Amalgamation of Clustering and Meta-heuristic Optimization Techniques for Automated MR Brain Analysis

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***Abstract:** Interest in computer-assisted image analysis in increasing among the radiologist as it provides them the additional information to take decision and also for better disease diagnosis. Traditionally, MR image is manually examined by medical practitioner through naked eye for the detection and diagnosis of tumor location, size, and intensity; these are difficult and not sufficient for accurate analysis and treatment. For this purpose, there is need for additional automated analysis system for accurate detection of normal and abnormal tumor region. This paper introduces the new semi-automated image processing method to identify the brain tumor region in Magnetic Resonance Image (MRI) using c means clustering technique along with meta-heuristic optimization, based on Jaya optimization algorithm. The resultant performance of the proposed algorithm (FCM +JA) is examined with the help of key analyzing parameters, MSE-Mean Square Error, PSNR-Peak Signal to Noise Ratio, DOI-Dice Overlap Index and CPU memory utilization. The experimental results of this method show better and enhanced tumor region display in reduced computation time.*

***Keywords:** Jaya Algorithm (JA), Tumor detection, Fuzzy C Means Clustering, Meta-heuristic Optimisation.*

I. INTRODUCTION

Worldwide, several researches reveal that death rate of children as well as in adults increase due to brain tumor and this has become a great concern of the time. So it turned to be a need for the hour to have automated detection system for better interpretation of diseases by the physicians at the early stage. Generally, a mass of abnormal lump or affected cells that grows and spreads uncontrollably in and around the brain region is called brain tumor. Magnetic Resonance imaging technique has received notable attention among the medical practitioner because of its high-resolution imaging feature. MRI is widely used for the analysis of human parts brains, spinal cord, bones and Joints etc…Difficulty in detection of small size tumors, similarity between the affected and unaffected regions, and limited time for the computation of large slice of images urges the radiologists to use various soft computation techniques for analyzing the MRI. Globally, numerous soft computation approaches are introduced by researchers for brain tumor detection using image analyzing techniques. In Section II, A detailed literature study on C-Means algorithm and novel Jaya Algorithm is given. SECTION III elaborates the algorithm proposed. Obtained results are stated briefly using parameters in SECTION IV. Results and future avenues were discussed in SECTION V.

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II. LITERATURE REVIEW

In the literature, there are substantial numbers of research work carried with C-Means clustering due to its proved efficiency and less computational complexity. In case of Jaya Algorithm as it was developed recently in 2015, there is no much exploration, particularity in the field of brain pathology diagnosis. For the image segmentation, Yunjie Chein et al. [1] discussed about spatially constrained hierarchy Fuzzy C-Means (FCM) method. The hierarchy strategy used in the method increases the complexity of process. Robust-Learning FCM clustering algorithm was proposed by Miin-Shen Yang and Yessica Nataliani [2], in which the computational time is high due to more number of iterations. An automated segmentation of tumor region using optimization and clustering techniques for three (T1, T2 & Flair) image modality was developed by Vishnuvarthanan Govindaraj et al. [3], requires improvement in segmentation accuracy. Deepak Ranjan et al. [4] formulated the pathological brain detection systems (PBDSs) using Jaya Algorithm and extreme learning machine combination for the identification of tumor region, and this method works well on 3 benchmark data sets. Suresh Chandra Satapathy et al. [5] worked on a methodology that encapsulates Jaya algorithm and Otsu's at pre-processing and post-processing stage of

image analysis. Later, Kanwarpreet Kaur et al. [6] have developed Graphical User Interface (GUI) using Neural Network Ensemble and Jaya algorithm for segmentation and also for extraction of pathology region. A GUI approach was proposed for acute classification of leukemia by Jothi et al. [7], which works only on single model data set. Smart pathological brain detection using Extreme Learning Machine and Jaya Algorithms proposed by Vishnuvarthanan et al. [8] requires improvement of time complexity. Shuihua Wang et al. [9] proposed abnormal breast classification method in mammogram images using forward feed network and Jaya Algorithm, and it is applied to train the classifier network, which requires improvement in accuracy. Rao has developed an algorithm for the optimization without the requirement of algorithm-described parameters to solve constrained and unconstrained problems. [10]. This paper addresses the above said limitations by combining the simple and novel algorithms, Fuzzy C-Means clustering (FCM) and Jaya algorithm.

III. METHODOLOGY

First, Image is enhanced and noise removing filters are applied at pre-processing stage. Next, tumor region is clustered by FCM technique, then the Jaya algorithm is used to optimize the clustered region. At last, results were analyzed with benchmark data. The proposed workflow consists of 4 modules and each is elaborated below.

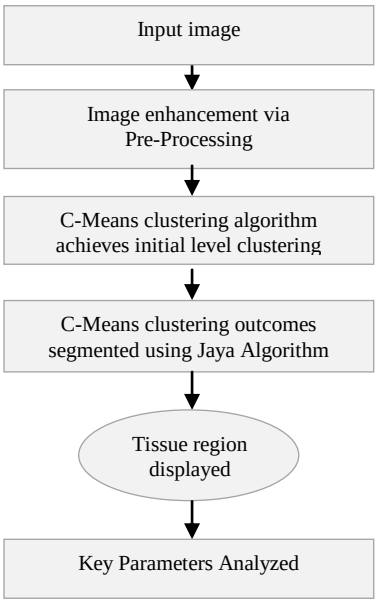

Fig. 1. Outline of workflow

A. Pre-Processing

In medical image analyzing procedure, pre-processing is the initial and most important task as it enhances the corrupted image's sharpness and it also reduces the noise content to produce high-quality image. In this stage, we resize the image's Region of Interest (ROI) by 256 x 256 and apply Gaussian filter to smoothing, remove noises and also to preserve the edges without any loss in information.

B. Fuzzy C-Means clustering

FCM is deployed in this paper in the clustering stage owing to its flexibility and its ability to augment more information in the input images while processing compared to other clustering algorithms. FCM uses fuzzy logic and fuzzy set theory to produce optimal number of clustering. Here, each data set (or pixels) is grouped into n clusters with assigned membership degree.

Algorithm for Fuzzy c means clustering:

- Step 1: Initialize the cluster centre point randomly and set iteration i=0.
- Step 2: Assign membership weightage to all the data points in a cluster.
- Step 3: Increase the iteration count by 1.
- Step 4: Update the cluster centre and membership weightage of each data points present in the clusters.
- Step 5: If the cluster centre does not change with the previous value, then end the process or repeat the step 3 until desired centre is fixed.

On each iteration, the cluster centre points move towards the correct centroid data points by minimizing the below objective function.

$$F_{fcm}(U,M) = \sum_{i=1}^{c}\sum_{j=1}^{N} U_{ij}^{m} \| w_i - c_i \|^2 \quad (1)$$

Where,

Data points for N pixels is

$$X = \{x_s\}_1^N \quad (2)$$

Membership weightage is

$$W = w_{ij} \in [0,1] \quad (3)$$

W_{ij} represents the weight component of ith data point in the jth cluster with the value between {0, 1}.

The centroid of the each cluster is updated by reducing the distance between the cluster centres C_i and the ith pixel x_s

$$c_i = \frac{\sum_{s=1}^{N} U_{ij}^{m} x_s}{\sum_{s=1}^{N} U_{ij}^{m}} \quad (4)$$

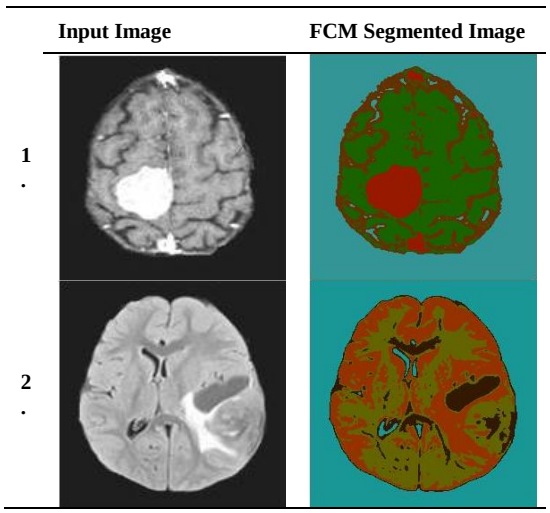

Fig. 2. Output image for FUM clustering

In literature, it is proved that the FCM based tumor region detection methods are more efficient and highly reliable compared to the K-Means clustering. On considering these, we have applied the FCM for our clustering process.

C. JAYA Algorithm-Optimization

FCM algorithm takes number of iteration to reduce the clusters membership degree and also to finalise the exact cluster points, and this may reduce the overall efficiency. To improve the over-all performance, we combined FCM with the Meta-heuristic optimization techniques.

A novel optimization technique Jaya optimization algorithm is employed to optimize the clustered image considering its effective and speedy computation features. This algorithm is successfully applied to the various constrained and unconstrained problems across domains universally and received wide acceptance among the researchers. In 2015, Jaya Algorithm was introduced by Venkata Rao [7]. This algorithm is derived from his previous optimization named as TLBO-Teaching and Learning Based Optimization, which also optimizes the objective function without any predefined parameters required by the underlying algorithm.

On Comparing with TLBO method, Jaya algorithm seems to be very simple and fast in execution as it does not need two phases namely teaching and learning phase for the computation. The advantage of Jaya Algorithm is Algorithm-Specific Parameters (ASP) are not required, and they are only in the need of general parameters like maximum iterations required to proceed, total population size and objective function to solve. The specialty of this algorithm is that on every end of iteration the desired variable is updated and it moves closer to the favorable solution, and eliminates or moving away from the unfavorable solution.

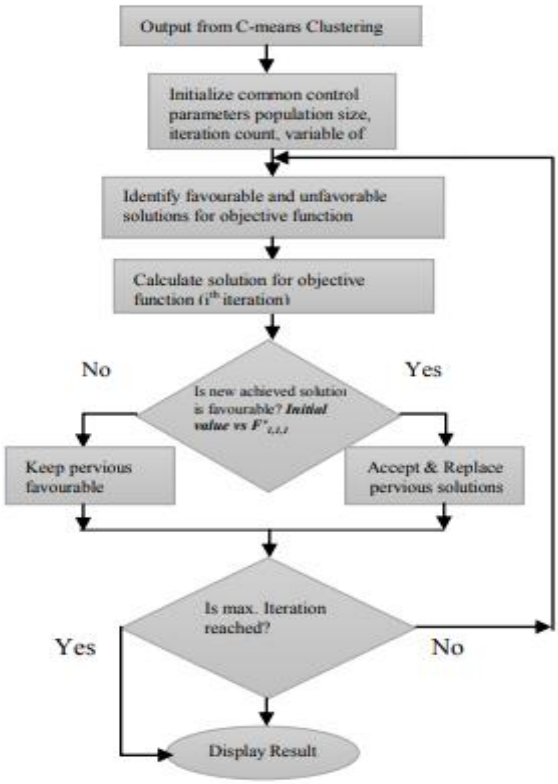

Fig. 3. Flow chart –JAYA algorithm

We assume that *p(x)* is the objective function desirable for processing. At any iteration *i*, if there are '*c*' variables in number (i.e., blocks based on clustering, where n=1,2,..*c*), and 'n' specifies the candidates count (i.e. size of the population p=0,1,2,…,S $_{(255)}$). Both the favorable and unfavorable candidate help to determine the objective function *p(x)* among the total population, and they are indicated as $p(x)_{fav}$ and $p(x)_{unfav}$.

At the instance of first step, the value $P_{c,s,i}$ represents the cth variable denoting the *s*th candidate at the time of *i*th iteration, and as per the following Eq.(5). The parameters rd (i,c,1) and rd (i,c,2) are the independently developed for each design variable at each iteration cycle. The value of the parameters is in [0,1].

$$P'_{c,s,i} = P_{c,s,i} + rd_{1,c,i}(P_{c,fav,i} - |P_{c,s,i}|) - rd_{2,c,i}(P_{c,unfav,i} - |P_{c,s,i}|) \quad (5)$$

From the above equation, the first term $rd_{1,c,i}(P_{c,fav,I} - |P_{c,s,i}|)$ shows the ability of desired objective moves towards favourable condition (denoted with + symbol) and the second term $rd_{2,c,i}(P_{c,unfav,i} - |P_{c,s,i}|)$ illustrates that the objective function is moving away from the unfavorable condition (denoted with - symbol). On next iteration, the new favorable and unfavorable values are replaced (given as input), and the iteration continued till it reaches either its final count or it reaches favourable solution for the desired objective function as shown in Eq (6).

$$P''_{c,s,i} = P_{c,s,i} + rd_{1,c,i}(P'_{c,fav,i} - |P_{c,s,i}|) - rd_{2,c,i}(P'_{c,funav,i} - |P_{c,s,i}|) \quad (6)$$

The proposed Jaya algorithm applied on the outcome of FCM clustering process, where it takes only few iterations to minimize the desired objective function. The robustness of segmentation improved significantly and makes the method more accurate in terms of segmented output.

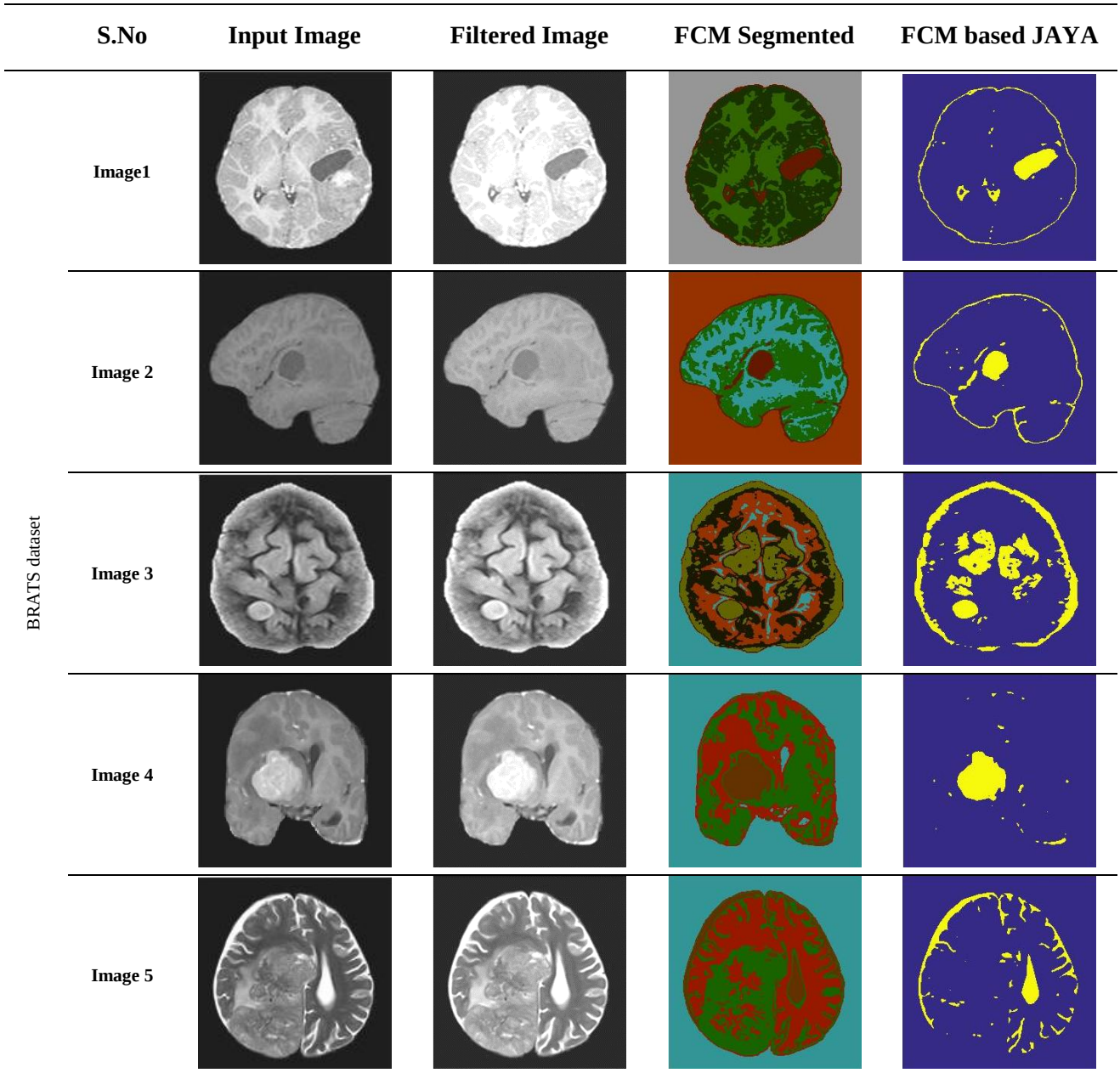

Fig. 4. Proposed FCM-JA method outcome.

IV. RESULT AND DISCUSSION

The proposed C-means clustering based Jaya Optimization method has been executed with MATLAB. Furthermore, the proposed method overcomes the drawbacks of computation time and accuracy by implementing novel optimization techniques, JA along with FCM. The segmented results were evaluated by key parameters, MSE-Mean Squared Error. PSNR-Peak Signal to Noise ratio, DOI, computation time, and system memory requirement. The proposed algorithm performs better endue on data processing time with low system memory utilization compared to the benchmark segmentation methods. Table 1, sums up the key evaluation parameters for five images belonging to clinical data set.

Table I: Key metrics analysis of the FCM – Jaya algorithm

Particulars	Image 1	Image 2	Image 3	Image 4	Image 5
MSE	2.0102	1.2701	1.0791	1.0060	1.0618
PSNR (Db)	5.0983	8.9538	7.8000	8.1048	7.8701
TC (%)	2.4865	2.6807	2.228	3.7855	2.3805
DOI (%)	3.9827	4.2281	3.6453	5.4920	3.8456
Computational Time (in seconds)	84.41	56.82	67.87	68.73	56.42
Memory requirement (in bytes)	2.21e+09	2.20e+09	2.27e+09	2.19e+09	2.21e+09

V. CONCLUSION

Universally, many researchers developing many optimization methods to detect the tumor region automatically from large slice of images consider the huge scope for efficient optimization techniques, in acquiescence to this, the paper propounds a novel combination of JAYA algorithm. We reduced the computation time, complexity and improved the performance of the clustering outcome by combining FCM with JA. The combined performance of the (FCM + JAYA) algorithm shows endue results compared to the segmentation results obtained by individual FCM method and is evident from the obtained superior numbers of the analyzing criteria mentioned in Table I. In future, we will extend the study a) with large and multimodal datasets b) and to enhance the performance of the segmentation process.

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