Guest Editorial: Advances in Computational Intelligence for Multimodal Biomedical Imaging

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Published online: 17 January 2019

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Nowadays, many modalities such as CT, X-ray scanners, MRI/fMRI, PET scan, etc. generate complex images with a large amount of data that are becoming extremely difficult to handle. This growing mass of data requires new strategies for the diagnosis of diseases and new therapies. In recent years, particular attention has been paid to computational intelligence methods in multimodal biomedical imaging applications. Inspired by artificial intelligence, mathematics, biology and other fields, these methods can find relationships between different categories of this complex data and provide a set of tools for the diagnosis and monitoring of the disease.

This special issue provides a forum to publish original research papers covering the state-of-the-art, new algorithms, methodologies, theories and implementations of computational intelligence methods for computer-aided diagnostic systems and multimodal biomedical imaging applications such as classification, restoration and registration.

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This special issue has attracted 48 manuscripts and the submissions have been strictly reviewed by at least three reviewers consisting of guest editors and external reviewers, leading to 19 high-quality articles accepted. Below, highlights of each paper are briefly summarized.

In the paper [6], the authors present a secure medical image watermarking technique applying spread-spectrum concept in the discrete wavelet transform domain (DWT). The robustness of the method is examined for various kinds of attacks. The obtained results show that the proposed technique offers more robustness than other state-of-the-art methods.

A modified intuitionistic fuzzy c-means clustering approach to segment human brain MRI image is proposed in [10]. Based on the fact that the Fuzzy c-means (FCM) is one of the most used methods for medical image segmentation, two complementary intuitionistic fuzzy functions, namely Sugeno's negation function and Yager's negation function, are investigated. The performance of the proposed method is compared with three intuitionistic fuzzy clustering methods and the FCM on two publicly available MRI datasets and a synthetic dataset. Experimental results demonstrate the superior performance of the proposed method compared to the others.

The paper [8] presents a survey of denoising techniques for multi-parametric prostate MRI. The study conducted by the authors evaluates the performance of fifteen denoising filters (Anisotropic, Median, Wiener, Gaussian, Mean, Wavelet, Contourlet, Bilateral, Curvelet, WHMT, NLM, GFOE, LMMSE, CURE-LET and ARF) w.r.t. mp-prostate MRI i.e. T2w, DCE and DWI images in the presence of Gaussian and Rician noise. Based on the comparisons, they concluded that anisotropic and NLM filters should be opted for denoising tasks because of their capability of preserving structural and other crucial details.

An efficient computerized decision support system for the 3D analysis and visualization of brain tumors is proposed in [13]. The aim is to develop an intelligent computer-aided diagnostic system focusing on human brain MRI analysis. Brain MRI images are segmented using a semi-automatic and adaptive threshold selection method. After segmentation and classification, the 3D visualization of the brain and tumor is achieved using a volume marching cube algorithm which is used for rendering medical data. Experimental results indicate that the proposed system performed better than existing systems and assists radiologists in determining the size, shape, and location of the tumor in the human brain.

The paper in [11] deals with the undersampled Compressive Sensing image reconstruction using nonconvex and nonsmooth mixed constraints. To do this, a hybrid TV ($TV^{1,2}$) regularizer is introduced by combining TV with its second-order version (TV^2). The authors propose their new CS-MRI framework by combining the $TV^{1,2}$ regularizer and L0-regularized tree-structured sparsity constraint. The results from simulation and in vivo experiments demonstrate the good performance of the proposed method compared with several conventional MRI reconstruction methods.

The paper [15] presents a novel approach to classify retinal vessels extracted from fundus camera images. The proposed method combines an orthogonal locality preserving projections for feature extraction and a Gaussian Mixture Model with an Expectation-Maximization unsupervised classifier. The classification rate on their own ORCADES dataset and the publicly available DRIVE dataset has achieved 90.56%.

The paper [14] deals with one of the major health issues across the world which is the Breast Cancer. The authors propose a hybrid Computer Aided Diagnosis framework to classify suspicious regions into normal or abnormal, and further, benign or malignant. Experimental results reveal that the proposed hybrid scheme is accurate and robust and can be considered as a reliable CAD framework to help the physicians for better diagnosis.

In the same way, the paper [17] deals with the detection of breast abnormalities in digital mammograms using the electromagnetism-like algorithm. The authors introduce an effective method for the detection of the ambiguous areas in digital mammograms. After noise and artifacts removal from the images using 2D Median filtering and labeling, they isolate the abnormalities using the meta-heuristic algorithm Electromagnetism-like Optimization (EML). The accuracy detection rate, for two different databases Mini-Mias and DDSM, achieves almost 85% for both databases and 91.07% for DDSM alone.

Applications on Brain-Computer Interface (BCI) systems are also evoked in this issue. The paper [19] introduces a new approach for the detection of SSVEP based on bispectral analysis to palliate the frequency-dependent bias. Using two datasets, the results of experiments on five (or ten) subjects show that the proposed approach significantly outperformed the standard CCA approach in distinguishing the target frequency and in average information transfer rate.

An efficient classification approach for detection of Alzheimer's disease from biomedical imaging modalities is proposed in [3]. The proposed system is a multi-stage system comprising four key phases namely, pre-processing, feature extraction, feature selection and detection phase. The proposed framework's efficiency is evaluated on the ADNI subset and then on the Bordeaux-3 city dataset. The experimental validation of the proposed approach attains an accuracy of 97.63%, 95.4%, 96.4% for the most challenging classification tasks AD vs NC, MCI vs NC and AD vs MCI, respectively.

A hybrid edge-based technique for segmentation of renal lesions in CT images is proposed in [9]. The authors suggest a hybrid segmentation technique based on two methods which include Spatial Intuitionistic Fuzzy C-Means clustering (SIFCM) that integrates spatial image details and, distance regularized level-sets method for extraction of renal lesions correctly and proficiently in computed tomography (CT) images. The method attains the better lesion segmentation, even for images with low-contrast and in the presence of noise components.

The paper presented in [2] proposes a Multi-scale Convolutional Neural Network (CNN) based on region proposals for efficient breast abnormality recognition. The authors develop a novel deep CNN approach to discriminate normal from abnormal breast tissues using Gaussian pyramid representation for multi-scale analysis (Pyramid-CNN). Their study demonstrates that the proposed approach has the potential to significantly improve the conventional recognition and classification strategies for use in advanced clinical application and practice or in general, biomedical imaging field.

In the same context, the paper [12] deals with the diagnosis of breast tissue in mammography images based on local feature descriptors. This work proposes a method for discriminating patterns of malignancy and benignity of masses in digitized mammography images through the analysis of local features. The method comparatively applies the Scale-Invariant Feature Transform (SIFT), Speed Up Robust Feature (SURF), Oriented Fast and Rotated BRIEF (ORB) and Local Binary Pattern (LBP) descriptors for local feature extraction. The method obtained significant results, reaching 100% sensitivity, 99.65% accuracy and 99.24% specificity for benign and malignant mass classification.

The paper [1] proposes a method for glaucoma diagnosis using fundus eye images. Diversity indexes, which are typically used in ecological studies, are used in this work as texture descriptors in the optic disc region. Then, a feature selection procedure is performed using Genetic Algorithm (GA) and Support Vector Machines (SVM) are used to classify fundus eye images in glaucomatous or normal. The proposed method obtained promising results for glaucoma diagnosis, reaching an accuracy of 93.41%, sensitivity of 92.83% and specificity of 93.69%.

The breast cancer detection in mammography using spatial diversity, geostatistics, and concave geometry is studied in [5]. These features are evaluated using Support Vector Machine in MIAS and DDSM database, with 74 and 621 mammograms, respectively. The obtained results are promising while reaching 97.30% of detection rate and 0.89 false positive per image for MIAS database and also 91.63% of detection rate and 0.86 false positive per image for DDSM database.

The aim of the paper presented in [4] is to propose a Diagnostic Aided System that is capable of segmenting and measuring the pleural thickening caused by a pleural disease called "Malignant Pleural Mesothelioma". The method was validated on a representative database and the results obtained for ten test series were very encouraging.

In [18], the authors propose a combined support vector machine-FCGS classification based on the wavelet transform for Helitrons recognition in *C.elegans*. This paper focuses on the discrimination between helitrons and non-helitrons using the Support Vector Machine (SVM) with all its kernels. The higher accuracy rates are obtained by reaching the optimal kernels-parameters. The classification results prove that the wavelet energy feature is more effective than the FCGS₂ features in the helitron's recognition system.

In [7], the authors propose a novel ECG signal enhancement method based on Complete Ensemble Empirical Mode Decomposition with Adaptive Noise (CEEMDAN) and Higher Order Statistics (HOS). The simulation results, carried on MIT-BIH Arrhythmia database, show that CEEMDAN method gives better performance than two other methods, and outperform some state-of-the-art methods in terms of Signal to Noise Ratio (SNR) and Root Mean Square Error (RMSE).

The paper [16] deals with ulcer abnormalities detection of small bowel from wireless capsule endoscopy images (WCE). The authors propose a multi-scale approach based on completed local binary patterns, and laplacian pyramid (MS-CLBP). The results obtained validate the efficiency of the proposed system with an average accuracy of 95.11 and 93.88% for both datasets. Finally, a comparison with the state-of-the-art methods shows that the proposed method is superior to the other approaches.

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References

1. Araújo JDL, Souza JC, Neto OPS et al (2018) Glaucoma diagnosis in fundus eye images using diversity indexes. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-6429-Z>
2. Bakkouri I, Afdel K (2018) Multi-scale CNN based on region proposals for efficient breast abnormality recognition. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-6267-Z>
3. Baskar D, Jayanthi VS, Jayanthi AN (2018) An efficient classification approach for detection of Alzheimer's disease from biomedical imaging modalities. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-6287-8>
4. Brahim W, Betrouni N, Mestiri M et al (2018) The pleural thickening approximation from thoracic CT scans. *Multimed Tools Appl.* <https://doi.org/10.1007/s11042-018-6400-z>
5. Braz Junior G, da Rocha SV, de Almeida JDS et al (2018) Breast cancer detection in mammography using spatial diversity, geostatistics, and concave geometry. *Multimed Tools Appl.* <https://doi.org/10.1007/s11042-018-6259-z>
6. Chauhan DS, Singh AK, Adarsh A et al (2017) Combining Mexican hat wavelet and spread spectrum for adaptive watermarking and its statistical detection using medical images. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-017-5348-8>

7. El Bouny L, Khalil M, Adib A (2018) ECG signal filtering based on CEEMDAN with hybrid interval thresholding and higher order statistics to select relevant modes. *Multimed Tools Appl.* <https://doi.org/10.1007/s11042-018-6143-x>
8. Garg G, Juneja M (2018) A survey of denoising techniques for multi-parametric prostate MRI. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-6487-2>
9. Kaur R, Juneja M, Mandal AK (2018) A hybrid edge-based technique for segmentation of renal lesions in CT images. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-6421-7>
10. Kumar D, Verma H, Mehra A et al (2018) A modified intuitionistic fuzzy c-means clustering approach to segment human brain MRI image. *Multimed Tools Appl.* <https://doi.org/10.1007/s11042-018-5954-0>
11. Liu RW, Yin W, Shi L et al (2018) Undersampled CS image reconstruction using nonconvex nonsmooth mixed constraints. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-6028-Z>
12. Matos CEF, Souza JC, Diniz JOB et al (2018) Diagnosis of breast tissue in mammography images based local feature descriptors. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-6390-X>
13. Mehmood I, Sajjad M, Muhammad K et al (2018) An efficient computerized decision support system for the analysis and 3D visualization of brain tumor. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-6027-0>
14. Mohanty F, Rup S, Dash B et al (2018) Mammogram classification using contourlet features with forest optimization-based feature selection approach. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-5804-0>
15. Relan D, Ballerini L, Trucco E et al (2018) Using orthogonal locality preserving projections to find dominant features for classifying retinal blood vessels. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-6474-7>
16. Souaidi M, Abdelouahed AA, El Ansari M (2018) Multi-scale completed local binary patterns for ulcer detection in wireless capsule endoscopy images. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-6086-2>
17. Soulami KB, Saidi MN, Honnit B et al (2018) Detection of breast abnormalities in digital mammograms using the electromagnetism-like algorithm. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-5934-4>
18. Touati R, Messaoudi I, Oueslati AE et al (2018) A combined support vector machine-FCGS classification based on the wavelet transform for Helitrons recognition in C.Elegans. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-6455-X>
19. Trigui O, Zouch W, Ben Slima M et al (2018) Bispectral analysis-based approach for steady-state visual evoked potentials detection. *Multimed Tools Appl.* <https://doi.org/10.1007/S11042-018-6029-Y>

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