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A Survey on Evolutionary Optimization Approaches towards Medical Image Segmentation using Thresholding

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ABSTRACT- In medical image processing, image segmentation has strong role to play. What image segmentation does that it splits medical image into finite number of parts such that it is easier to analysis the region we are looking for in the medical image that is Region of Interest (ROI). Image segmentation in medical image processing is basically needed for identifying abnormalities in biomedical anatomy and help doctor and physician for diagnose. Image thresholding is an elementary method for digital image segmentation based on optimum intensity or threshold value. A computer aided autonomous process where threshold value can be obtained through a fitness function such as maximum entropy method, k-means clustering and so on. Now all it needs to optimise the fitness function using any optimisation method.

General Terms: Thresholding, Image Processing, Image Segmentation, Evolutionary Optimization.
Keywords: Optimization, Particle Swarm Optimization (PSO), Fish School Search Optimization (FSS), Medical Image Segmentation, Kapur's entropy, Fitness Function.

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1. INTRODUCTION

Medical Image processing deals with Non-destructive Testing (NDT) i.e. used to take image of internal structure of human body without affecting outer body with help of imaging tools like Magnetic Resonance Imaging (MRI), Nuclear Medicine or Positron Emission Tomography (PET), X-rays, Radiography, Fundus Image, Ultrasound, Computed Tomography (CT scan), Endoscopy, etc. This phase of Image processing is called Image acquiring. There after medical image goes through noise reduction using filters which is called Image de-noising. If medical image needs visual improvisation to improve the perception of information in the image is called Image enhancement. Extracting of ROI is possible through separating dissimilar regions and merging similar regions depending on an image attribute, to spot the abnormalities which was not visible before to the unaided eyes. This process of segregating the regions and labelling them is called Image segmentation. After Image Segmentation Image analysis, Image classification and Image management can be done according to the need of application.

A chief trouble in medical image processing is due to high changeability in medical images and due to the fact that human structure itself has leading variations upon that there are different modalities to deal with for image acquisition. It has become a necessity to use computers to assist experts in clinical studies, diagnosis, and treatment planning, etc., due to the fact that diseases are on rise so as the population and if it is not checked in time might become global health concern that is pandemics. That's the objective for us to find more reliable techniques and fine-tuning existing arsenals that we could to identify such abnormalities in an early stage. As a popular proverb states "A picture is worth a thousand words", medical image can be the epitome for a larger solution. Thresholding is one such method which is an image segmentation method, not only it is the simplest method but also an efficient method to separate regions according to a threshold value. Some of the best suited methods to pick threshold are Kapur's method and Otsu's method. Searching for best threshold value has its share complication which affects accuracy and makes computation expensive and time consuming.

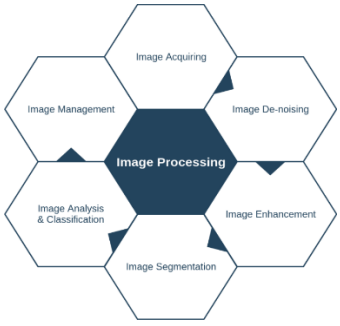

Figure 1: Image Processing

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2. MEDICAL IMAGE THRESHOLDING

Discriminating foreground from the background which segments an image into several regions of same color or gray level or intensity. Pixel intensity below threshold value (T) is marked as black (0) and those above T is marked as white (1). This means choosing proper threshold value (T) is a mammoth job. Intensities of image can be represented in an image histogram form which a threshold value need to be chosen. The basis on which threshold value can be selected can be listed as 1. Global 2. Semi 3. Multiple 4. Variable 5. P-tile Thresholding

2.1 Global Thresholding

Thresholding in which we take one intensity value i.e., threshold (T), chosen as a global threshold as a result a binary image is obtained. While considering Global Thresholding we assume image has a histogram with two peaks that represent background and object of image intensity. It means intensity value of background and object are fairly consistent over the whole image then global threshold value can be picked. In below equations I is intensity function I (x, y).

$$I = \begin{cases} 1, if\ I \geq T \\ 0, if\ I < T \end{cases} \quad (1)$$

2.2 Semi Thresholding

In this kind of thresholding the image background is masked out leaving the gray level information intact as the original medical image, this is a variation to the global thresholding as intensity level less than T is modified to black (0) and rest above T retain their gray value.

$$I = \begin{cases} I, \ if\ I \geq T \\ 0, \ if\ I < T \end{cases} \quad (2)$$

2.3 Multi Thresholding

Thresholding where multiple i.e. more than one threshold values is chosen in order to partition image into different segments. So, the resulting image no more binary image rather a multi-level image.

$$I = \begin{cases} I1, \ if\ I \geq T2 \\ I2, \ if\ T1 \leq I < T2 \\ I3, \ if\ I \leq T1 \end{cases} \quad (3)$$

2.4 Variable/Adaptive Thresholding

In here Threshold value varies throughout the image dynamically using variable value. To find out this value there are some approaches such as local thresholding depending on surrounding pixels or to find threshold value for some pre-divided regions then take those intensity values as factor while thresholding.

2.5 P-tile Thresholding

The objective of p-tile thresholding is to choose a threshold as such 1/p of the image area has gray value less than value T and rest greater than T.

3. PARTICLE SWARM OPTIMIZATION

Kennedy and Eberhart presented the heuristic worldwide optimization process in their research paper named "Particle swarm optimization", in the year 1995. PSO inclines to find the best solution as point in a D-dimensional space. In PSO a set of randomly created particles in the initial swarm are flown through the hyper dimensional search space according their pervious knowledge. They keep track of their position in the problem space which help to find the best solution. PSO algorithm is computationally cheap in the updating of the individuals per iterations.

Pseudo algorithm: PSO (Algorithm 1)
Begin
Parameter settings and initialization of swarm;
Evaluate fitness (initialize Pbest) and locate the leader (Gbest);
It = 0
Reiteration
For each particle update its V & P;
Evaluate fitness;
Update Pbest;
Terminate
Update leader (i.e. Gbest);
It ++;
Reiterate until the stopping criterion is not met, It < It_{max};
Where, V velocity, P position and It iteration parameter

3.1 PSO used in thresholding

PSO separates medical image into regions by finding the optimize threshold value such that background and foreground can be obtained. That being said PSO can be obtained through a fitness function whose task is to find the best suitable value that would optimize the function. Kapur's entropy criterion method is the best suitable fitness function adopted by many. For better results maximizing the entropy criterion method would get us optimized threshold value. Following equation is a function of threshold that represents Kapur's entropy criterion method.

$$f(t) = F0 + F1 \quad (4)$$

$$\text{Where } F0 = \sum_{i=0}^{-t1} \frac{Pi}{w0} \log_e \frac{Pi}{w0} \quad \text{where } w0 = \sum_{i=0}^{t-1} Pi \quad (5)$$

$$\text{Where } F1 = \sum_{i=t}^{L-1} \frac{Pi}{w1} \log_e \frac{Pi}{w1} \quad \text{where } w1 = \sum_{i=t}^{L-1} Pi \quad (6)$$

4. FISH SCHOOL SEARCH OPTIMIZATION

Fish School Search Optimization imitates be actions of fish swimming and searching for food. FSS is one of the recent bio inspired optimization introduced by Bastos Filho and Lima Neto in 2017 with their paper "A novel search algorithm based on fish school behavior". FSS has some operators based on its behavior pattern such as a) feeding operator, b) Swimming operator and depending on reasons one the following 1) Individual movement 2) Collective-Instinctive Movement 3) Collective- Volitive movement is performed. If an aquarium is the search space then fish could increase its weight if it gets food otherwise might lose weight. It also must be noted swimming is

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a nature of fish, individually or collectively for search of food, escaping danger, etc.

4.1 FSS used in thresholding

FSS helps in finding optimized threshold value for medical image segmentation to detect brighter and dark regions. Optimized threshold value could only accomplished through a fitness function. Using Kapur's entropy criterion method it can be observed better segmentation is possible to get through maximization.

Pseudo algorithm: FSS (Algorithm 2)

Step1: Take medical image as input

Step2: 'f' thresholds are selected as fishes and $w_{max} = 255$

Step3: FSS operates with fitness function and all

Fishes with the mass equal to $w_{max}/2$.

Step4: Consider 'T' as optimized threshold from FSS.

Step5: Take Threshold (T) for Image segmentation done

Black region = MAX when $I_m > T$

White/gray region = MIN / 0 when $I_m \leq T$

Where I_m is image(x, y)

5. PSO BASED THRESHOLDING VS. FSS BASED THRESHOLDING

For better segmentation both optimization methods try to find optimum threshold value. Both use fitness function to find the optimum value, it could be maximized or minimized to get optimum result. For Kapur's entropy criterion maximizing would get us best result. PSO and FSS both are effective optimization method with thresholding technique, is capable of segmenting medical image and detecting better darker and brighter regions. In FSS due to premature convergence of search space sometimes it converges towards local minima and contrary to common-sense increase in number of fishes may be counterproductive. The PSO grounded methodology is believed that it has less negative impact on the results than other heuristic-based methods. However, it still has the difficulties of dependency on initial point and parameters, difficulty in finding their optimal design parameters, and the stochastic characteristic of the final productions.

6. CONCLUSION

Thresholding could be the simplest arsenal in image segmentation but it is robust and can deal noisy medical images. Thresholding steals the limelight even today due to demand Computer Vision applications. Some of the other Meta-heuristic algorithms that can be used for Image segmentation other than PSO and FSS are Cuckoo Search Algorithm (CS), Bat Algorithm (BAT), Artificial Bee Colony (ABC), Firefly Algorithm (FF), Social Spider Optimization (SSO), Whale Optimization Algorithm (WOA), Moth- Flame Optimization (MFO), Grey Wolf Optimization (GWO), and many more to come.

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