub-class of partial class.

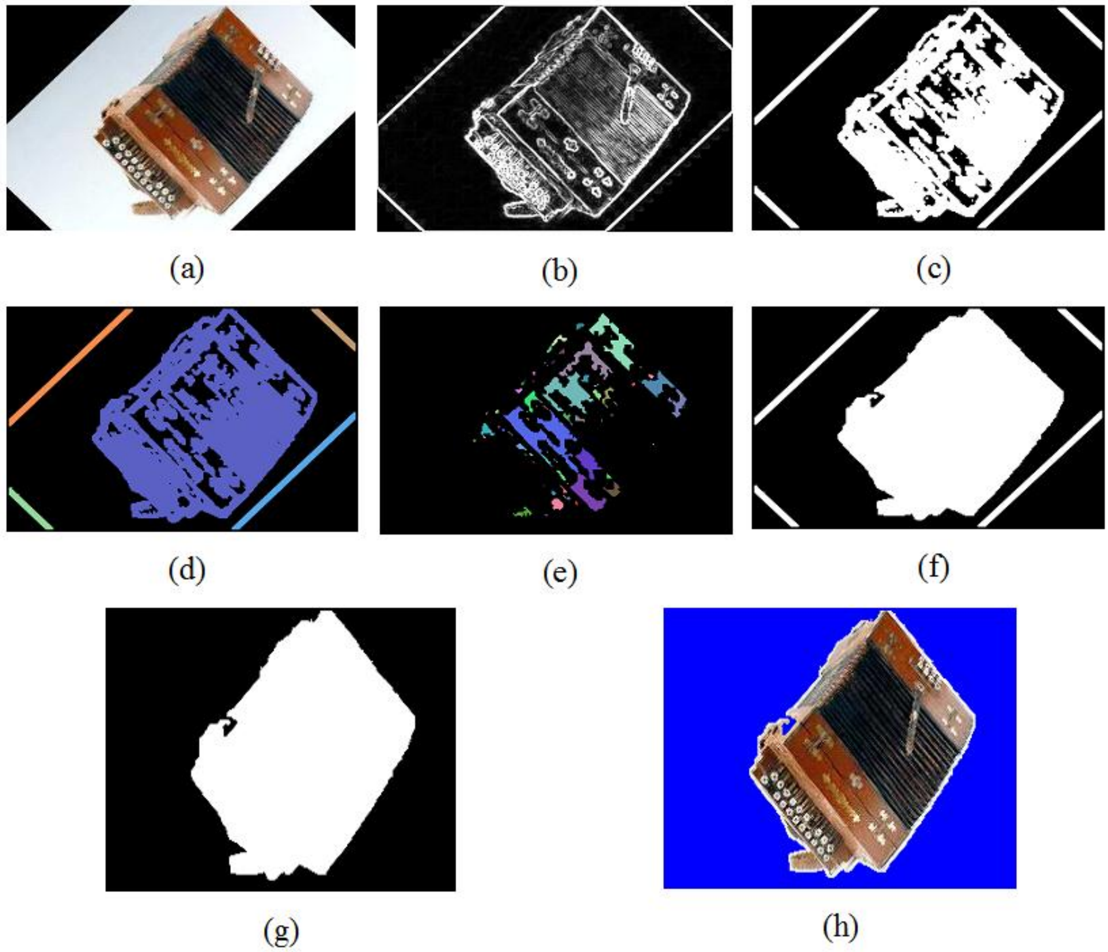

Figure 4- Segmentation based Sobel filter, **(a)** Original image, **(b)** Edge map based Sobel with threshold equal to 70, **(c)** Edge map after applying and Smudging Morphology, **(d)** Segments of connect pixels of object boundaries, **(e)** Segments of connect pixels of gaps inside the object boundaries, **(f)** Object Mask after applying gaps filling**, (g)** Apply seed filling to remove the outliers in the image**, (h)** Isolated object.

Algorithm (2): Success Isolation
Input:- $Isolated_{object}$, STD_{low}, $Boundary_{thre}$
Output:- $Success$

Begin
Step1:- // Calculate the geometric metrics to the isolated object
$Object_{STD} = Calculate\ the\ standard\ Deviation\ for\ the\ object$
$Image_{STD} = Calculate\ the\ standard\ Deviation\ for\ the\ whole\ image$
$Boundary_{Pixels} = Calculate\ the\ object\ pixels\ that\ lay\ out\ the\ the\ boundary\ box$
Step2:- // Check the geometric metrics have met the criteria
$Difference_{STD} = Image_{STD} - Object_{STD}$
$\boldsymbol{if}\ (Object_{STD} < STD_{low})\ \boldsymbol{Then}\ Success = true$
$\boldsymbol{Else\ if}\ (Difference_{STD} \leq STD_{low}\ and\ Boundary_{Pixels} \leq Boundary_{thre})$
$\boldsymbol{Then}\ Success = true$
$\boldsymbol{Else}$
$Success = false$
End

2. Sobel Filter Based Gamma Stretching

This method has been selected because some images have weak edges, and this means there is an inclusion of the background intensity with the object boundaries. The edge detector, as a result, fails to construct connected boundaries. Therefore, an intensity transformation is required to allow the edge detector work efficiently. One of the well-known methods is gamma stretching. In fact, gamma stretching makes the black intensities dark and the light intensities lighter. In other words, the intensity transformation is going to increase the contrast between a particular intensities values. Gamma stretching algorithm is illustrated in algorithm (3).

Algorithm (3): Gamma Stretching
Input:- $Image, Alpha$
Output:- $Stretched_{Image}$

Begin
Step1:- // Calculate the Mean and Standard Deviation of the Image.
$Max = Mean + (alpha \times STD)$
$Min = Mean - (alpha \times STD)$
Step2:- // Calculate the new intensities values to the image
$\boldsymbol{For}\ i = 0\ to\ Image_{width}$
$\boldsymbol{For}\ j = 0\ to\ Image_{Height}$
{
$\boldsymbol{if}\ (image(i,j) \leq Min)\ \boldsymbol{Then}\ Stretched_{Image}(i,j) = 0$
$\boldsymbol{Else\ if}(image(i,j) \geq \boldsymbol{Max})\ \boldsymbol{Then}\ Stretched_{Image}(i,j) = 255$
$\boldsymbol{Else}\ \ Stretched_{Image}(i,j) = 255 \times \left(\frac{image(i,j)-Min}{Max-Min}\right)$
}
End

The Gamma stretching is applied to the best channel of the image because not all the channels contain characteristic information. For this purpose, the Contrast Energy (CE) factor of each channel is calculated and the channel with highest CE entered to the Gamma Stretching algorithm. The algorithm (4) will illustrate the calculation of the CE component and selects the best channel.

Algorithm (4):- Selecting Best Channel
Input:- $Image_{channel}$
Output:- $\boldsymbol{CE}$

Begin
Step1:- // Calculate the first-order derivative and find the histogram of the maximum value among neighboring pixels.
$\boldsymbol{For}\ i = 0\ to\ Image_{width}$
$For\ i = 0\ to\ Image_{Hieght}$
{
$Pixel_1 = Image_{channel}(i,j),\ Pixel_2 = Image_{channel}(i+1,j),$
$Pixel_3 = Image_{channel}(i,j+1),\ Pixel_4 = Image_{channel}(i+1,j+1)$
$\nabla h = |Pixel_1 - Pixel_2|$
$\nabla v = |Pixel_1 - Pixel_3|$
$\nabla d = |Pixel_1 - Pixel_4|$
$Max_{Value} = Max(\nabla h, \nabla v, \nabla d)$
$Increament\ the\ Hist[Max_{Value}]\ by\ one$
}
Step2:- // Calculate the CE factor
$CE = 0$ // Initial value
$\boldsymbol{For}\ i = 0\ to\ Hist_{Length}$
$CE = CE + Hist[i] \times i$
End

Algorithm (5) explains the main steps in isolating the object through using Gamma stretching with Sobel edge detection, as well as, the proposed method iteratively adjusting its alpha value based on the same proposed criteria.

Algorithm (5) :- Sobel Based Gamma Stretching
Input:- $Image, Edge_{Thre}, Alpha_{Thre}$
Output:- $Isolated_{Object}$

Begin
Step1:- Find the Region of interest through applying Sobel edge detector with Gamma stretching
$\boldsymbol{Do}$
{
// Choose the best channel of (Red, Green, Blue) based on its Ac component.
$CE = \ Call\ algorithm\ (4)\ to\ Calculate\ the\ CE\ component\ for\ each\ channel$
$Max_{CE} = Max(CE_{Red}, CE_{Gren}, CE_{Blue})$
$\boldsymbol{if}\ (CE_{Red} == \ Max_{CE})\ Then\ Best_{channel} = Red$
$\boldsymbol{Else\ if}\ (CE_{Gren} == Max_{CE})\ \boldsymbol{Then}\ Best_{channel} = Green$
$\boldsymbol{Else}\ \ Best_{channel} = Blue$
// Calculate the new intensities values of the best channel through applying Gamma Stretching.
$Stretched_{Img} = Call\ Algorithm\ (3)\ on\ the\ Best_{channel}\ With\ Alpah_{Thre}$
// Calculate the edge map based on the stretched image.
$Edge_{map} = get\ the\ edges\ maps\ based\ on\ \ initial_{thre}$
// Find regions of connected pixels and remove the small regions that are considered outliers.
$Mask_{boundaries} = Apply\ the\ seed\ filling\ algorithm\ on\ the\ edge_{map}$
// Find the holes in the object to make gaps filling.
$Mask_{holes} = Apply\ the\ seed\ filling\ algorithm\ on\ the\ edge_{map}$
$Mask_{connected\ regions} = Combine\ (\ Mask_{boundaries}\ , Mask_{holes}).$
$Isolated_{object}\ = map\ the\ pixels\ of\ the\ Mask_{connected\ regions}\ to\ the\ original\ image\ pixels$
// Check the isolated object has successfully satisfy the requirements.
$Success = Call\ algorithm\ (2)\ to\ the\ Isolated_{object}$
$Increament\ the\ Alpha_{Thre}\ by\ one$
}$\boldsymbol{While}\ (Success == false)$
End

Figure- 5 illustrates the comparison between the Sobel based segmentation and the Sobel based Gamma Stretching based segmentation.

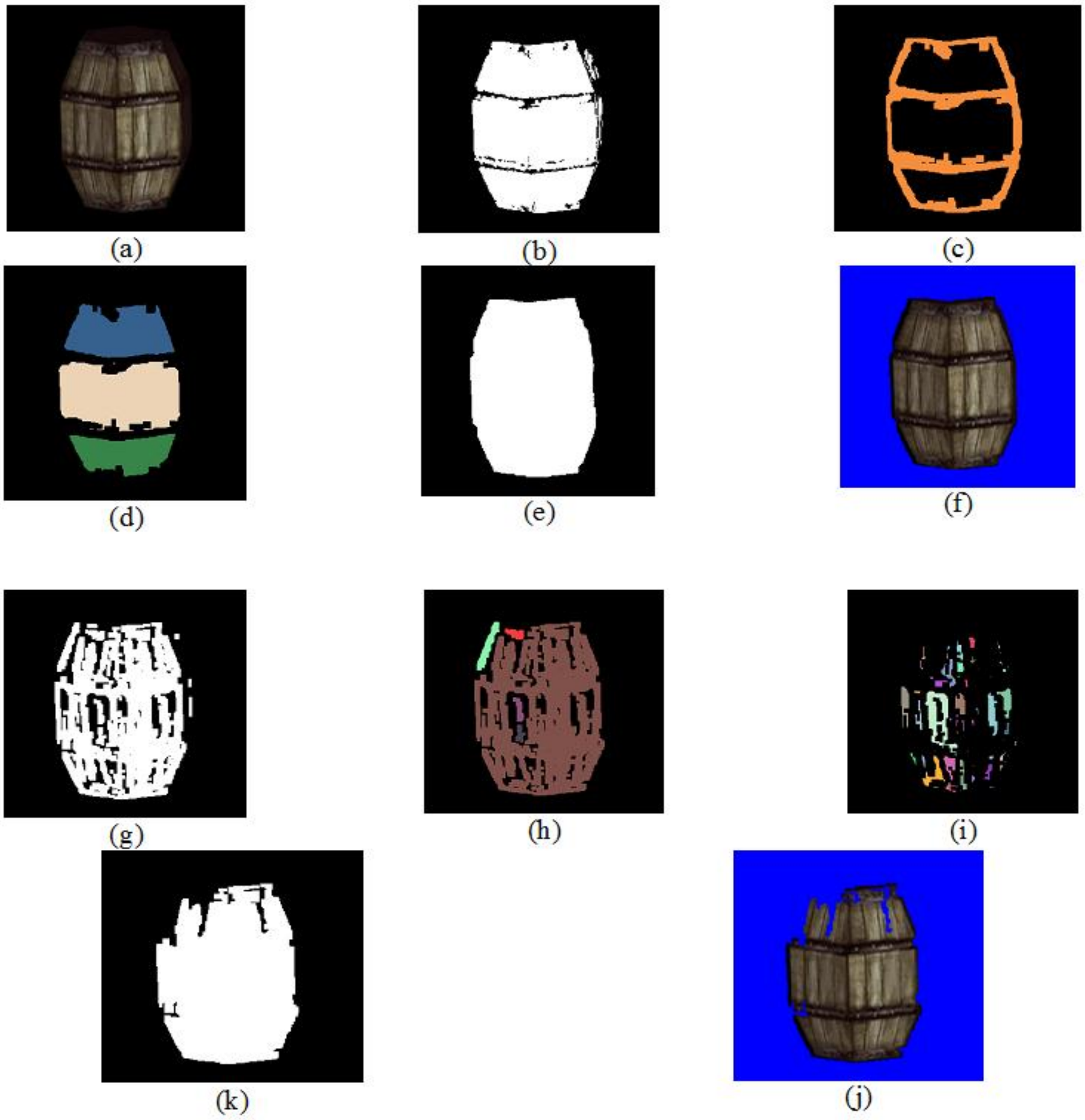

Figure 5-Image Segmentation based Sobel Edge Detector with and without Gamma Stretching, **(a)** original image**, (b)** Stretch image with Red channel and alpha= 0.1, **(c)** Edge map after applying Sobel edge detector and noise removal by Seed filling**, (d)** Black segment, **(e)** object after gabs filling With Gamma Stretching, **(f)** Isolated object with Gamma Stretching**, (g)** Edge map by Sobel edge detector with threshold =70**, (h)** connect boundaries pixels after applying seed filling algorithm, **(i)** Black segments**, (j)** Object after applying gabs filling Without Gamma Stretching, **(k)** Isolated object Without Gamma Stretching.

Based on Figure- 5, it can be simply noticed that the proposed Sobel based segmentation fails to capture the object because the light intensities of the object boundaries and background are similar. Therefore, the object has been processed through Gamma stretching to isolate the object boundaries pixels from the background pixels.

Experimental Results and Performance Comparison

There are several parameters will be tuning before applying the segmentation algorithm which are the boundary box, standard deviation threshold, and the number of pixels out of boundary box threshold. Fundamentally, the best boundary box threshold is 0.1 from the width and the height of the image, while the best low standard deviation threshold that has been applied is 25. Besides, the best threshold for the pixels that exceed the boundary box is 0.05 from the image perimeter.

As it is considered briefly earlier, different edge thresholds and alpha values have been used to get the optimal parameters and improving the segmentation process. Table-1 shows the Sobel based segmentation result of the empty class.

Table 1- Results of the proposed Adaptive segmentation based Sobel edge detector

Test Images	Edge Threshold	Success Isolation	Failed Isolation	Accuracy%
760	50	526	234	69.2105263
760	60	535	225	70.3947368
760	70	570	190	75
760	80	578	182	76.0526316
760	90	526	234	69.2105263

The best result that has been achieved with edge threshold is equal to 80. Besides, the failed images are entered to the second proposed segmentation method to isolate the failed images. Table-2 illustrates the segmentation accuracy of Sobel operator with Gamma Stretching.

Table 2- Results of the proposed Adaptive Segmentation based on Sobel with Gamma stretching

Test Images	Edge Threshold	Alpha	Success Isolation	Failed Isolation
182	80	0.1	9	173
182	80	0.15	10	172
182	80	0.2	8	174
182	80	0.25	8	174
182	80	0.3	8	174
182	80	0.35	7	175

The second proposed method has solved some of the images issues and improved the segmentation process. In fact, it could isolate some of the images which have weak edges intensities between the boundaries of the object and background. However, to draw the final segmentation accuracy, the results of the two proposed methods are aggregated. Table- 3 illustrates the segmentation results based on the proposed segmentation algorithms.

Table 3-The final segmentation accuracy of the proposed segmentation methods

Method	***Correct Segmentation***
Segmentation based Sobel edge detection	578
Segmentation based Sobel operator with Gamma Stretching	10
Total Success	588
All Images	760
Total Success	588
Accuracy %	77.368

After drawing the final segmentation accuracy of the proposed methods, it is satisfactory to compare the results of the proposed methods with the state-of-the-art method. In fact, saliency Cut method has been adopted for this purpose. Table- 4 demonstrate the segmentation accuracy of the proposed method and the Saliency Cut method.

Table 4-Results of comparison between the proposed adaptive segmentation method and Saliency Cut segmentation method

Method	***Total***	***Success***	***Fail***	***Accuracy %***
Proposed Adaptive Segmentation method	760	588	172	77.368
Novel Saliency Cut Method	760	471	289	61.9737

Based on the results of Table-4, it becomes evident that the proposed method outperforms the benchmark method denoted by Saliency Cut. Based on the analysis of the experiments results; the Salience Cut segmentation method has faced several problems such as the intensities pixels of the object boundary and background which are almost similar, and it's very sensitive to highly textured images. Since the Saliency Cut method is mainly based on global contrast to capture the saliency regions in the image, this approach could fail to isolate the region of interest when there are objects which have almost similar contrast for both foreground and background. This issue is considered as the main problem which faces this segmentation approach. Figure -6 provides examples of the images which have passed and failed through using the proposed adaptive segmentation method.

Figure 6- Examples to some of the images that have been successfully isolated by the proposed segmentation methods.

Conclusion

In this research paper, a modified adaptive segmentation method has been proposed and evaluated based on standard real world images dataset namely Caltech 101 dataset. Fundamentally, the proposed iterative segmentation process based on the new segmentation criteria has shown effective results because of its flexibility in verifying the region of interest. Apart from that, the proposed adaptive segmentation method gives satisfactory segmentation results when it compared with the state-of-the-art method namely Salience Cut with 77.368 %. In summary, the proposed method has fallen to capture the region of interest in some images because of high interference between the object foreground and background and the non-homogenate object. Therefore, as future works, it can use other metric such as colors to find the homogenate regions and extract the objects.

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