Development of Softcomputing Tool to Evaluate Heart MRI Slices

Hong Lin and V. Rajinikanth

***Abstract*—Magnetic Resonance Imaging (MRI) is a common imaging procedure widely adopted in hospitals to examine the disease in internal organs. Compared to other imaging techniques, MRI can be recorded with a variety of modalities, such as Flair, T1, T1C, T2, Diffused Weighting (DW) and fMRI. Further, it can provide a reconstructed Three-Dimensional (3D) view of the internal organ under study. In this work, a hybrid approach based on the combination of thresholding and segmentation is implemented to examine the congenital heart defect using the Heart MRI (HMRI) recorded using T2 modality. The thresholding is implemented with Differential Evolution (DE) based Shannon's Entropy (SE) and the segmentation are implemented using the Level Set (LS). In this work, the axial view of the HMRI images of the HVSMR 2016benchmark dataset is considered for the analysis. The main aim of this work is to extract the Region Of Interest (ROI) from the HMRI and compare the extracted section with the Ground Truth (GT) images. The experimental investigation of the proposed work confirms that, proposed work offers enhanced average image similarity values (> 88%) on the considered dataset.**

***Index Terms*—Heart MRI, axial view, differential evolution, Shannon's entropy, level set.**

I. Introduction

Magnetic Resonance Imaging (MRI) is one of the widely adopted imaging systems in medical domain and is widely adopted in medical clinics to record the functioning of various internal organs [1]. Normally, the MRI is recorded by an experienced radiologist, and the final form of the MRI is obtainable as a reconstructed three-dimensional (3D) picture. The merit of the MRI compared to other bio-imaging techniques is as follows; (i) Available as 3D picture, (ii) Obtainable with varied modalities, such as Flair, T1, T1C, T2, DE and fMRI, and (iii) Can be recorded with or without the contrast agent [2].

From the above discussion, it is clear that, the raw MRI is in 3D form and it can be examined in its original form or in the form of 2D slices. Even though the information existing in 3D MRI is superior; it demands more computation effort to examine the information because of its complexity. Hence, in most of the cases; the 3D picture is initially divided into 2D slices of axial, coronal and sagittal views and this 2D slices are then examined physically with the help of a radiologist and/or with the help of a Computerized Image Examination System (CIES) [3], [4]. In most of the cases, 2D slices of the axial view (top-view) are widely adopted due to its superiority.

The main aim of the proposed research work is to develop a CIES to examine the Chest/Cardiac MRI. This imaging system is widely used in the clinics to detect heart's anatomy, functioning of heart and cardiac diseases. Like other MRI, this images are also in 3D form and in this work, the 2D slices of axial-vied is adopted for the examination. The proposed work implements a CIE system which includes an image pre-processing and post-processing practices. The pre-processing is adapted to threshold the MRI slice to enhance the abnormal cardiac section. The thresholding is achieved with Differential-Evolution and Shannon-Entropy (DE+SE). After the enhancement; the abnormal cardiac section is then extracted using the Level-Set (LS) function. The LS approach is a semi-automated segmentation procedure, which is to be initiated in the form of a bounding-box (BB). This BB will converge towards the origin according to the iteration and finally it extracts the abnormal region from the cardiac MRI. The performance of the proposed technique is then evaluated based on Image Similarity Values (ISV). The ISVs are computed based on a relative assessment between the extracted cardiac section and the Ground-Truth (GT) [5], [6].

The proposed work considers the HVSMR 2016's benchmark cardiac MRI dataset for the investigation [7]. The remaining part of the work is presented as follows; Section II describes the related work in the literature, Section III presents the methodology adopted in this study; the results and dissuasions and conclusion are depicted in Sections IV and V respectively.

II. Related Works

Recently, a considerable number MRI evaluation works are proposed and implemented by the researchers. Most of the works are related to the brain MRI. The work implemented on the brain MRI can be accounted for the cardiac MRI too.

The work of Guttman *et al*. (1997) discusses the procedures to be followed while evaluation the cardiac MRI [8]. Backhaus *et al*. (2019) implemented a technique for a computerized quantification of biventricular volumes and function using the cardiac MRI [9]. The work of Khan *et al*. (2016) presented a detailed review of cardiac MRI evaluation procedures discussed in 100 related articles [10]. Friedrich (2017) presented a detailed evaluation regarding the future of Cardiac MRI and its clinical application [11]. The research by Attili *et al*. (2010) presented the quantification procedure for the cardiac MRI during the disease evaluation process.

Manuscript received July 15, 2019; revised August 29, 2019.

Hong Lin is with the Department of Computer Science & Engineering Technology, University of Houston-Downtown, Houston, Texas, USA (e-mail: linh@uhd.edu).

V. Rajinikanth was with Department of Electronics and Instrumentation Engineering, St. Joseph's College of Engineering, Chennai, Tamilnadu, India (e-mail: rajinikanthv@stjosephs.ac.in).

[12]. The work of Gupta *et al*., (2012) also presents a detailed evaluation of the cardiac MRI for the disease identification practice [13]. Along with the specific cardiac MRI evaluation procedures, brain MRI examination procedures discussed in the literature [1]-[5] also adopts the similar practice to extract the abnormal section from the MRI of chosen modalities. Irrespective of the internal organ structure (Brain/Heart), the techniques implemented for the MRI examination is common.

In the proposed work, a softcomputing technique based image examination practice is implemented to evaluate the axial-view of the cardiac MRI recorded with the Flair modality. The procedures followed for the brain MRI [1]-[5] is adopted in the present work to evaluate the extracted section with the Ground-Truth and the essential performance metrics are computed.

III. Methodology

The performance of CIES depends mainly of the procedures implemented to evaluate the chosen test picture. Various sections present in the proposed CIES are shown in Fig. 1.

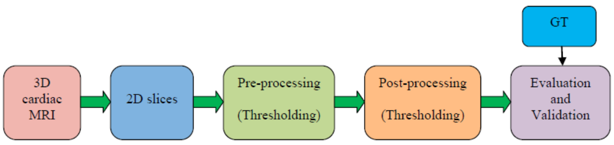

Fig 1. Various stages existing in the proposed Computerized Image Examination System.

The 3D MRI slices are initially collected from the HVSMR 2016 dataset. Later, the 2D slices from the 3D MRI are extracted using the ITK-snap tool [14]. The abnormal cardiac section is then enhanced using the DE+SE thresholding and the enhanced region is then extracted using the Level-Set technique. Finally, the necessary image similarity values are computed and the performance of the proposed system is validated [15].

A. Database

In order to accomplish a better result in the computer based disease examination task, choice of a finest image database is essential. In the proposed work the benchmark grand-challenge database known as 'HVSMR 2016' is adopted for the examination [7]. From this dataset, two-volunteer's cardiac MRI is adopted for the examination. From these two MRIs, around 80 slices (2 volunteers x 40 images/volunteer) of the axial view is then extracted using the ITK-snap tool. This work offered the cardiac MRI slices and the Ground-Truth (GT) slices of the dimension 174x118 pixels. This gray scale picture database is then examined using the proposed CIES. In this work, the Flair modality based axial view offers more information compared to T1, T1C and T2 modalities. Hence, this work considered the Flair modality MRI.

B. Pre-processing

Pre-processing is an essential task in most of the image processing domain. In medical image analysis, the pre-processing scheme can be adopted to enhance the test picture. In the proposed work, DE+SE based three-level thresholding is adopted to enhance the cardiac MRI slices.

Differential-Evolution is a successful softcomputing procedure widely adopted in the literature to find solutions for a class of engineering optimization problems. In this work, the main aim of the DE is to randomly vary the threshold value till the SE reaches the maximal limit. The essential details regarding the DE [16] and the SE [17] is extensively discussed in the literature.

In this work, the DE algorithm is initiated with these values; number of agents = 25, dimension of search=3, number of iterations = 2000 and terminating function = maximized SE.

C. Post-processing

This technique is employed to mine the abnormal cardiac section from the thresholded picture. In this work, Level-Set (LS) segmentation is employed [18].

The mathematical expression of LS is;

$$OP = \frac{\partial \varphi(F,V)}{\partial V} \tag{1}$$

where, ϕ =curve vector with spatial constraint (F) and sequential variable (V), O= speed utility and P= inmost curve normal vector ϕ. The curve growth can be implemented as LSS by implanting the dynamic contour $\phi(\mathrm{F},\mathrm{V})$ as the preliminary bounding-box (BB).

The inmost usual vector P is signified as:

$$\mathrm{P} = \frac{-\nabla\varphi}{\nabla\varphi} \tag{2}$$

where ∇ =gradient function.

The final LS growth is articulated as:

$$\frac{\partial\varphi}{\partial \mathrm{V}} = \mathrm{O}|\nabla\varphi| \tag{3}$$

Other details on the LS can be found in [19].

D. Examination and Validation

Performance evaluation and validation plays a major role to judge the superiority of the proposed technique. In this work, the essential Image Similarity Values (ISV) are computed with an examination between the GT and extracted cardiac section (CS) [1]-[6].

The mathematical expressions of the ISVs are depicted below;

$$Jaccard = GT \cap CS / GT \cup CS \tag{4}$$

$$Dice = 2(GT \cap OD)/|GT| \cup |OD| \tag{5}$$

$$Accuracy = (TP + TN)/(TP + TN + FP + FN) \tag{6}$$

$$Precision \;\; = TP/(TP + FP) \tag{7}$$

$$Sensitvity = TP/(TP + FN) \tag{8}$$

$$Specificit\,y = TN/(TN + FP) \tag{9}$$

where *TP*=true-positive, *FP*=false-positive, *TN*=true-negative, and *FN*=false-negative.

IV. Results and Discussion

This section presents the experimental outcome and its discussions. All the experimental work is implemented using the Matlab software. Fig. 2 depicts the sample test image adopted for the examination. Fig. 2 (a) denotes the image class and Fig. 2(b) to (f) signifies chosen 2D slices. On these images, the thresholding and the segmentation procedures are then implemented and the corresponding outcomes are presented in Fig. 3. Fig. 3(a) depicts the image class and Fig. 3(b) to (f) shows the processed 2D cardiac MRI slices. Similar procedure is employed for all the test images (80 numbers) and the corresponding results are then recorded. These results confirm that, the extracted section is approximately identical with the GT. Finally, for every image, the ISV is then compared and the average of the ISVs obtained from all the test images (80 numbers) are presented in Fig. 4. From this image, it is clear that, the proposed CIES on the MRI database offered an overall ISV of 88.61%. From this study, it can be confirmed that, proposed CIES works well on the cardiac MRI dataset and in future, it can be considered to examine the clinical grade cardiac MRIs.

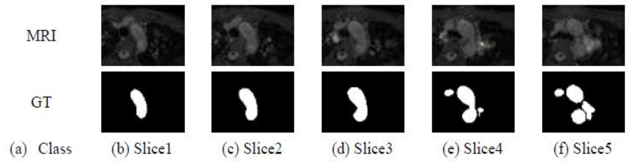

Fig. 2. Sample cardiac MRIs.

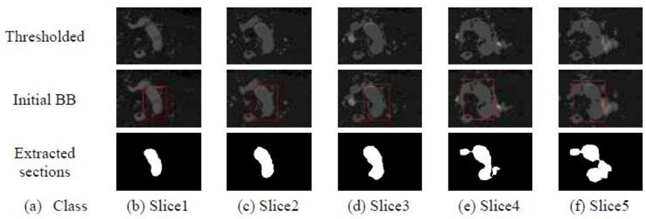

Fig. 3. Results of the pre- and post-processing techniques.

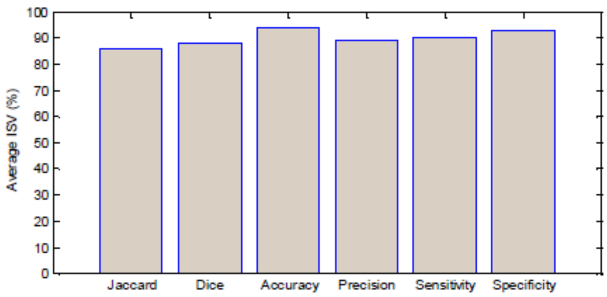

Fig. 4. Average ISV (%) obtained for the adopted database.

In future, the SE can be compared with Otsu's, Kapur's and Tsalli's methods existing in the literature. Furthermore, the performance of LS can be evaluated with other segmentation procedures, such as watershed algorithm, region-growing segmentation and active contour techniques.

V. Conclusions

This work presents a Computerized Image Examination System (CIES) to extract and evaluate the abnormal section from the cardiac MRI. This work implements a fusion of the pre- and post-processing technique to extract the cardiac section with better accuracy. This work initially implemented the DE+SE based three-level thresholding technique to enhance the test picture and later implemented the LS segmentation to extract the section. The proposed system is experimentally investigated on the benchmark HVSMR 2016 cardiac MRI database. The results of the proposed study confirms that, this technique offered an average ISV of >88%. In future, a clinical grade cardiac MRI can be considered to assess the performance of the proposed tool.

References

[1] S. C. Satapathy, S. L. Fernandes, and H. Lin, "Stroke lesion segmentation and analysis using entropy/Otsu's function–a study with social group optimization," *Current Bioinformatics*, vol. 14, no. 4, pp. 305-313, 2019.

[2] V. Rajinikanth, S. C. Satapathy, N. Dey, and H. Lin, "Evaluation of ischemic stroke region from CT/MR images using hybrid image processing techniques," *Intelligent Multidimensional Data and Image Processing*, pp. 194-219, 2018.

[3] V. Rajinikanth, K. P. Thanaraj, S. C. Satapathy, S. L. Fernandes, and N. Dey, "Shannon's entropy and watershed algorithm based technique to inspect ischemic stroke wound," *Smart Innovation, Systems and Technologies*, vol. 105, pp. 23-31, 2019.

[4] V. Rajinikanth, S. C. Satapathy, S. L. Fernandes, and S. Nachiappan, "Entropy based segmentation of tumor from brain MR images – A study with teaching learning based optimization," *Pattern Recognition Letters*, vol. 94, pp. 87-95, 2017.

[5] N. S. M. Raja, S. Arunmozhi, H. Lin, N. Dey, and V. Rajinikanth, "A study on segmentation of leukocyte image with Shannon's entropy," *Histopathological Image Analysis in Medical Decision Making*, pp. 1-27, 2019.

[6] V. Rajinikanth, N. Dey, S. C. Satapathy, and A. S. Ashour, "An approach to examine magnetic resonance angiography based on Tsallis entropy and deformable snake model," *Future Generation Computer Systems*, vol. 85, pp. 160-172, 2018.

[7] HVSMR 2016's benchmark cardiac MRI dataset. [Online]. Available: http://segchd.csail.mit.edu/

[8] M. A. Guttman, E. A. Zerhouni, and E.R. McVeigh, "Analysis of cardiac function from MR images," *IEEE Computer Graphics and Applications*, vol. 17, no. 1, pp. 30–38, 1997.

[9] S. J. Backhaus *et al*., "Fully automated quantification of biventricular volumes and function in cardiovascular magnetic resonance: Applicability to clinical routine settings," *Journal of Cardiovascular Magnetic Resonance*, vol. 21, p. 24, 2019.

[10] M. S. Khan *et al*., "Top 100 cited articles in cardiovascular magnetic resonance: A bibliometric analysis," *Journal of Cardiovascular Magnetic Resonance*, vol. 18, p. 87, 2016.

[11] M. G. Friedrich, "The future of cardiovascular magnetic resonance imaging," *European Heart Journal*, vol. 38, no. 22, pp. 1698–1701, 2017.

[12] A. K. Attili *et al*., "Quantification in cardiac MRI: Advances in image acquisition and processing," *The International Journal of Cardiovascular Imaging*, vol. 26, no. 1, pp. 27–40, 2010.

[13] V. Gupta *et al*., "Cardiac MR perfusion image processing techniques: A survey," *Medical Image Analysis*, vol. 16, no. 4, pp. 767-785, 2012.

[14] ITK-SNAP. [Online]. Available: http://www.itksnap.org/pmwiki/pmwiki.php

[15] H. Lin, S. L. Fernandes, and V. Rajinikanth, "An empirical study on the measurability of meditation," in *Proc. the SDPS 22nd International Conference on Emerging Trends and Technologies in Convergence Solutions*, 2018, pp. 181-188.

[16] R. Storn and K. Price, "Differential evolution – A simple and efficient heuristic for global optimization over continuous spaces," *Journal of Global Optimization*, vol. 11, no. 4, pp. 341-359, 1997.

[17] P. L. Kannappan, "On Shannon's entropy, directed divergence and inaccuracy," *Probab. Theory Rel. Fields*, vol. 22, pp. 95–100, 1972.

[18] C. Li, C. Xu, C. Gui, and M. D. Fox, "Distance regularized level set evolution and its application to image segmentation," *IEEE Transactions on Image Processing*, vol. 19, no. 12, pp. 3243–3254, 2010.

[19] V. Rajinikanth, S. L. Fernandes, B. Bhushan, and N. R. Sunder, "Segmentation and analysis of brain tumor using Tsallis entropy and regularised level set," *Lecture Notes in Electrical Engineering*, vol. 434, pp. 313-321, 2018.

Hong Lin earned his PhD in computer science at the University of Science and Technology of China, and was a postdoctoral research associate at Purdue University, an assistant research officer at the National Research Council, Canada, and a software engineer at Nokia, Inc. Dr. Lin is currently a professor with the University of Houston – Downtown. His research interests include parallel/distributed computing, data analytics, and human-centered computing. He is a senior member of the ACM.

V. Rajinikanth earned his PhD in electrical engineering from Anna University, Tamilnadu of India. Currently, he is working in the Department of Electronics and Instrumentation Engineering, St. Joseph's College of Engineering, Chennai, India. He is a member in IEEE and life member in Soft Computing Research Society, India. He is serving as an associate editor in International Journal of Rough Sets and Data Analysis (IJRSDA), IGI Global publisher. His research interest includes heuristic algorithm assisted medical image and signal processing, machine learning and deep learning for the medical data analysis.