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Research paper

The problem of image segmentation and de-noising methods and various approaches to its solution

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Abstract

Image segmentation and de-noising are required to be used in digital image processing according to the recent since researches in this field, At present image de-noising and segmentation take part in real-world applications such as medical fields, computer vision, computer graphic, satellite, magnetic resonance imaging, computed tomography, single photon emission and computed tomography etc. These two methods are used for different images but mainly focus on medical images. In this paper provides an overview of the main classes of methods for segmentation of images, analysis of the effectiveness of their application and development prospects for the implementation of methods adaptive segmentation for the conditions of significant variations in the parameters of images. After that we present the comparison between segmentation techniques based on some specific parameters and find out suitable one.

Keywords: *Image Segmentation; Image De-Noising; Medical Images; Assessment Methods; Structural Similarity; Non-Linear Method.*

1. Introduction

Famous techniques of image segmentation which are still being used by the researchers are Edge Detection, Threshold, Histogram, Region based methods, and Watershed Transformation etc. These are discussed below. Since images are divided into two types on the basis of their color, i.e. gray scale and color images. Actually, Color image segmentation process is completely different than the grayscale images [1]. The algorithm functions and performance depends on the image type [2]. The image contains pixels and each pixel contains information, the property of each pixel and its neighbor is a very important process for any segmentation algorithm. It can also be representing as similarity of pixels in any region and discontinuity of edges in image. Edge based segmentation is used to divide image on the basis of their edges. Region based methods used the threshold in order to separate the background from an image, whereas neural network based techniques used the learning algorithm to train the image segmentation process [3]. There are generally two types of image- raster type and vector type. Raster images are images having a finite set of digital values which are represented in a fixed number of rows and columns of pixels where these pixels are stored in memory as a two-dimensional array. Digital images are usually referred as raster images. Vector images are images generated from mathematical geometry known as vector which have points having both magnitude and direction. [4]. Some segmentation methods often have poor results, as they do not use previous information about objects containing elements to be segmented.[5]. Medical imaging is the technique and process used to create images of the human body for clinical purposes or medical science. It is widely acclaimed as a hallmark of modern medicine. Diagnostic imaging is an umbrella term for a wide variety of scans, examinations and images that are used in the field of medicine such as X-ray, computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US) and dermoscopy images (DI). [1], [22] There is no doubt that medical imaging solution technology plays a vital role in the diagnosis and treatment of patients suffering from serious illness.
Moreover, the medical images contain a numerous number of noises as (Gaussian, Poisson, Rician and impulse noise i. e. (salt and pepper noise)[7]. The technique of image segmentation usually depends on the image de-noising, for that; different numbers of techniques were used by different researchers for both image segmentation and diagnosing. In this paper, we are discussing and explaining the different image segmentation and de-noising, techniques which are organized into sections. Section (i) image de-noising method, section (ii) image segmentation and algorithms, section (iii) Review of Literature and section (iv) Conclusion.

2. Analysis of parameters of image segmentation methods

2.1. Image de-noising method

The performance of the Image de-noising method is measured by using the mathematically defined measures such as: (i)Average pixel intensity (M), (ii)Standard Deviation, (iii)Mean Square Error(MSE),(Iv)Root Mean Square Error(RMSE),(V)Mean Absolute Error(MSE),(vi)Peak Signal to Noise Ratio(PSNR),(vii)Structural Similarity, (viii), Entropy (ix) and Universal Image Quality Index[8,9].

i) Average Pixel Intensity (M).

It determines the dissimilarity of the image by adding all the pixels and dividing the total pixels of the image.

$$Mn = \frac{\sum_{x_1=1}^{A}\sum_{x_2=1}^{B} Q(x_1, x_2)}{N \times M} \quad (1)$$

Where $Q(x_1,x_2)$ is the intensity value at the pixel location (x_1,x_2) , Mn Average pixel intensity or mean, N and M are the rows and columns of the image.

ii) Standard Deviation (SD).

standard deviation indicates that the data points are spread out over a large range of values. Mathematically standard deviation is given by

$$\sigma = SD = \left(\frac{\sum_{x_1=1}^{A}\sum_{x_2=1}^{B}\left(Q(x_1,x_2)-Mn\right)^2}{N \times M} \right)^{\frac{1}{2}} \tag{2}$$

iii) Mean Square Error (MSE)

MSE is a measure of image quality index. The large value of mean square means that image is a poor quality. MSE is calculated by the formula.

$$MSE = \frac{1}{N \times M}\sum_{x_1=1}^{A}\sum_{x_2=1}^{B}\left[Q(x_1,x_2)-\tilde{Q}(x_1,x_2)\right]^2 \tag{3}$$

Where N and M are image size in pixels (the rows and columns of the image), Q and $\tilde{Q}$ are the original and enhanced images, x_1, x_2 are integers , If the images are the same, then MSE = 0.

iv) Root Mean Square Error (RMSE)

The RMSE of an estimator Q with respect to the estimated parameter $\tilde{Q}$ is defined as the square root of the mean square error. Its mathematical equation is [12].

$$RMSE = (MSE)^{\frac{1}{2}} = \left(\frac{1}{N \times M}\sum_{x_1=1}^{A}\sum_{x_2=1}^{B}\left[Q(x_1,x_2)-\tilde{Q}(x_1,x_2)\right]^2\right)^{\frac{1}{2}} \tag{4}$$

v) Mean Absolute Error (MAE)

The Mean Absolute Error measurement is accomplished to find proximity between source and fused image. MAE is calculated by the formula.

$$MAE = \frac{1}{N \times M}\sum_{x_1=1}^{A}\sum_{x_2=1}^{B}\left|Q_f(x_1,x_2)-Qs(x_1,x_2)\right| \tag{5}$$

In which $Q_f(x_1,x_2)$ is fused image, $Q_s(x_1,x_2)$ is the source image respectively.

vi) Peak Signal to Noise Ratio (PSNR)

PSNR tells about the revamped image is defined as

$$PSNR = 10\log_{10}\left(\frac{(\max)^2}{MSE}\right) \tag{6}$$

Where the MAX value taken by the image pixel (for 8-bit images), MSE is the mean square error.

vii) Structural Similarity (SSIM)

The main purpose of is SSIM to display the quality of the image.SSIM depends on three parameters such as contrast, luminance, and structural term. The product of these parameters gives the Structural Similarity of the image. The parameter $L(x_1,x_2)$ is the luminance assessment function determines the quality of having only a small margin between two images in terms of mean luminance (μ_{x_1} and μ_{x_2}). The parameter $C(x_1,x_2)$ is the contrast assessment function compute the quality of having only a small margin between two images in terms of standard deviations (σ_{x_1} and σ_{x_2}). The parameter $S(x_1,x_2)$ is the structure assessment function determines the correlation coefficient between two images in terms of covariance ($\sigma_{x_1x_2}$). [21], [24].

$$SSIM(x_1,x_2) = \left[L(x_1,x_2)\right]a_1 \times \left[C(x_1,x_2)\right]b_1 \times \left[S(x_1,x_2)\right]c_1 \tag{7}$$

Where,

$$L(x_1,x_2) = \frac{2\mu_{x_1}\mu_{x_2}+D_1}{\mu_{x_1}^2+\mu_{x_2}^2+D_1} \tag{8}$$

$$C(x_1,x_2) = \frac{2\sigma_{x_1}\sigma_{x_2}+D_2}{\sigma_{x_1}^2+\sigma_{x_2}^2+D_2} \tag{9}$$

$$S(x_1,x_2) = \frac{\sigma_{x_1x_2}+D_3}{\sigma_{x_1}\sigma_{x_2}+D_3} \tag{10}$$

Where D1, D2 and D3 are small constants given by

$D_1 = (R \times S_1)^2$ And $D_2 = (R \times S_2)^2$

Where R is the size of the image , D_1 is a small constant value at $S_1 \ll 1$, D_2 is positive constant value at $S_2 \ll 1$ and $D_3 = D_2/2$. μ_{x_1} and μ_{x_2} are the local mean, σ_{x_1} and σ_{x_2} are the standard deviation, $\sigma_{x_1x_2}$ is the cross-covariance of x_1, x_2 for the image. Assume $a_1 = b_1 = c_1 = 1$, $D_1 = (R \times S_1)^2$ and $D_2 = (R \times S_2)^2$.

The resulting Structural Similarity (SSIM) index is given by

$$SSIM(x_1,x_2) = \frac{\left(2\mu_{x_1}\mu_{x_2}+D_1\right)\left(2\sigma_{x_1x_2}+D_2\right)}{\left(\mu_{x_1}^2+\mu_{x_2}^2+D_1\right)\left(\sigma_{x_1}^2+\sigma_{x_2}^2+D_2\right)} \tag{11}$$

The similarity measure satisfies the following conditions:

1) Symmetry: SSIM(x_1, x_2) = SSIM(x_2, x_1)
2) Boundedness: SSIM(x_1, x_2) ≤ 1
3) Unique maximum: SSIM(x_1, x_2) = 1 if and only if $x_1 = x_2$

viii) Entropy

Entropy is defined as amount of information contained in a image. The entropy of the image can be evaluated as:

$$E = -\sum_{x_1=0}^{A-1}\sum_{x_2=0}^{B-1} f(x_1,x_2) \times \log\left(f(x_1,x_2)\right) \tag{12}$$

Where, function $L(x_1,x_2)$ is the intensity value at the location (x_1,x_2), x_1 and x_2 are integers. [25], [26]:

ix) Average gradient (Ag)

Average gradient gives the and clarity of the image, it is given by the formula:

$$Ag = \frac{\sum_{x_1=1}^{A}\sum_{x_2=1}^{B}\left(\left(Q(x_1,x_2)-Q(x_1+1,x_2)\right)^2+\left(Q(x_1,x_2)-Q(x_1,x_2+1)\right)^2\right)^{\frac{1}{2}}}{N \times M} \tag{13}$$

x) Universal Image Quality Index (UQI)

UQI is given by the formula:

$$UQI = \frac{\left(4\times\sigma_{x_1x_2}\right)\left(\mu_{x_1}+\mu_{x_2}\right)}{\left(\mu_{x_1}^2+\mu_{x_2}^2\right)\left(\sigma_{x_1}^2+\sigma_{x_2}^2\right)} \tag{14}$$

That may be used as image quality distortion measure through three factors, such as luminance distortion, contrast distortion and loss of correlation. [29].

2.2. Image segmentation methods (ISM)

Segmentation is a step of digital image processing associated with splitting an image into areas of interest or elements. The quality of image segmentation is estimated according to factors such(i) Similarity Index, (ii)Dice Score(iii) Sensitivity or Overlap fraction,(iv) Extra Fraction,(v)Specificity,(vi)Accuracy,which can be mathematically calculated.[32], [37], [41].

i) Similarity Index (SI)

Similarity Index tells about the mutual value among input medical image and segmented output image

$$Sim.Index = SI = \frac{2 \times Tr\ Po}{2 \times Tr\ Po + Fa\ Po + Fa\ Ne} \quad (15)$$

Where Tr Po is the True Positive, it gives the volume of positive pixels properly segmented. Fa Po is the False Positive, it tells the volume of positive pixels imperfectly segmented. Fa Ne- is the False Negative, it gives the volume of negative pixels incorrectly segmented. Tr Ne is the True Negative, it tells the volume of negative pixels properly segmented.

ii) Jaccard co-efficient or dice score (DS)

Jaccard coefficient is a similarity measure used in the medical image to comparison among the performance of segmentation algorithms which has a predefined ground truth data. It is calculated using the formula

$$DS = \frac{2 \times Tr\ Po}{(Tr\ Po + Fa\ Ne) + (Fa\ Po + Tr\ Po)} \quad (16)$$

iii) Sensitivity

It describes appropriate segmentation associated with input medical images. It provided the ability of the test to identify positive results.

$$Sensitivity = \frac{Tr\ Po}{(Tr\ Po + Fa\ Ne)} \quad (17)$$

iv) Extra Fraction

Total voxels not detected as a tumor region given by the extra fraction. It is calculated using the formula

$$Extra\ Fraction = \frac{Fa\ Po}{(Tr\ Po + Fa\ Ne)} \quad (18)$$

v) (v). Accuracy

Accuracy to evaluate the performances of either manual or automated segmentations. It is calculated using the formula

$$Accuracy = \frac{Tr\ Ne + Tr\ Po}{(Tr\ Ne + Tr\ Po + Fa\ Ne + Fa\ Po)} \quad (19)$$

vi) Specificity

The true fraction of the target voxels of the entire image, It is calculated using the formula

$$Specificity = \frac{Tru\ Neg}{(Tru\ Neg + Fa\ Po)} \quad (20)$$

3. Review of literature

3.1. Classification of image segmentation techniques

There are several existing techniques which are used for image segmentation, These all Various algorithms and techniques are considered to segment the image and shown below fig(1).

a) Threshold-based methods

Threshold processing is the simplest method of segmentation, From a gray scale image, focused on image processing, thresholding is used to split an image into smaller segments, using at least one color or gray scale value to define their boundary. Current threshold-based approaches remain categories as global and local thresholding. If an image has objects with the same intensity or dissimilarity amid items furthermore high contextual, the global thresholding remains the best option to separate objects and backgrounds. In addition, the Gaussian distribution was used to determine the thresholds for common medical images. [18], [32], 36], [38].

b) Edge Based Segmentation Method

Edge detection is a fundamental tool for image segmentation. Edge detection methods transform original images into edge images benefits from the changes of grey tones in the image. In image processing especially in computer vision, the edge detection treats the localization of important variations of a gray level image and the detection of the physical and geometrical properties of objects of the scene. This is a very important and a fundamental process used to find and detect the object boundaries and the background, where, most of the image information is included in the edges boundaries, so the edge detection process actually search for the discontinuity in the pixel intensity values. [38].

c) Region Based Segmentation Method

This method work depends on the continuity, where the entire image is divided into a sub regions based on some rules such as all the pixels in one region should have the same gray level. Region based techniques work according to the common pattern in intensity values within the neighbor pixels of each cluster. Each cluster is indicated as a region and the grouping of the regions according to their anatomical or functional roles is the main objective of image segmentation. [39-42].

d) Clustering Based Segmentation Method

Content (description). In keyword based clustering, a keyword is a form of font which describes about the image keyword of an image refers to its different features. The similar featured images are grouped to form a cluster by assigning value to each feature.[39] The tools, techniques and algorithms that are used originate from fields such as statistics, pattern recognition, signal processing etc. Clustering based on the optimization of an overall measure is a fundamental approach explored since the early days of pattern recognition. The most popular method for pattern recognition is K-means clustering. [23], [39].

e) Artificial Neural Network-Based techniques (ANN).

An artificial neural network is a simulation of a real nervous system. It consists in a number of neurons that communicate with each other. The NN-based image segmentation techniques reported in the literature can mainly be divided into two categories: supervised and unsupervised methods .More details about Neural Networks are presented in [40].

f) FCM based methods

FCM remains a clustering technique that splits two or more clusters in the data collection. This scheme is often cast-off in pattern recognition. This procedure works through allocating every point allocated to each cluster center through the length amid the cluster and information point. Further details are in the cluster center, where its members are likely to move towards a special cluster center. The advantages of FCM algorithms are providing better results for overlapped datasets and better than the rule of k-means, and the implementation of FCM data into (MR) data shows the incentive result [42].

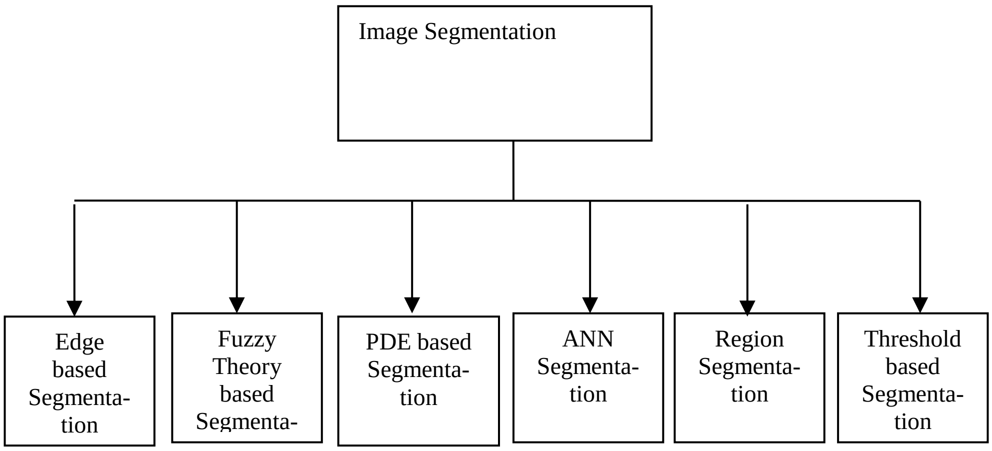

Fig. 1: Image Segmentation Techniques.

4. Conclusion

This paper explains and emphasizes a number of a non-linear image Segmentation and de-noising methods which are widely used in medical image analysis such as(MRI), also has delivered an outline the parameters of the Image de-noising method which can be calculated in terms of Mean or Average pixel intensity, Standard Deviation, Mean Square Error, Root Mean Square Error, Mean Absolute Error, Peak Signal to Noise Ratio, Structural Similarity, Universal Image Quality Index, and Entropy. Due to all above factors, and comparing the results of all variables to the experiments of medical images, in the references below, there is no single method which can be considered good for all type of images, nor all methods equally good for a particular type of image.But the majority of the approaches gives the better results and appearance can be calculated in terms of Similarity Index (SI), Dice Score (DS), Sensitivity, Extra Fraction, Specificity, Accuracy.

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