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Multilevel image thresholding based on cuckoo search algorithm

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Abstract

In this paper, optimal thresholds for multi-level thresholding in image segmentation are gained by maximizing the Renyi entropy using cuckoo search algorithm. The proposed method is tested on standard set of images. Besides, the control parameter of the Renyi entropy is discussed. Experiment results show that the effect of segmented image is not significantly affected by varying the parameter value when the thresholds to 2 then to 5.

Keywords

Image segmentation, multi-level thresholding, Renyi entropy, cuckoo search algorithm.

1. Introduction

Image segmentation has play an important role as a preprocessing step in image processing. Thresholding is useful in image segmentation [1]. Note that Image segmentation deals with subdividing the image into objects of meaningful information, which is widely used in computer vision [2], biomedical imaging [3], pattern recognition [4], Recent years, many techniques for image segmentation have been developed and proposed in the literature [5]. Due to the fact that image segmentation based on thresholding is very simple and efficient. Thresholding is considered the most preferred technique out of all the existing methods used for image segmentation [6]. Various methods for global thresholding are available in the literature to segment images and extract meaningful patterns of interest. Bi-level global thresholding is used to divide the image into object and background [7-8]. However, for real life images bi-level thresholding does not acquire appropriate results. Hence, there is a strong need for multi-level thresholding which divides the histogram of the image into number of classes of homogenous gray levels such that some criterion is optimized [9]. Various thresholding algorithms are proposed which use different kinds of heuristic method such as PSO [10], ABC [11], GA[12],CS[13]and hybrid algorithms.

This has motivated us to introduce a new method for finding the optimal thresholds effectively for multi-level thresholding. Here we consider optimal thresholding as a constrained optimization problem. The desired stability yields appropriate constraints for the maximization problem. Interesting and stable solutions are obtained through the convergence of a new meta-heuristic algorithm called cuckoo search. Renyi entropy also called non-extensive entropy has been studied in image segmentation.

2. Multilevel image thresholding based on Renyi entropy

Shannon entropy has been used in a variety of applications. Extensions of Shannon original work have resulted in many alternative measures of information. Renyi proposed a one parameter generalization of the Shannon entropy as

$$R_\alpha(A)=\frac{1}{1-\alpha}\ln\sum_{i=1}^{L}p_i^\alpha \tag{1}$$

Where, the α>0, is a non-extensive control parameter which depend on the Accordingly for each class, Kapur's entropy can be expressed as:

$$R_{\alpha}^{A_1}(t)=\frac{1}{1-\alpha}\ln\sum_{i=1}^{t}\left(P_i/P^{A_1}\right)^{\alpha},\quad R_{\alpha}^{A_2}(t)=\frac{1}{1-\alpha}\ln\sum_{i=t+1}^{L}\left(P_i/P^{A_2}\right)^{\alpha} \tag{2}$$

Where, $\alpha>0$ is a parameter. The different from Tsallis entropy, the Renyi entropy will meet the extensive property

$$R_{\alpha}(A_1+A_2)=R_{\alpha}(A_1)+R_{\alpha}(A_2) \tag{3}$$

Similarity, according to the additive rule, the extensive Renyi entropy can be computed by

$$R_{\alpha}^{A_1}(t)=\frac{1}{1-\alpha}\ln\sum_{i=1}^{t_1}\left(P_i/P^{A_1}\right)^{\alpha},\quad R_{\alpha}^{A_2}(t)=\frac{1}{1-\alpha}\ln\sum_{i=t_1+1}^{t_2}\left(P_i/P^{A_2}\right)^{\alpha},$$
$$\cdots,\ R_{\alpha}^{A_{m+1}}(t)=\frac{1}{1-\alpha}\ln\sum_{i=t_m+1}^{L}\left(P_i/P^{A_{m+1}}\right)^{\alpha} \tag{4}$$

The total Renyi entropy can be gained by

$$R_{\alpha}(A_1+A_2+\cdots+A_{m+1})=\sum_{i=1}^{m+1}R_{\alpha}(A_i) \tag{5}$$

Then, Renyi entropy based thresholding approach obtains the optimal threshold can be described:

$$R_{\alpha}^{opt}=\arg\max\left[R_{\alpha}(A_1+A_2+\cdots+A_{m+1})\right] \tag{6}$$

3. Cuckoo search algorithm

Recently, the Cuckoo Search (CS) algorithm is proposed by Yang and Deb . The choice of control parameters in CS algorithm is simple and required for implementing the algorithm. Note that the control parameters of the CS algorithm are the scale factor (β) and the mutation probability value (p_{α}). While generating new solution $x^{(t+1)}$, for a cuckoo *i*, a Levy flight is performed:

$$x_i^{t+1}=x_i^t+\alpha\oplus Levy(\lambda) \tag{7}$$

where $\alpha>0$, is the step size. Here we choose $\alpha=1$. Levy flights provide a random walk while their random steps are drawn from a Levy distribution for large steps defined by:

$$Levy\sim u=t^{-\lambda},\quad (1<\lambda\le 3) \tag{8}$$

which has an infinite variance and infinite mean.

4. Experiments results

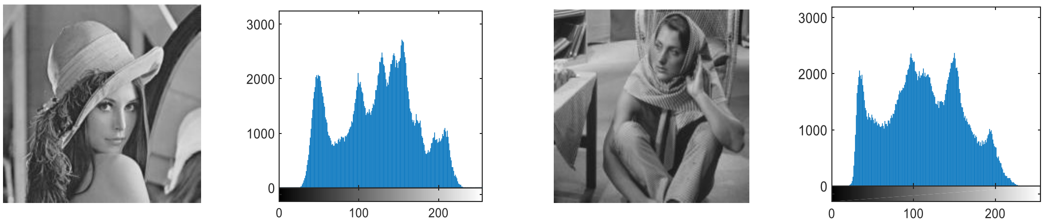
The proposed method has been tested under a set of benchmark images. Some of these images are widely used in the multilevel image segmentation literature to test different methods (Lena, Barbara, Goldhill and Peppers), as shown in Figure 1. The popular performance indicator, peak signal to noise ratio (PSNR), is used to compare the segmentation results by using the multilevel image threshold techniques. For the sake of completeness we define PSNR, measured in decibel (dB) as

$$PNSR=20\log_{10}\left(\frac{255}{RMSE}\right),(dB) \tag{9}$$

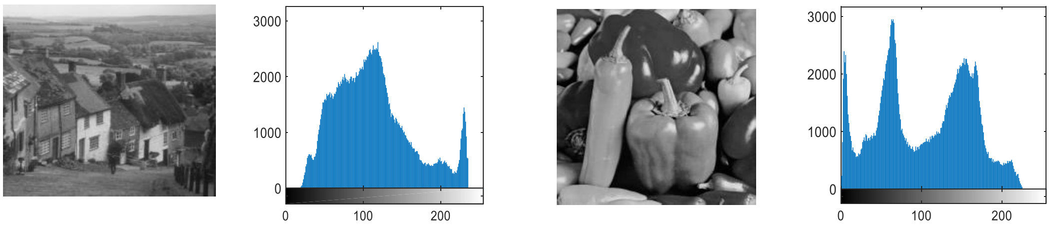
where RMSE is the root mean-squared error, defined as:

$$RMSE=\sqrt{\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(I(i,j)-\hat{I}(i,j)\right)^2}{M*N}} \tag{10}$$

Here I and $\hat{I}$ are original and segmented images of size $M*N$, respectively.



(a) Lena (b) Barbara



(a) Goldhill (d) Peppers

Fig.1. The original images and their histograms

For evaluating the performance of the method, we have implemented this method on the four test images, when the typical parameter α is 0.3. The performance metrics for checking the effectiveness of the method are chosen as the PSNR and RMSE. At first, we focus on the image segmentation quality sensitivity to the number of thresholds *k*. Table 2 shows the selected thresholds, RMSE value and PSNR value with different thresholds. Analysis from the table shows that the numberof thresholds increase, the RMSE are decrease and the PSNR is enlarge.

Table 1 Experiment results based on Renyi entropy with typical parameter α=0.3

Images	k	Thresholds	RMSE	PSNR
Lena	2	96 164	0.9549	21.2301
	3	79 128 178	0.6975	24.0058
	4	69 109 148 187	0.6082	25.2711
	5	65 101 139 177 191	0.5849	25.6394
Barbara	2	90 160	1.0267	20.7698
	3	74 125 176	0.7091	23.9719
	4	68 112 156 198	0.6136	25.2521
	5	58 93 129 166 183	0.5515	26.1555
Goldhill	2	90 160	0.9951	21.0574
	3	64 117 173	0.7644	23.3453
	4	62 105 148 191	0.6118	25.2749
	5	56 95 134 172 191	0.5431	26.3047
Peppers	2	74 147	1.2134	19.2759
	3	60 120 176	0.8188	22.7348
	4	44 87 132 178	0.5882	25.5982
	5	44 86 131 177 191	0.5491	26.2049

5. Conclusion

An extensive study on the application of Cuckoo search algorithm for multilevel thresholding for image segmentation is made. As seen from the experimental results, non-extensive entropy based image thresholding using Cuckoo search algorithm is useful for image segmentation. An interesting feature of the proposed method is that Renyi entropy uses global and objective property of the image histogram and is easily implemented. The parameter α of Renyi entropy be used as a tuning parameter for improvising image thresholding results.

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