Multilevel Image thresholding using Fuzzy Entropy and firefly algorithm

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Abstract: Image thresholding is a very effective and popular technique for Image segmentation. Other conventional methods are very time exhaustive and take large amount of time. In this paper we have proposed a new method based on firefly algorithm and fuzzy entropy as objective function. Firefly algorithm is one of the best algorithm to solve optimization problem in various applicable fields because of its prodigious conversion rate and reduced computational time. Firefly algorithm is applied to optimize both parameter incorporated with maximum fuzzy entropy as objective function and computational time. Proposed method is very efficient and less time consuming as compared to other method. Experiment result shows that this method gives more accurate and stable results.

***Index Terms*: Image thresholding, Histogram, optimization technique, Firefly Algorithm, Fuzzy Entropy**.

I. Introduction

Image segmentation is an elementary step of many image processing applications. There are various methods incorporated by researchers for efficient and stable segmentation. Image thresholding is one of the most proficient method for dividing the image into different parts. Two types of thresholding are implemented one single level and other is multilevel thresholding. In single level thresholding image is divided into two parts where as in multi-level thresholding image is divided into multiple part based on multiple threshold values. Multilevel thresholding is much complicated and complex task compared to single level thresholding. So, maintaining accuracy is challenging task for researchers in multi-level thresholding. For solving this problem swarm algorithm are adopted in which firefly algorithm is best suited because of its advantage over other swarm algorithms. Results shows that FA is far superior than PSO (Particle Swarm Optimization), ACO (Ant Colony Optimization), Cuckoo Search (CS) and GA (Genetic Algo.) in term of CPU time and fitness function value [1-5]. In current scenario maximizing only entropy function is not suitable for image thresholding, better to implement fuzzy entropy as objective function for image segmentation. Information theory and fuzzy set theory has a great significance to image segmentation. The idea of fuzzy entropy is first introduced by De Luca in 1972 [6]. Fuzzy entropy is a function on fuzzy sets that becomes reduced when the sharpness of its argument fuzzy set is enhanced. In recent year various researchers have proposed method based on fuzzy entropy. Yang et al. presented 2D fuzzy Tsallis entropy function and infrared are segmented using maximum entropy principle [7]. Further MRI images are segmented using fuzzy entropy. The optimal parameters of fuzzy membership functions were obtained using modified particle swarm optimization (MPSO) [8]. fuzzy entropy expands the searching space with the increase of the number of fuzzy parameter [9].

This paper introduced a modified FA to search for the optimal fuzzy parameters for multilevel thresholds using the maximum fuzzy entropy principle. The rest of the paper is organized as follows. Section II explains about multilevel fuzzy entropy. In Section III, a modified FA for multilevel image thresholding based on fuzzy entropy is proposed. In Section IV, shows experimental results for several test images. Finally, some conclusions are made in Section V.

II. Fuzzy Entropy Function

2.1 Kapoor Entropy

Kapoor et al proposed a Maximum entropy method for accurately segment the image in 1985 [10]. This method is based on maximizing the entropy of histogram. In this method, if grey level image has been chosen the intensities are $I \in [1, 256]$. A threshold 'th' has been taken in this way that it separates an image into different parts.

$$H_1 = -\sum_{k=0}^{th1} \frac{P_k}{P_0} \ln \frac{P_k}{P_0}$$

$$H_2 = -\sum_{k=th1+1}^{th2} \frac{P_k}{P_1} \ln \frac{P_k}{P_1}$$

$$H_{m+1} = -\sum_{k=thm+1}^{l} \frac{P_k}{P_{k-1}} \ln \frac{P_k}{P_{k-1}}$$

(1)

Here $Prob_0, Prob_1, \ldots\ldots Prob_{k-1}$ probability occurrence of k levels of intensity. Optimized threshold value can be determined using following objective function:

$$\{th'_1, th'_2, th'_3 \ldots \ldots th'_m\} = \arg Max\ Entropy(th_1, th_2, th_3, th_4 \ldots \ldots th_m) = \arg max\ F_{kapoor}(Th)$$ (2)

2.2 Fuzzy Entropy

Trapezoidal membership function is

$$\mu_1(i) = \begin{cases} 1 & i \le a_1 \\ \frac{i - c_1}{a_1 - c_1} & a_1 \le i \le c_1 \\ 0 & i > c_1 \end{cases},$$ (3)

$$\mu_n(i) = \begin{cases} 0 & i \le a_{n-1} \\ \frac{i - a_{n-1}}{c_{n-1} - a_{n-1}} & a_{n-1} \le i \le c_{n-1} \\ 1 & c_{n-1} \le i \le a_n \\ \frac{i - c_n}{a_n - c_n} & a_n \le i \le c_n \\ 0 & i > c_n \end{cases},$$ (4)

$$\mu_{n+1}(i) = \begin{cases} 1 & i \le a_n \\ \frac{i - a_n}{c_n - a_n} & a_n \le i \le c_n \\ 0 & i > c_n \end{cases},$$ (5)

Where $(a_1, c_1, a_2, c_2 \ldots a_n, c_n)$ are fuzzy parameters with following condition:

$$0 \le a_1 \le c_1 \le a_2 \le c_2 \le a_n \le c_n \le L - 1.$$

Then the fuzzy entropy for the multilevel thresholding:

$$H_1 = -\sum_{k=0}^{th1} \frac{P_k \mu_0(k)}{P_0} \ln \frac{P_k \mu_0(k)}{P_0}$$

$$H_2 = -\sum_{k=th1+1}^{th2} \frac{P_k \mu_1(k)}{P_1} \ln \frac{P_k \mu_1(k)}{P_1}$$

$$H_{m+1} = -\sum_{k=thm+1}^{l} \frac{P_k \mu_{m+1}(k)}{P_{k-1}} \ln \frac{P_k \mu_{m+1}(k)}{P_{k-1}}$$

(6)

The optimal fuzzy parameters of this multilevel fuzzy entropy can be obtained using

$$(a_1, c_1, a_2, c_2 \ldots a_n, c_n) = argMax(H)$$

(7)

And threshold can be calculated as

$$t_1 = (a_1 + c_1)/2,\ t_2 = (a_2 + c_2)/2, \ldots, t_n = (a_n + c_n)/2.$$

(8)

III. FIREFLY ALGORITHM FOR IMAGE SEGMENTATION

Yang proposed FA which is one of the well-known stochastic algorithm for optimization [11]. This algorithm is nature inspired where behavior of firefly is utilized for the getting solution for the various problems. They work by specific rules.

a. All firefly are unisex means all can attract other fireflies regardless of their sex.
b. Attractiveness between two fireflies is directly proportional to Intensity of light or luminance hence more brighter means more attractive. Firefly having low light intensity will move towards the brighter one.
c. Brightness of firefly is achieved through cost function or fitness function which is used for searching purpose.

Mathematical representation of FA is as follows.
Movement of firefly i which is attracted toward a brighter firefly j is obtained by following equation.

$$x_i' = x_i + \beta(x_j - x_i) + Randomization\ parameter \tag{9}$$

$$\beta = \beta_0 e^{-\gamma\, r_{ij}^2} \tag{10}$$

where x_i and x_j are the position of firefly i and firefly j respectively. x_i' ia the updated position of firefly and x_i is initial position of firefly. $\beta(x_j - x_i)$ is considered as attraction force between firefly. γ is called as absorption coefficient. r_{ij} is relative distance between two fireflies. $\alpha 1.sign(rand - 0.5)$ is called disturbing term or distressing term because it can wide the search space and it can be used to advert the local optima problem. $\alpha 1$ is according to situation and condition it is termed as step size [12].

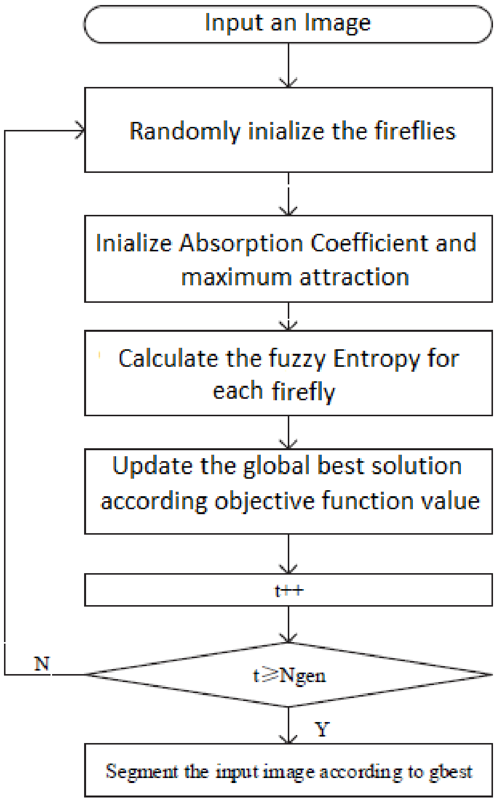


Figure 1: flow diagram of fuzzy entropy based image thresholding

To evaluate the performance of proposed method we have implemented some parameters such as Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index Matrix (SSIM) which are used for investigation about the quality of segmented image [13]. PSNR values are used for analyzing the similarity between original and segmented image using mean square error. The SSIM is generally shows the proximity of the image supremacy and relativeness between the original and the segmented image.

IV. Experimental Result and Analysis

Table 1: Experimental Setup

Parameter	Value
Platform	Matlab 2013a
Operating system	Windows 10
Processor	Dual Core I5
RAM	4 GB
Test images (set1)	Mandrill, Lena, Cameraman, Pirate
Test Images (Set 2)	Seastar, horse, Flower, Lady
Image Size(Grey Scale)	512×512
Population size (N)	30
Iteration(Ngen)	50
Attractiveness β_0	1
Absorption coefficient γ	1

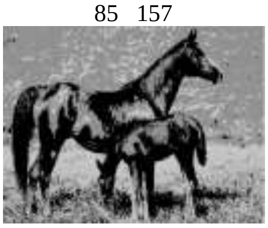
Table 1 shows the Experimental parameters while in table 2 it shows the fitness value of objective function which is derived from Fuzzy Entropy, PSNR and SSIM values for indicating the quality of segmented image. Computational time is measured in seconds for threshold m=2 to 5. Table 3 shows the segmented images for image 'mandrill', 'lena, 'cameraman', 'pirate', 'seastar', 'horse', 'flower' and 'lady'. Results shows that fuzzy entropy based image segmentation has many advantage over other methods. It provides stable results in less computational time.

Table 2: Showing objective function value, PSNR, SSIM and computational time for multiple threshold

Image name	No of threshold	Fitness value	PSNR	SSIM	Computational time in Sec
Mandrill	2	13.43	16.2523	0.7323	0.699
	3	17.84	19.4120	0.8423	1.122
	4	21.36	20.5521	0.8589	1.277
	5	23.23	23.6592	0.8216	1.565
Lena	2	14.77	10.1478	0.5534	0.619
	3	17.28	13.3463	0.7374	1.212
	4	21.59	17.5331	0.7603	1.338
	5	24.68	19.8430	0.8224	1.453
Cameraman	2	13.42	9.2848	0.5647	0.261
	3	17.26	14.5643	0.6834	1.546
	4	21.83	17.6374	0.7387	1.792
	5	23.37	25.9582	0.8445	1.928
Pirate	2	14.46	15.3764	0.4485	0.385
	3	17.72	19.5489	0.6640	1.134
	4	21.86	22.6398	0.7132	1.465
	5	24.87	23.7473	0.8639	1.776
Seastar	2	14.77	10.7478	0.5334	0.219
	3	18.78	13.7463	0.7674	1.512
	4	21.89	12.3331	0.7803	1.738
	5	25.36	17.8430	0.8224	1.953
Horse	2	13.42	10.4848	0.5347	0.461
	3	17.23	13.7643	0.6634	1.246
	4	21.83	17.8374	0.7587	1.492
	5	24.32	28.3582	0.8845	1.628
Flower	2	14.43	15.8764	0.4885	0.485
	3	18.78	19.4489	0.6340	1.334
	4	21.83	21.2398	0.7832	1.765
	5	24.82	23.8473	0.8339	1.896

Lady	2	14.43	16.6523	0.7723	0.399
	3	18.84	18.5120	0.8523	1.422
	4	21.36	21.6521	0.8289	1.777
	5	25.23	23.3592	0.8416	1.855

Table 3: Showing segmented image with threshold values

Original Image	**M=2**	**M=3**	**M=4**	**M=5**
 Mandrill	 74 143	 47 92 159	 32 78 118 151	 25 58 118 153 218
 Cameraman	 127 187	 62 137 204	 68 84 156 210	 48 83 128 171 212
 Lena	 59 179	 73 129 167	 40 114 146 191	 24 67 117 169 201
 Pirate	 78 197	 59 148 178	 87 112 69 198	 65 118 151 179 219
 Seastar	 85 157	 68 119 177	 60 101 138 187	 51 85 116 149 193
 Horse	 145 197	 117 162 204	 110 149 179 210	 98 131 161 186 213

Flower | 74 143 | 50 87 150 | 45 79 120 180 | 40 69 95 133 189

Lady | 100 167 | 93 138 196 | 73 105 149 205 | 69 98 128 165 214

V. CONCLUSION

In the proposed method, fuzzy entropy method is used for multilevel image segmentation for gray scale images. Firefly algo. is used for searching best threshold values based on Fuzzy Entropy objective function for segmenting image efficiently. Performance of this method was evaluated using PSNR, SSIM and computational time along with fitness function value. Results shows that proposed algorithm outperform in term of efficiency and computational time over many other algorithms. This work can be extended to color image segmentation.

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