Brain Tumor Segmentation using Cuckoo Search Optimization for Magnetic Resonance Images

E. Ben George
Lecturer, Department of IT,
Higher College of Technology,
Muscat
ben.george@hct.edu.om

G. Jeba Rosline
Lecturer, Department of IT,
Higher College of Technology,
Muscat
jroseline@hct.edu.om

D. Gnana Rajesh
Head, Department of IT, Al-Musanna College of Technology, Oman
rajesh@act.edu.om

Abstract - **Nature enthused algorithms are the most potent for optimization. Cuckoo Search (CS) algorithm is one such algorithm which is efficient in solving optimization problems in varied fields. This paper appraises the basic concepts of cuckoo search algorithm and its application towards the segmentation of brain tumor from the Magnetic Resonance Images (MRI). The human brain is the most complex structure where identifying the tumor like diseases are extremely challenging because differentiating the components of the brain is complex. The tumor may sometimes occur with the same intensity of normal tissues. The tumor, edema, blood clot and some part of brain tissues appear as same and make the work of the radiologist more complex. In general the brain tumor is detected by radiologist through a comprehensive analysis of MR images, which takes substantially a longer time. The key inventiveness is to develop a diagnostic system using the best optimization technique called the cuckoo search, that would assist the radiologist to have a second opinion regarding the presence or absence of tumor. This paper explores the CS algorithm, performing a profound study of its search mechanisms to discover how it is efficient in detecting tumors and compare the results with the other commonly used optimization algorithms.**

Keywords - Magnetic Resonance Image; Brain Tumor; Brain Image Segmentation; Markov Random Field; Cuckoo Search Algorithm

I. INTRODUCTION

Brain tumor is one of the foremost reasons for the rise in mortality among children and adults. A tumor is a mass of tissue that propagates out of control of the normal forces that regulate growth. A brain tumor appears when one type of cell changes from its normal characteristics and grows and multiplies in an abnormal manner. The unusual growth of cells within the brain or inside the skull, which can be cancerous or non-cancerous. The tumor is one form of cancer. Cancer starts from cells, the building blocks that make up tissues. These tissues make up the organs of the body.

Generally, cells grow and split to form new cells as the body requires them. According to the International Agency for Research on Cancer (IARC) it is estimated that more than 1,26,000 people are diagnosed for brain tumor per year and around the world with more than 97,000 mortality reported [1].

MRI systems are very important in medical image analysis. MRI has a multidimensional nature of the data provided from different sequential pulses. MRI can provide detailed information about the disease and can identify many pathologic conditions, giving an accurate diagnosis. Segmentation describes the separation of the suspicious region from the background MR image using various optimization techniques. Segmentation process can be made more accurate by including the best optimization algorithm.

Optimization is a major apprehension in many functional areas such as production, healthcare distribution, image processing etc. [14]. For example, an optimized application is benefiting from huge amounts of memory available on a particular computer or the speed of the specific input, output device available or specific features of the processor being used [15]. Always an application is to perform well; otherwise it will not be an accomplishment. So the benefits of optimization are as much commercial as they are simple and convenient for end users.

As there is an inordinate demand for intelligence products, optimization algorithms play a vital role in implementation of computational intelligence. It creates a wide impact on many of the upcoming applications in engineering, business, education and other fields. This research will spotlight on the cuckoo search as a prevailing, temperament enthused metaheuristic algorithm to employ optimization and computational intelligence towards the segmentation of tumor from the brain MRI.

Swarm Intelligence (SI) based algorithms are the collective behavior of distributed self-organized systems. Swarm intelligence systems are naturally made up of a population of simple agents cooperating locally with one another and with their environment. Interactions between such agents lead to the emergence of intelligent global

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behavior unknown to the individual agents. Natural examples of SI comprise ant colonies, bird flocking, bacterial growth, bee colony, fish schooling, cuckoo search etc. [10]. Cuckoo search algorithm was developed by Yang and Deb in 2009 which is instigated by the coerce brood parasitism of some cuckoo species by laying their eggs in the nests of other host birds. Some host birds can slot in unswerving clash with the obtrusive cuckoos. For example, if a host bird discovers the eggs that are not their own, it can neither throw these unfamiliar eggs nor leave the nest and erecting up a new nest. In some cuckoo species the female cuckoos are experts in the parody in colors and pattern of the eggs in certain host species. Cuckoo search has idealized such breeding behavior and so can be applied to a wide range of optimization problems which surpass the other metaheuristic algorithms in relevance [19].

There are various image segmentation methods presented in the literature. Azadeh et al documented a new k-means clustering algorithm for the segmentation of background from brain tissue and separates normal brain pixels from the pixels inside the brain [4]. Tsai et al. presented a method of histogram and morphological operation for segmenting the various tissues from MRI data [5]. Logeswari et. al. implemented the Hierarchical Self Organizing Map (HSOM) for segmenting the tumors [3]. Ben George et. al. proposed the innovative approach of Bacteria Foraging Optimization algorithm to segment the tumor from the brain images [2]. Zhang et. al. implemented the segmentation and classification of MRI by an improved Artificial Bee Colony Algorithm [6].

The overall process of segmentation of brain tumor from MR images is explained in the Figure1.

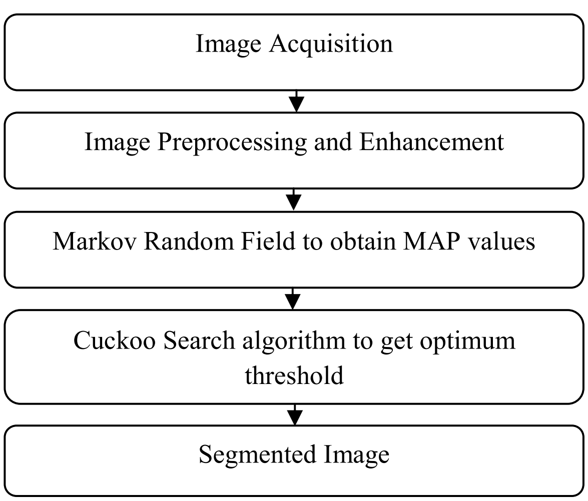

Fig. 1. Overall process of segmentation of the brain tumor

This paper is organized as follows. Section II describes the brain MRI acquisition, preprocessing and enhancement process. Section III deals with the segmentation of MR images using a Cuckoo Search algorithm. Section IV does the result and performance evaluation of the recommended algorithm. Section V gives the conclusion of this paper.

II. MRI Acquisition, Preprocessing and Enhancement

The main objective of this part of the research is to get the brain MR images and to enhance the images by removing the noise. In the first phase, the MR image is acquired from standard online databases at the McConnell Brain Imaging Center (MBIC) of the Montreal Neurological Institute (MNI), McGill University [7] and Harvard Medical School website [8]. A sample of 200 T1 weighted images is taken and used for this analysis purpose. In the second phase, it is pre-processed by applying the modified tracking algorithm to remove all the film artifacts. In the third phase the high frequency components are removed from MR image using the Hybrid Center Weighted Median Filter (HCWMF). This HCWM filter is a combination of the Center Weighted Median Filter (CWMF) and the Wiener Filter (WF) which produces high quality images for further processing [9].

III. Segmentation using Cuckoo Search Algorithm

The normal brain is characterized by having Gray Matter (GM), White Matter (WM) and Cerebrospinal Fluid (CSF) tissues. The abnormal brain usually contains the active tumor, necrosis and edema in addition to normal brain tissues. Necrosis is a dead cell located inside an active tumor, while edema is located near active tumor borders. Edemas, which results from local disruption of blood brain barrier, often overlap with normal tissues and it is always difficult to distinguish [11].

The intensity values seen on an MRI scan for a specific brain depends predominantly on the content of that pixel versus neighboring tissue and on other factors comprising the presence of abnormality. In normal brain MR images, the intensity level of brain tissues in the order of increasing brightness is CSF, GM, WM in T1-weighted (T1-w) and WM, GM and CSF in T2-weighted (T2-w) image. In tumorous brain MR images the intensity level of tumorous tissues displays a different intensity level on T1-w and T2-w images based on the type of tumor. On T1-w most tumors have low or intermediate signal intensity and T2-w most tumors have bright intensity.

A. Markov Random Field (MRF)

An optimization problem is the one that involves finding the optimum values for a function. Most of the optimization problems have the problem of uncertainty in finding an exact solution. Optimization in an MRF problem involves finding the maximum of the joint probability over the image, usually with some of the variables given by some observed data. This can be done by minimizing the total energy [12,13].

MRF hybrid with CS algorithm is used to segment the tumor from the brain MR image. Initially, a unique label is assigned to similar patterns in the brain MR images. A kernel of 3×3 matrix is selected randomly from the enhanced image. The MRF is used to compute the maximum a-posteriri (MAP) value of each kernel. The metaheuristic algorithm CS is implemented to obtain the optimum labels by minimizing the MAP values. The intensity value corresponding to the central pixel of the kernel that holds the optimum label is used as the threshold value for segmentation.

The brain MR image is segmented using the Markov random field hybrid with cuckoo search algorithm in two steps, labeling the image using MRF then optimization using the CS. Figure 2 explains the procedure for applying MRF on the enhanced brain MR images to provide the label and to calculate the posterior energy for each kernel.

Input: Enhanced brain MR image
Output: Labeled image with the relevant posterior energy
Step 1: Read the MR image stored in a two dimensional matrix.
Step 2: Consider kernels of size 3 x 3 pixels from the image. The kernels with same gray value are labeled with the same number.
Step 3: For each kernel (3x3) in the image, the posterior energy J(x) is calculated

$$J(X) = \{\sum [(y - \mu)^2 / (2 * \sigma^2)] + \sum \log (\sigma) + \sum V(X) \} \quad (1)$$

where, y is the intensity value,
μ is the mean value of the kernel,
σ is the standard deviation,
V is the potential function for set of all kernels over the image, i.e. $V(x)=v_{i0}$ a constant penalty if X(label) is a NULL label, otherwise it is 0.

Fig. 2. Steps for applying MRF on brain MRI

B. Segmentation using Cuckoo Search (CS)

Each egg in a nest represents a new solution, and a cuckoo egg symbolizes a new solution. The objective is to use the innovative and prospectively better solutions to replace a solution. The algorithm can be in the simplest form with each nest has one egg. The algorithm is extended to more complicated cases in which each nest has multiple eggs representing a set of solutions [14].

Cuckoo Search (CS) is based on three idealized rules

i. Each Cuckoo bird lays one egg at a time and abandon its egg in a randomly chosen nest;
ii. The nests that have preeminent qualities of eggs will carry over to the next generation.
iii. The Number of host nests available is fixed and the probability in which the host bird discovers the egg laid by the cuckoo is P_a □ (0, 1). Discovering of the eggs is operated on some set of worst nests and discovered solutions dumped from further calculations [16- 18].

The Pseudo code for the CS schema for segmentation of brain tumor can be summarized as in figure 3,

Objective function: $J(X)$, $X = (X_1,X_2, ,X_d)$ (2)
Generate an initial population of n host nests;
X i (i = 1, …, n)
While (kernels are left)
Get a cuckoo randomly (say, i) with the posterior energy level J(Xi) and replace its solution by performing levy flights;

- Evaluate its energy level Ji
- Choose a nest among n (say, j) randomly;

If Ji<Jj then
Replace j by the new solution
End if

- A fraction P_a of the worse nests is abandoned and new ones are built;
- Keep the best solutions/nests;
- Rank the solutions/nests and find the current best;
- Pass the current best solution G_{best} to the next generation;

End while
The G_{best} has the optimum label.

Fig. 3. Pseudo code for segmentation using CS algorithm

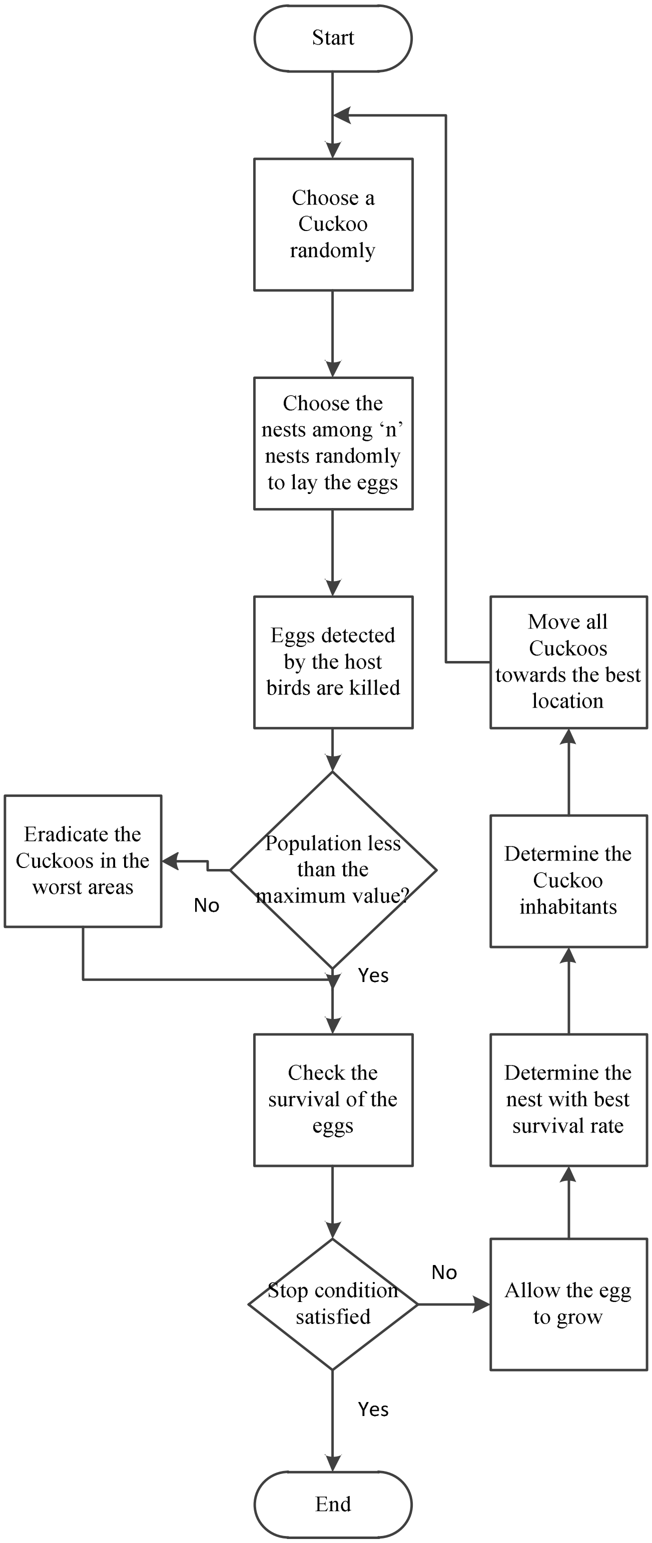

Fig. 4. Flow chart for the cuckoo search schema

Figure 4 gives the overall outline about the cuckoo search algorithm. This algorithm finds the optimum label G_{best} which will be used to find the threshold of the segmentation process Find the 3 x 3 block with the optimum label and consider the center pixel of the block, this value will be the threshold for the segmentation process. Store the pixels has higher value than the threshold in a separate image, that is the segmented image.

IV. RESULT AND PERFORMANCE ANALYSIS

The segmentation algorithm using CS is applied on 200 standard images for segmenting the tumor regions from it. After segmentation the results are tested with the ground truth and the following performance parameters are analyzed.

The results of segmentation using the CS algorithm are demonstrated in the following figure 5. Figure 5 (a) is the enhanced brain MR image which is given as input to the segmentation algorithm. Figure 5 (b) is the ground truth segmented image which is used to compare the segmentation process. Figure 5 (c) is the segmented images which shows the white continuous region in the brain region is the tumor portion segmented by the proposed CS algorithm. The skull (in white border) is retained in order to show the structure of the human brain. Figure 5 (d) is the superimposed segmented tumor portion with the original image.

The effectiveness of the proposed technique is determined by certain parameters like sensitivity, specificity [20], Jaccard Similarity Index (JSI) [21], Dice Similarity Score (DSS) [22] and accuracy [24]. The following equations (3) to (7) are used to determine the performance parameters.

$$\text{Sensitivity} = \frac{TP}{(TP + FN)} \qquad (3)$$

$$\text{Specificity} = \frac{TN}{(TN + FP)} \qquad (4)$$

$$\text{JSI} = \frac{TP}{(TP + FP + FN)} \qquad (5)$$

$$\text{DSS} = \frac{TP}{\frac{1}{2}(2TP + FP + FN)} \qquad (6)$$

$$\text{Accurcy} = \left(\frac{N_r}{N}\right) \qquad (7)$$

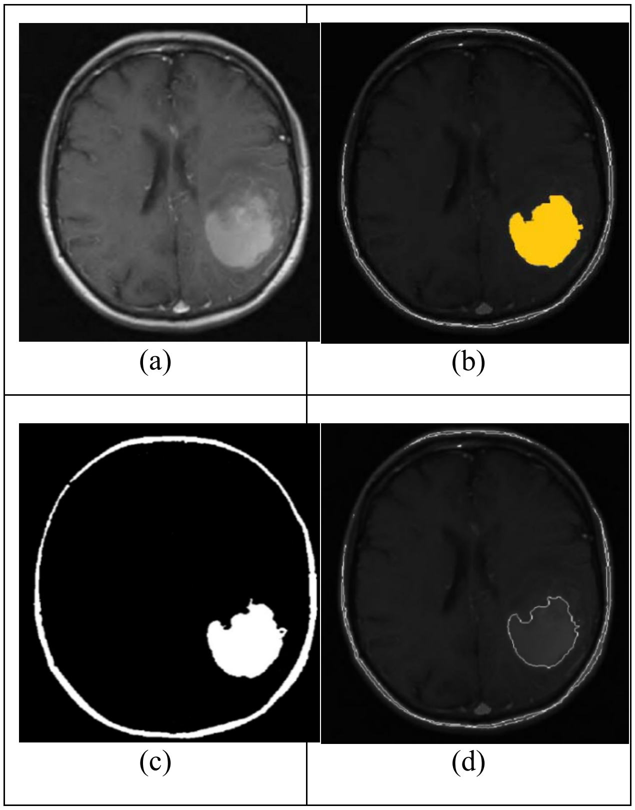

Fig. 5. Results obtained from segmentation using cuckoo search algorithm

(a) Enhanced brain image (b) Ground truth image (c)Segmentedimage using CS algorithm (d) Superimposed tumor over the original image

where, TP is true positive, FP is false positive, TN is true negative, FN is false negative, N_r is the number of correctly segmented MR brain images and N is the complete number of test MRI. These parameters are computed for the CS segmentation algorithm which produces the average sensitivity of 98.8 percent, which means this algorithm has the ability to segment the tumor images perfectly. The specificity of the algorithm is 93.3 percent, which shows the performance of the algorithm to predict the absence of tumor.

The Jaccard similarity index (JSI) produces the average value 97.67 percent and the Dice similarity score (DSS) gives a score 98.82 percent. If the JSI and DSS parameters produce high value which indicates that the segmentation algorithm is efficient. The overall accuracy of the CS segmentation algorithm is 98 percent.

The performance of the CS based brain tumor segmentation algorithm was compared with the other swarm based optimization algorithms like Artificial Bee Colony (ABC) and Bacteria Foraging Optimization (BFO) algorithms [23]. The results of the comparison are listed in the table I. From the table it is very clear that the segmentation using the CS algorithm has a higher percentage for all the evaluation parameters and hence outperforms other methods.

TABLE I. PERFORMANCE ANALYSIS OF BRAIN TUMOR SEGMENTATION ALGORITHMS

Method	**Sensitivity (%)**	**Specificity (%)**	**JSI (%)**	**DSS (%)**	**Accuracy (%)**
ABC	96.5	83.3	93.75	96.73	94.5
BFO	98.2	93.3	97.12	98.52	97.5
CS	98.8	93.3	97.67	98.82	98.0

V. CONCLUSION

In this paper, the swarm based optimization algorithm called the cuckoo search was explained and its application towards the brain tumor detection was studied and compared with the other existing techniques. Initially the MR brain images were smoothened and enhanced by Hybrid Center Weighted Median Filter. In brain MRI segmentation the Markov Random Field is used to label the image pixels and their posterior function values were calculated.

The optimum label was computed by the CS algorithm that minimizes the MAP estimate to segment the image. The CS optimization algorithm identifies the optimum label for image segmentation. The center pixel intensity from the selected label's kernel is the threshold for the segmentation of tumor region. The CS algorithm for segmentation results were compared with the ABC and BFO algorithms. The result shows that CS performs superior segmentation of tumors from MRI.

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