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Comparing the Main Approaches of Image Segmentation

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Abstract

Images are important medium for conveying information; this makes improvement of image processing techniques also important. Interpretation of image content is one of the objectives of image processing techniques. Image interpretation that segments the image to number of objects called image segmentation. Image segmentation is an important field to deal with the contents of images and get non overlapping regions coherent in texture and color, it is important to deal only with objects with significant information. This paper presents survey of the most commonly used approaches of image segmentation and the results of those approaches have been compared and according to the measurement of quality presented in this paper the Otsu's threshold method give the best result with less time.

Keywords: segmentation, threshold, region growing, region split and merge.

مقارنة بين الطرق الاساسية لتجزئة الصورة

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الخلاصة

الصور تعد وسط مهم لنقل كمية كبيرة من المعلومات لذلك من الضروري تطوير طرق معالجة الصور الرقمية. من اهم خوارزميات معالجة الصور هي عملية تجزئة الصور التي تهدف الى تجزئة محتويات الصورة الى عدد من الكائنات بحيث تكون الاجزاء غير متداخلة من ناحية الالوان اوالنسيج. في هذا البحث سوف يتم مناقشة الطرق الاكثر استخداما لتجزئة الصور ومقارنة نتائج هذه الطرق حيث وضحت النتائج ان طريقة OTSU هي افضل طريقة من ناحية الكفاءة وسرعة المعالجة.

1. Introduction

Digital image processing, or computer imaging, can be defined as the acquisition and processing of visual information by computer. The importance of digital image processing is derived from the fact of visual sense that is a primary sense. *Image analysis* involves the examination of the image data to facilitate solving an imaging problem. [1]

The image analysis process requires taking vast amounts of low level pixel data and extracting useful information. Mid-level process is characterized by the fact that its inputs generally are images, but its outputs are attributes extracted from those images such as, edges, contours, and the identity of

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individual objects. Mid-level processing on images involves tasks such as segmentation (partitioning an image into regions or objects), description of those objects to reduce them to a form suitable for computer processing, and classification (recognition) of individual objects. [1]

The image segmentation aims to find regions that represent objects or meaningful parts of objects. Division of the image into regions corresponding to objects of interest is necessary before any processing can be done at a level higher than that of the pixel. Image segmentation methods will look for objects that either have some measure of homogeneity within them, or have some measure of contrast with the objects on their border. Most image segmentation algorithms are modifications, extensions, or combinations of these two basic concepts. The homogeneity and contrast measures can include features such as gray-level, color, and texture. Once some preliminary segmentation performed higher level object properties may incorporated, such as shape or color features, into the segmentation process [1].

The remaining paper organized as follows, in section 2 some works that have the similar objective of this paper presented. In section 3 some of the image segmentation algorithms discussed briefly. In section 4 the results of the discussed algorithm showed on three images. In section 5 the measurement of the performance of these algorithms calculated and discussed. In section 6 conclusion of this work presented.

2. Related Work

Image segmentation can be viewed as a partitioning of an image into regions having some similar properties, (e.g. color, texture, shape), or as a partitioning of the image into semantically meaningful parts [2].

There is neither one algorithm can be look good for all type of images, nor all algorithms equally good for a specific kind of image. Image segmentation process stills a challenge trouble in image processing and computer vision and remains a pending problem. There is number of research for comparison the essential image segmentation technique, the work that most related are:

1. In [3] this paper illustrates various segmentation methods applied in the field of ultrasound and SAR Image Processing, introduces the term image segmentation, characterize major image segmentation algorithms.
2. In [4] this paper illustrates summarization of main segmentation methods, its benefit and its drawbacks.
3. In [5] this paper gives overall view of achievements, problems and image segmentation open issues in the area of research and the use of the methods in different areas. The techniques considered according to three methods: Threshold method, Edge detection method and Region growing method.
4. In [6] this paper gives survey of various approaches of image segmentation.
5. In [7] this paper provides survey of several approaches of segmentation methods with their clustering techniques.

3. Image Segmentation Algorithms

Image segmentation techniques can be divided to the following three main categories: (1) Segmentation Based on Edge Detection, (2) Thresholding Method, and (3) Region Based Segmentation [1].

3.1 Segmentation Based on Edge Detection

Edge based segmentation is the location of pixels in the image that correspond to the boundaries of the objects seen in the image. It is then assumed that since it is a boundary of a region or an object then it is closed and that the number of objects of interest is equal to the number of boundaries in an image. For precision of the segmentation, the perimeter of the boundaries detected must be approximately equal to that of the object in the input image. For instance, these methods have problems with images that are: edgeless, very noisy, very smooth boundary, and texture boundary [5].
Edges defined as discontinuities of brightness in the image. Pixel value in a region is compared with neighboring pixels to identify edges. There are different edge detectors used to partition image such as Robert, Sobel, Prewitt, Canny, Laplacian of Gaussian, and Gradient [3].

The **Roberts operator** is a simple approximation to the first derivative. It marks edge points only; it does not return any information about the edge orientation. It is the simplest of the edge detection operators and will work best with binary images. Two forms exist for Robert operator the first is:

$$\sqrt{[I(r,c) - I(r-1,c-1)]^2 + [I(r,c-1) - I(r-1,c)]^2}$$

The second form of Robert operator is:

$$|I(r,c) - I(r-1,c-1)| + |I(r,c-1) - I(r-1,c)|$$

Where I(r,c) is image pixel at r (row) and c (column). [1]

The **Sobel and Prewitt operators** are similar but with different masks coefficients, they approximate the gradient by using a row and a column mask, which will approximate the first derivative in each direction. They find edges in both the horizontal and vertical directions, and then combine this information into two metrics magnitude and direction. [1]

Sobel horizontal and vertical masks are:

VERTICAL EDGE

$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

HORIZONTAL EDGE

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

Prewitt horizontal and vertical masks are:

VERTICAL EDGE

$$\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

HORIZONTAL EDGE

$$\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

These masks are each convolved with the image. At each pixel location we find two numbers corresponding to the result from the vertical edge mask and from the horizontal edge mask. These results used to determine two metrics, the edge magnitude and the edge direction, which are defined as follows: [1]

Edge Magnitude:

$$\sqrt{c_1^2 + c_2^2} \quad \text{.....(1)}$$

Edge Direction:

$$\text{Tan}^{-1}\left[\frac{c_1}{c_2}\right] \quad \text{.....(2)}$$

Where, c_1 corresponding to the result from the vertical edge mask, and c_2 from the horizontal edge mask [1].

Canny edge detector Canny Edge Detector requires more calculation than Sobel and Robert's Edge Detector. Canny edge detector consists of four primary steps which are as follows [4]:

1. Blur image by convolve Gaussian filter with image to reduce the effect of noise.
2. Sobel operator is applied to the image to detect the edge strength (magnitude) and edge directions.
3. The directions of edge can be considered by detecting and minimize the pixels that not related to the edges.
4. At the end removing non continuous edges, this required calculating of threshold value for image and compares the pixel value with threshold obtained. If pixel value is more than the threshold, it is considered as an edge or it is rejected.

Laplacian Unlike the Sobel and Prewitt edge detection masks, the Laplacian masks are rotationally symmetric, or isotropic, which means edges at all orientations contribute to the result. They are

applied by selecting one mask and convolving it with the image. The sign of the result (positive or negative) tells us what side of the edge is brighter. [1]

Type 1

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

Type 2

$$\begin{bmatrix} -2 & 1 & -2 \\ 1 & 4 & 1 \\ -2 & 1 & -2 \end{bmatrix}$$

Type 3

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

3.2 Thresholding Method

Threshold based segmentation is the easiest way of segmentation but powerful method for partition images that have bright objects on dim background. Thresholding method depends on characteristics of image; it converts an input image *f* into an output binary image *g* based on a given threshold *T* as follows:

$$g(i,j) = \begin{cases} 1 & for\ f(i,j) \geq T \\ 0 & for\ f(i,j) < T \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where *i* and *j* are X and Y coordinates, g(i,j)=1 indicates the pixel *(i,j)* belongs to the object, and g(i,j)=0 means it belongs to the background (or vice versa). T is a threshold value in the selected feature space [8].

There are two methods of selecting threshold value, global thresholding and local thresholding. When Threshold value (T) is constant, the method become global thresholding otherwise it becomes local thresholding. Limitations of thresholding method are only two classes are generated; segmentation technique is not applicable for complex images. In addition, thresholding is sensitive to noise because it does not take into account the spatial characteristics of the image, so separation of the image histogram becomes more difficult. [3]

Otsu approach is successful approach for image thresholding. Otsu approach select best threshold T by calculating *between class variance* that have maximum value, (i.e the *within class variance* that have minimum value). Compute weight, mean, and variance for every value in the graylevel image (i.e. 0-255) and the optimal threshold will be equal to the lowest sum of weighted variance. Faster approach is to select the threshold with the maximum between class variance also has the minimum within class variance [9].

Within Class Variance σ_w:

$$\sigma_w^2 = W_b * \sigma_b + W_f * \sigma_f \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Between Class Variance σ:

$$\sigma_b^2 = \sigma^2 - \sigma_w^2 = W_b W_f (\mu_b - \mu_f)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where

$\boldsymbol{\sigma_b}$ is the background variance, $\mathbf{W_b}$ is the weight of background, $\boldsymbol{\sigma_f}$ is the foreground variance, $\mathbf{W_f}$ is the weight of foreground, $\boldsymbol{\mu_b}$ is the Mean background, and $\boldsymbol{\mu_f}$ is the Mean foreground.

3.3 Region Based Segmentation Methods

Method for grouping pixels that are belongs to an object. The part that is discovered for segmentation might be closed. Segmentation by region referred to it as "Similarity Based Segmentation" [4].

By comparing region method to edge method, region algorithms are simple and more insusceptible to noise. Edge algorithms for segmentation depend on abrupt changes in intensity near edges whereas region algorithms segment image to regions that are similar according to a set of predefined criteria. Segmentation algorithms based on region mainly include following methods [3]:

3.3.1 Region Growing

Region growing based on predefined criterion for grouping pixels in image to sub regions or larger regions. These criteria depend on brightness information or edges in the image. One example for the region growing method is seeded region growing method. It works on the assumption that, the intensity values within each region conforms to Gaussian distribution; the mean intensity (brightness) value for each region is different. Region growing approach is the opposite of the split and merges approach. The procedure as follows [10]:

1. Region growing takes initial set of seeds for image every seed point corresponds to a single region.
2. The regions are iteratively grown by comparing all neighboring pixels to the regions (the seed points are compared to their neighbors based on a criterion of similarity such as grey level brightness and make a stopping rule). The neighbors of a pixel are computed either by 4-connectivity or 8-connectivity.
3. The difference between a pixel's intensity value and the region's mean is used as a measure of similarity.
4. The pixel with the smallest difference measured is allocated to the respective region.
5. This process continues until all pixels are allocated to a region (region growing Stops when there isn't any more pixels applicable to the criterion).

This method can be easily applied to gray scale images, and can be extended to color images after suitable choice of color space.

The region based segmentation is partitioning of an image into similar/homogenous areas of connected pixels through the application of homogeneity/similarity criteria among candidate sets of pixels. Every pixel in a region is similar based on some features or calculated property like colour, intensity and/or texture. Failure to adjust the homogeneity/similarity criteria accordingly will produce undesirable results, some of them are, the partitioned region could be smaller or larger than actual, this is classified as over segmentation or under segmentation of the image, and Fragmentation [5].

Seed Selection

Selection of seed is based on the nature of the problem. The conventional seed selection method is non automatic. The edge based method is used by some researchers to select seeds. If the seed selection is from the center of the region segmentation becomes more effective and efficient. The criteria for automatic seed selection are [11]:

1. Seed must have high similar to its neighbor.
2. For an expected region there must be at least one seed.
3. Seeds for different regions must be disconnected.

3.3.2 Region Splitting and Merging

Image can be divided into a set of random non connected regions then merge regions that satisfy the conditions of image segmentation instead of choosing seed points. Split and merge region method is usually applied based on quad tree method. Suppose R represent the all image region and choose a predicate Q this can be clearer by going through these steps [3]:

1. At the beginning entire image uses, if Q(R) = FALSE, means if the condition not met for this region the image divided into quadrants, then every quadrant is checked if the condition not met again for this segmented region then subdivide the quadrants to sub quadrants and so on until there is no more splitting possible.
2. To avoid drawback of many splitting that may create adjacent regions have same properties allow merging. Any regions adjacent R_j & R_k for which ,$Q(R_j \cup R_k)$ = TRUE will mereged.
3. If there are no more matching for merging then stop.

4. Implementation

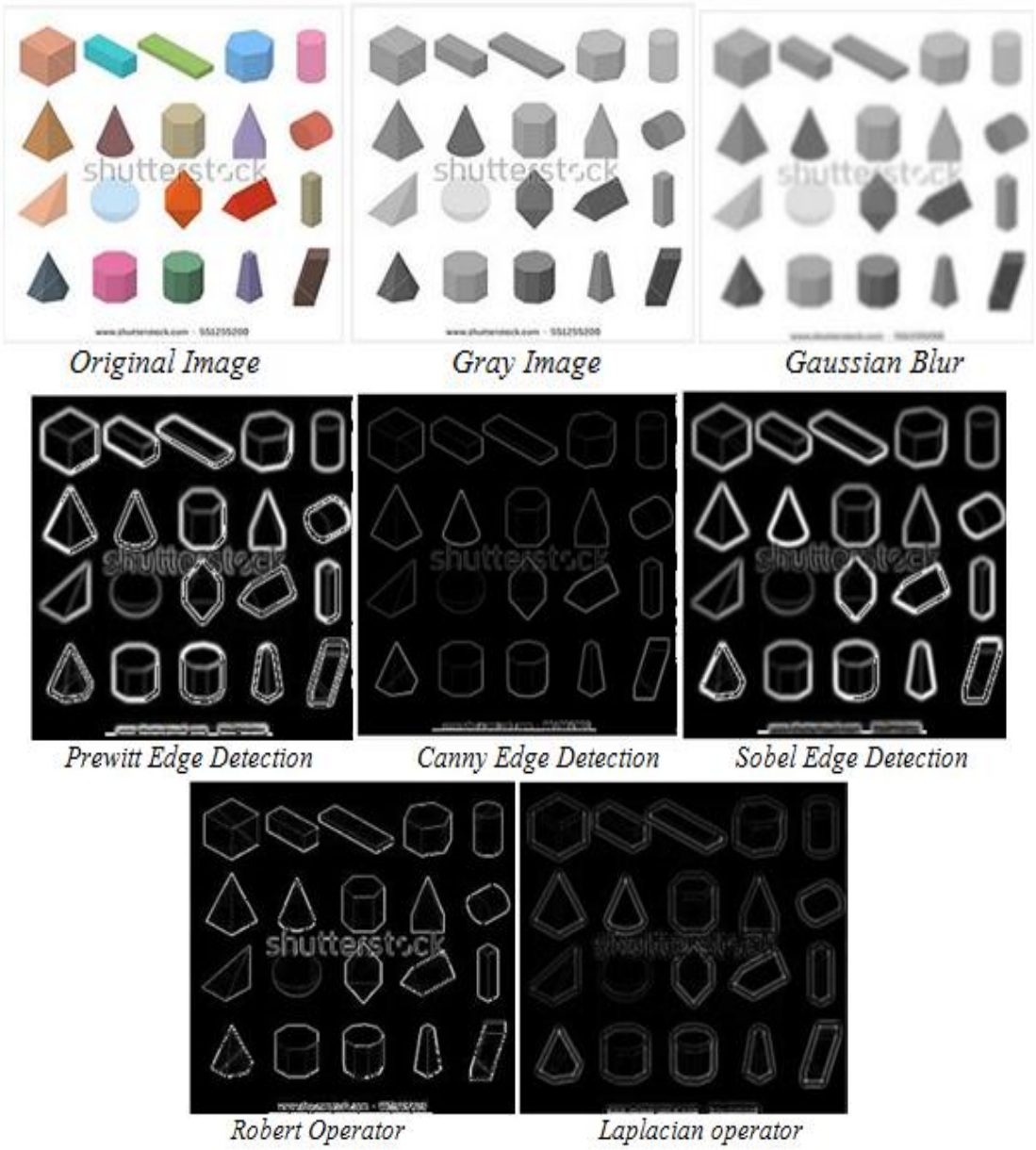
The segmentation methods proceeded by conversion of colored image to gray scale image, and blurring gray scale image by Gaussian filter then image segmentation method apply to processed image.

Image segmentation approaches have been performed on many images using Microsoft visual basic.net software. Segmentation method has been applied to 61 images, only four of them illustrated with their results.

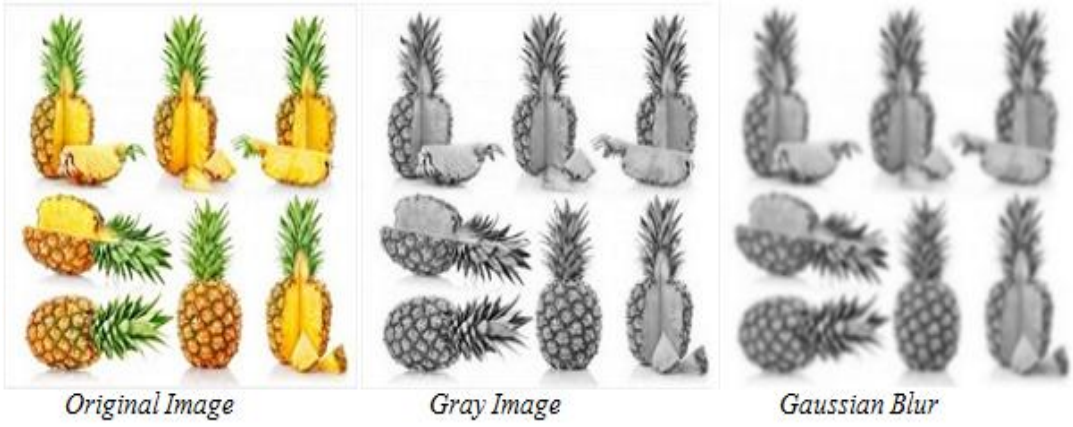
The window size was chosen by trial-and-error a size less than (5 × 5) was inadequate for smoothing caused by the noise, whereas a larger size produced an over smooth segmentation.

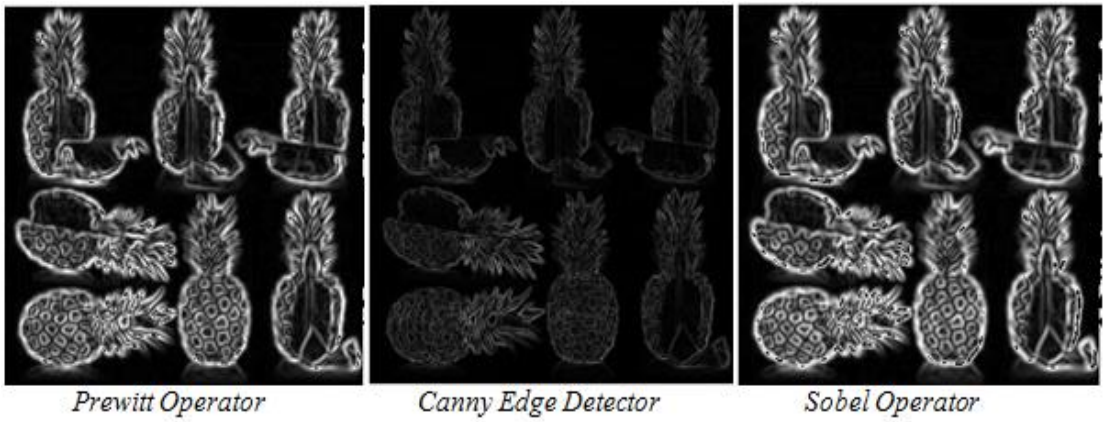
- **Edge Detection**

1. ***Geometrical shapes picture***

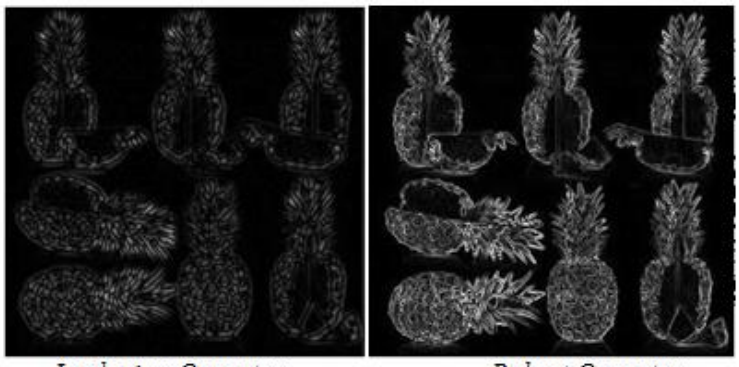


2. ***Pineapple Picture***





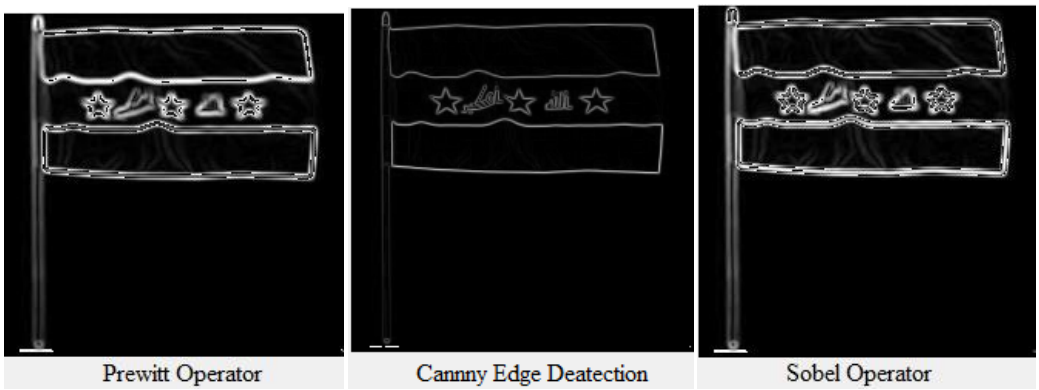
Prewitt Operator *Canny Edge Detector* *Sobel Operator*



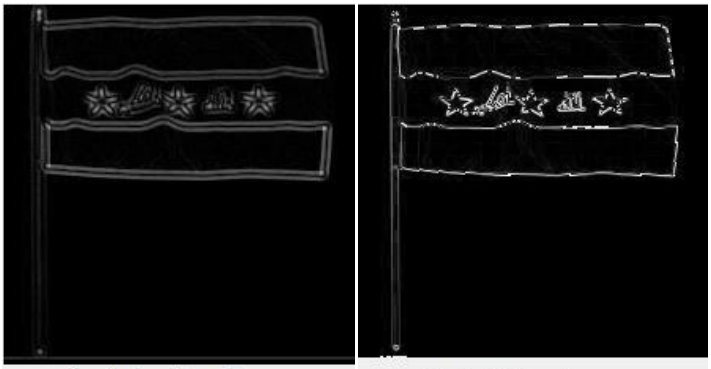
Laplacian Operator *Robert Operator*

3. *Iraqi Flag picture*

Original Image Gray Image Gaussian Blur

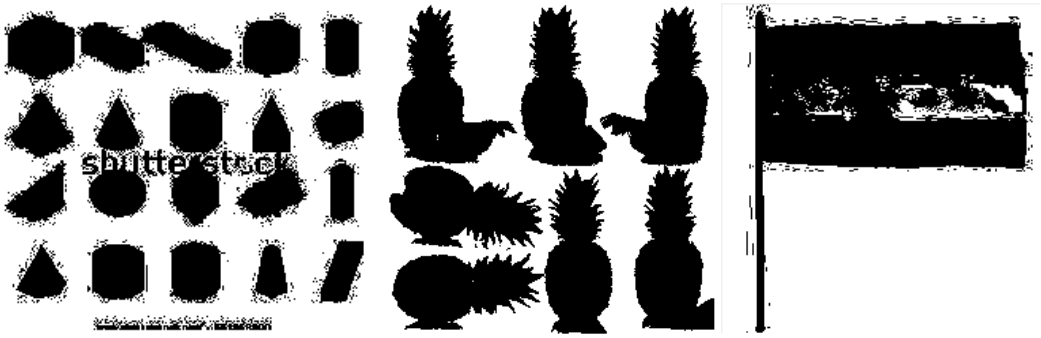


Prewitt Operator Cannny Edge Deatection Sobel Operator



Laplacian Operator Robert Operator

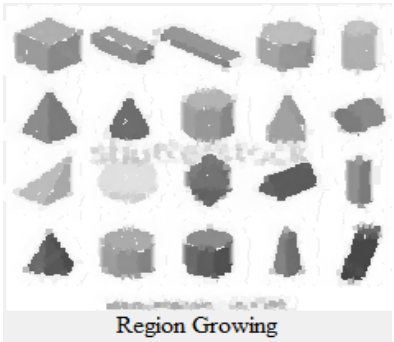
- **OTSU's Threshold method**



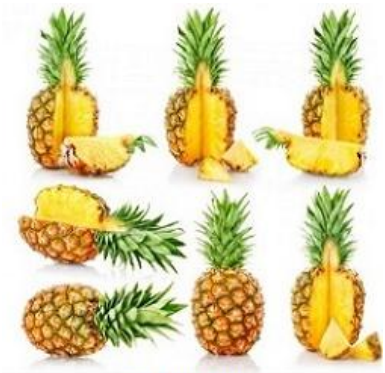
Otsu's within class variance Otsu's within class variance Otsu's within class variance

- **Region Growing**

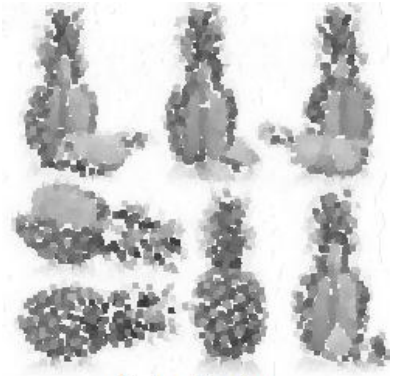
Original Image



Region Growing



Original Image



Region Growing

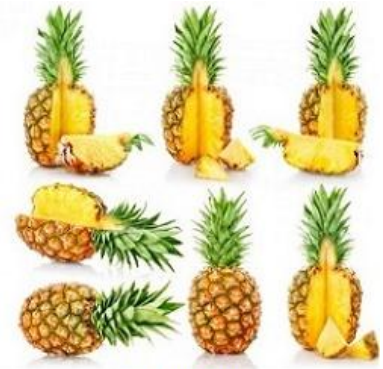
Original Image

Region Growing

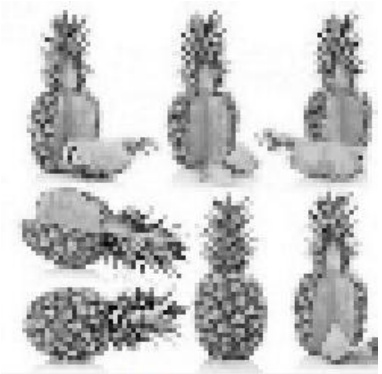
- **Split and Merge**

Original Image

Geometric shapes



Original Image



Pineapple

Original Image

Iraqi flag

5. Experimental Results

Quantitative performance of algorithms is reported in terms of sensitivity, specificity:

$$Sensitivity = \frac{TP}{TP + FN} \quad \text{... (6)}$$

$$Specificity = \frac{TN}{TN + FP} \quad \text{... (7)}$$

Where,

TP= Pixels correctly classified as object in ground truth and by algorithm, FP= Pixels not classified as object in ground truth, but classified as object by algorithm, TN= Pixels not classified as object in ground truth and by algorithm, FN= Pixels classified as object in ground truth, but not classified as object by algorithm [12].

Table-1, Table-2 and Table-3 show the performance results of image segmentation techniques.

In this paper Ground truth for every image created by calculating local mean of image versus global mean while the algorithm represent the segmentation method.

Local mean versus global mean create image of objects which is useful for comparison with other segmentation methods (difference between local mean versus global mean image and segmented image) to determine false pixels classification (accuracy of algorithm).

Increase the value of specificity and sensitivity increase the performance of segmentation method. The result of sensitivity and specificity shows Otsu's method gives the best result (e.g. pineapple picture have 0.9815 for sensitivity that is larger than the value of sensitivity of the same picture in region growing method 0.7991 and split and merge method 0.7139), and so on for the other two pictures. The ratio of sensitivity and specificity is limited between 0 and 1; it is the ratio of true classification.

Table 1- OTSU's Method

Segmentation Method	**Otsu's Method**		
Measure | Picture	**Pineapple**	**Geometric Shapes**	**Iraqi Flag**
Sensitivity	0.9815	0.9663	0.9668
Specificity	0.8699	0.8781	0.8722

Table 2- Region Growing Method

Segmentation Method	**Region Growing Method**		
Measure | Picture	**Pineapple**	**Geometric Shapes**	**Iraqi Flag**
Sensitivity	0.7991	0.5863	0.9339
Specificity	0.7866	0.8472	0.9321

Table 3-Split and Merge Method

Segmentation Method	**Split and Merge Method**		
Measure | Picture	**Pineapple**	**Geometric Shapes**	**Iraqi Flag**
Sensitivity	0.7139	0.7496	0.908
Specificity	0.8881	0.8946	0.882

The evaluation procedure is always critical because it quantifies the efficiency of an algorithm, and provides a complete overview of algorithms. A common problem is that it is difficult to objectively measure the goodness of a segmentation produced for such a task. Obtaining absolute ground truth is almost impossible since different people produce different manual segmentations of the same images. Segmentation methods applied to gray images smoothed using (5*5) Gaussian filter with sigma (1.5). Region growing method performed on image using automatic seed selection (seeds selected every n pixels) and compared to the mean of its neighbors if there are small difference then set all these pixels to the same color else set the two regions to different color.

Experiment done on many images, every image contain number of objects. As seen in image (a) image contains many objects each object has more than one color, the segmentation procedure has responsibility to display each object as one object, in image (b) the picture of Iraq flag showed as one object while multiple parts in the same object and so on.

6. Conclusion

This paper presents a brief discussion of the common image segmentation methods and comparing the results of these methods based on performance measurement. Before executing image segmentation algorithms the image must be converted from color to gray then blurring grayscale image using Gaussian filter to remove noise and increase the quality and accuracy of algorithms.

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