An Automated Map Process Based Improved Fuzzy C-Means Algorithm for Pathological Detection in MR Image

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Abstract*: Automated brain MR slices segmentation process is difficult, and further difficult is the process of detecting the tumor and tissue regions, with a constraint of delivering higher segmentation accuracy within reduced processing time. Automated algorithms were developed with an onus of reducing the intricacies involved during the manual inspection of the pathologies (radiologist/operator involvement). The shortages of an automated process are overthrown with the development of a novel combination of soft computing algorithms, and it employs automated map and clustering approaches. Self-Organizing map (SOM) and Improved Fuzzy C-Means clustering (IFCM) are the automated map and clustering approaches that are used to precisely provide the MRI slice analysis. The authors have utilized the quality metrics, such as Dice overlap Index (DOI), Jaccard index, Peak Signal to Nosie Ratio (PSNR) and Mean Squared Error (MSE) for verifying the performance of the SOM based IFCM, and the recommended algorithm tenders the corresponding values of the above as 84.83%, 91.69%, 0.0824 and 49.25dB. The novel SOM- IFCM algorithm delivers better demarcation outcomes when compared with other soft computing approaches. The exemplified outcomes of the proposed SOM-IFCM algorithm provides superior segmentation quality of MR brain slices and offers versatile usage to the radiologists.

***Keywords* : Improved fuzzy c-means clustering, self-organizing map (som), MR brain image analysis, pathological detection, tumor identification.**

I. INTRODUCTION

In recent medical image analysis, MR brain slices are mostly supportive for identifying tumor and tissue regions, and at some instances, one cannot easily understand the pathological structures within it (cannot vision the pathological portion due to humor operability). Successively, these lacks can be undone using the soft computing algorithms, which help in the deep analysis of the pathological portion in less computational time. Some researchers have provided the different combinational state-of-the-art methodologies to identify the pathological structures for successful oncological treatment. Pham [1] suggested the Robust Fuzzy C–Means approach and this process analyses the MR brain slices that required more processing time for effective demarcation outcomes. Ahmed et al. [2] formulated the objective function of modified FCM algorithm, which provides the better MR slices analysis in more time. Pathological detection using Modified Fuzzy C – Means and Gaussian Mixture Model was epitomized by Karim et al. [3], and it is capable of demarcating the MR brain slices. Higher processing time is required by the technique suggested by the authors. The amalgamation of Modified Fuzzy C - Means (MFCM) approach and histogram based cluster design process intended by Karan et al. [4] requires improvement of time complexity. Govindaraj et al. [5] have used Fuzzy Inference System approach for carrying out the demarcation of MR brain slices, which provides lower PSNR values and higher MSE values. Moreover, a demarcation of MR slices process used Particle Swarm Optimization and Fuzzy C – Means approach by Govindaraj et al. [6]. The algorithm propounded requires improvement in segmentation accuracy. Guler et al. [7] proposed an automated demarcation of MR brain slices using SOM neural network, which is related to the processing of noise input images. SOM based Leaning Vector Quantization algorithm represented by Demirhan et al. [8] requires improvement in human interaction process. The ample path detection using SOM based extended FCM approach intended by Aghajari et al. [9] needs development in processing time. Tumor and tissue detection using SOM based FKM algorithms proposed by Vishnuvarthanan et al. [10] provides ample MR brain slices analysis. Segmentation accuracy and computational time presented by SOM based FKM algorithm needs improvement. The above-mentioned are the drawbacks that can be resolved through the novel combinational framework presented in this paper.

Section II clearly illustrates the proposed methodology. Section III exposes that the proposed methodology is better when compared with the other soft computing methodologies. Section IV discusses the completion of this process.

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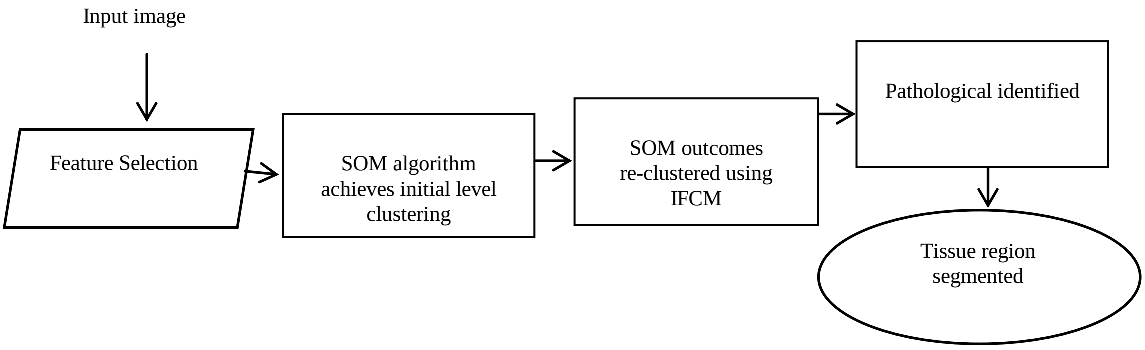

Fig. 1. Performance of the recommended SOM-IFCM methodology

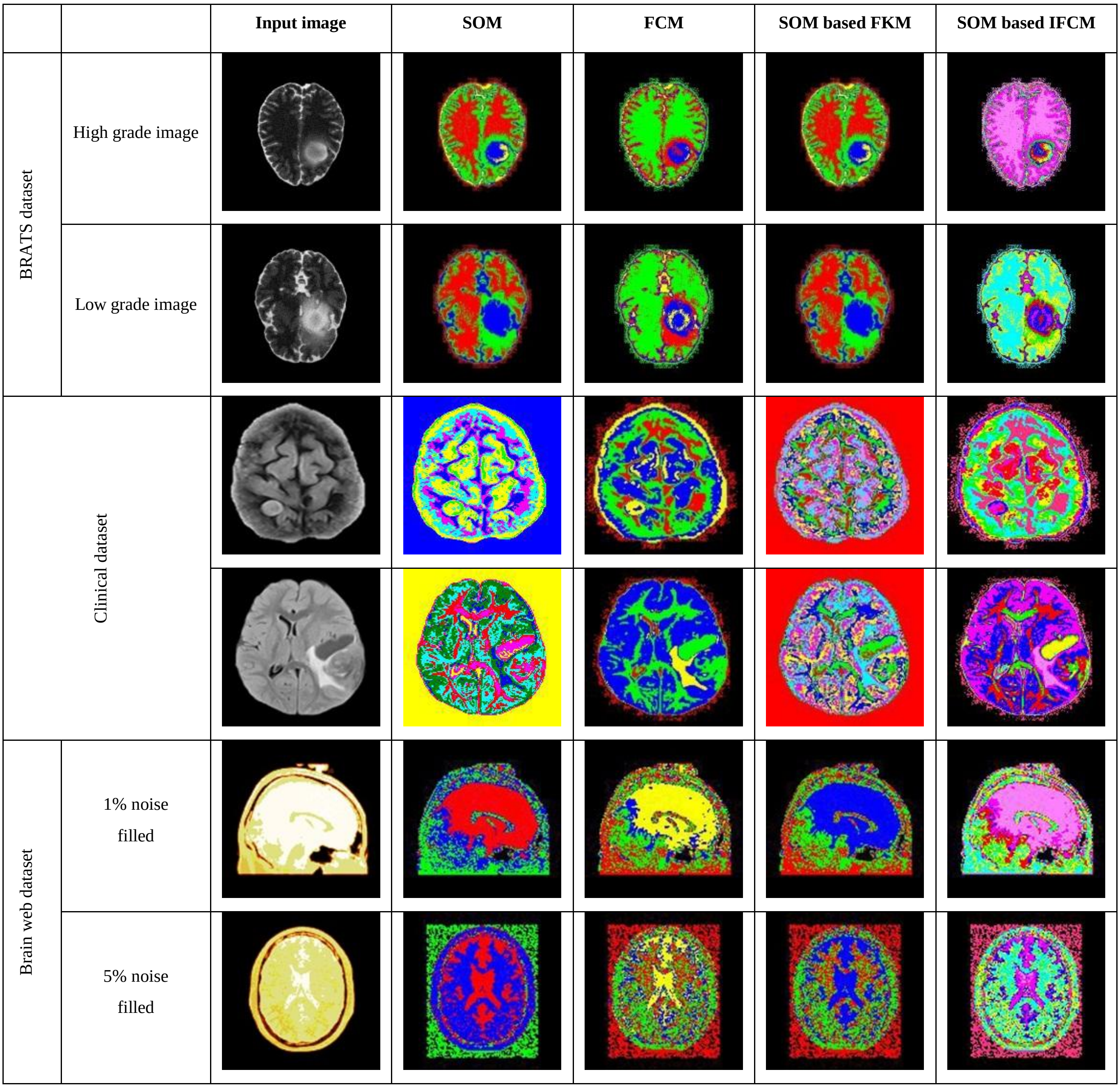

Fig. 2. Segmentation outcomes of various soft computing methodologies

II. METHODOLOGY

Fig 1 spotlights the combination of SOM-IFCM algorithm. SOM neural network certainly performs the classification of same set pixel and also the segmentation process. It specifies that SOM neural network provides the dimensionality reduction with the aid of the mapping function.

Table- I: Quality metrics analysis of the proposed algorithm

Parameters	Clinical image		BRATS image		Brain web database	
			High grade	*Low Grade*	*1% noise filled*	*5% noise filled*
MSE	0.0767	0.0804	0.0605	0.0939	0.0593	0.1235
PSNR	59.2809	59.0796	60.3116	58.4020	60.4010	57.2152
Jaccard Index in %	0.7509	0.8626	0.9169	0.8795	0.7980	0.8822
DOI values in %	0.8577	0.9262	0.9566	0.9359	0.8877	0.9374
Computational Time in seconds	7.5854	6.9007	6.5933	6.5049	6.7291	5.3836
Memory requirement in bytes	2.21e+09	2.20e+09	2.27e+09	2.19e+09	2.21e+09	2.19e+09

Table- II: Quality metrics analysis of the proposed algorithm

Algorithm	MSE	Memory Requirement in bytes	PSNR	DOI in bytes	Jaccard Index in bytes	Computational Time in seconds
SOM	1.98	2.68E+13	46.3817	80.89	67.91	2.0877
FCM	0.2731	5.20E+12	53.7832	81.02	68.1	27.7746
SOM based FKM	2.421	1.45E+14	43.8567	86.88	76.69	3.7741
SOM based IFCM	0.0824	2.21E+09	49.249	91.69	84.83	6.6161

$$D_{\min}(z) = \min\left\{\sum_i (x_i(z) - w_i(z))^2\right\} \quad (1)$$

Automated mapping process is utilized as 8×8 map function, which is to inspire this process with the aid of the input vector and nearest neighbour. We obtained the nearest neighbour with the help of equation (1).

$$w_i(z+1) = w_i(z) + \alpha(z) * (i - w_i(z)) \quad (2)$$

Then, the end-result of SOM denotes the updated weighted vectors 'w_i' (refer to the equation (2)), which is obtained from Best Matching Unit (BMU) of nearest neighbour and Euclidean distance. The operational parameters of equation (3) and (4) depend upon the exponential decay function of time.

$$\alpha(z) = \alpha_0 \exp\left(-\frac{t}{2T}\right) \quad (3)$$

$$h(z) = \exp\left(-\frac{dist^2}{2\sigma^2(t)}\right) \quad (4)$$

Consecutively, the ample SOM outcomes are given to the input of improved FCM unsupervised clustering algorithm. The underlying concept of improved FCM is each and every pixels connected by the minimum Euclidean distance have obtained the nearest neighbour pixel to close the cluster centroid. In clustering process, the equivalent pixels are associated with the same membership values. This proposed algorithm has the enhanced membership values that are coherence to the input vectors (for quickly convergence process). The FCM was recommended by Dunn [11] and later extended by Bezdek [12], which has now been modified and the same is given in equation (5).

$$J(U, M) = \sum_{i=1}^{c}\sum_{j=1}^{N} U_{ij}^{m} \left\| w_i - c_i \right\|^2 \quad (5)$$

An enhanced FCM objective function is denoted as J, which is determined by the membership function with squared Euclidean distance of iterative optimization approach. The updated membership function of improved FCM is employed with the help of the equation (7) and (8).

$$U_{ij}^{m} = \frac{(u_{ij})^m}{1 + \alpha d_{ij}} \quad (6)$$

$$u_{ij} = \left[(d_{ij})^{1/m-1} \sum_{l=1}^{k} \left(\frac{1}{d_{il}}\right)^{1/m-1} \right]^{-1} \quad (7)$$

$$c_i = \frac{\sum_{i=1}^{N} U_{ij}^{m} x_i}{\sum_{i=1}^{N} U_{ij}^{m}} \quad (8)$$

Here, c_i refers to the cluster center and also u_{ij} refers to the membership function. Consequently, the efficient segmentation outcomes are delivered by the proposed algorithm, and they are obtained using the modified membership function, which delivers equivalent pixels associated with the same set.

III. RESULT AND DISCUSSION

The suggested SOM based IFCM methodology processes the BRATS-2013 challenge medical images [13], brain web dataset [14] and the clinical dataset. A total of 112 input medical images are operated by the single framework of novel methodology, and the proof of efficiency of this algorithm is evaluated by quality metrics like Dice overlap Index, Jaccard index (TC), Peak Signal to Nosie Ratio and Mean Squared Error [15]. Fig 2 reveals the demarcation outcomes of SOM based IFCM methodology, and it is compared with SOM and FCM algorithms. Table I denotes the quality metrics of SOM based IFCM algorithm, which is useful to analyze the ample segmentation process. Table II exemplifies the performance of novel SOM based IFCM algorithm, which provides better segmentation accuracy in the form of Jaccard index when compared with the other soft computing approaches.

IV. CONCLUSION

In this paper, a novel SOM based IFCM algorithm is offered, which needs less processing time for 112 input medical MR slices. Successively, IFCM approach is entirely enhanced by SOM outcomes. The combinational novel segmentation approach proffers better brain MR slice analysis when compared with other soft computing algorithms like SOM and FCM. SOM-IFCM approach mandates minimal processing time for identifying the pathological structures, and is mitigated in Fig 2 and Table I. Precise pathological portions in brain MR slices are represented by the SOM-IFCM algorithm, which has also delivered uppermost Jaccard index and DOI values (refers to table II), and it can sure be a matter of importance during the diagnosis of patients.

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