Introduction to the special issue on deep learning for biomedical and healthcare applications

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1 Background

Deep learning (DL) provides an effective method to learn the low-level structure of original data to obtain a more abstract description, implicitly capturing intricate associations and features of the large-scale input. In recent years, both theory development and practical applications of deep learning have gradually made a significant difference in biomedical and healthcare areas due to existing large-scale medical data and the huge potential, strongly pushing state-of-the-art of this field into a broad and high-level research hot spot, largely outperforming the conventional methods.

Because neural computing plays an important role in machine learning and deep learning, the Special Issue on Deep Learning for Biomedical and Healthcare Applications published on *Neural Computing and Applications* can play an important role by providing a venue for academics as well as industrial practitioners to disseminate their results in a peer-reviewed environment. This special issue aims to bring articles on both theoretical and model development along with innovative applications of deep learning. Important examples include the use of deep

learning for image classification and drug discovery, while some of the specific challenges that should be addressed include human body sensor fusion, assistant medical diagnosis, and clinical decision making. There were five submissions for this special issue, of which three high-quality ones were accepted and selected to be included in the special issue.

2 Papers in the special issue

Reversible watermarking has been widely applied in managing digital contents such as digital images, texts, audios and videos, especially in managing medical data regarding DICOM images. It is lossless watermarking because of its preservation of all details of host and hidden data. The first article, “A Lossless Data Hiding Scheme for Medical Images Using a Hybrid Solution Based on IBRW Error Histogram Computation and Quartered Interpolation with Greedy Weights,” authored by Mohammad Khosravi, Mehran Yazdi, enhances interpolation-based reversible watermarking for DICOM images based on computing error histogram and applying an image interpolation with greedy weights (adaptive weighting). And simulation results clearly show the proposed scheme outperforms the state-of-the-art methods on different DICOM images.

The second article “Convolutional Neural Network Based Multimodal Image Fusion Via Similarity Learning in The Shearlet Domain” proposed a fusion method with convolutional neural network (CNN) architecture in the field of shearlet, which can be used for CT and MR medical images. Firstly, the Siamese fully convolutional neural network with a pre-trained architecture learned from natural data is initialized, and secondly, the network is trained using medical images in a transfer learning fashion. Training dataset is composed of positive and negative patch pair of Shearlet coefficients. In order to extract features maps, samples are feed in two-stream deep CNN. Next, a similarity metric learning based on cross-

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correlation is performed aiming to learn mapping among features. To solve the minimization of the logistic loss objective function, stochastic gradient descent (SGD) is applied. Therefore, source CT and MR images are initially decomposed into several sub-images flow by the non-subsampled Shearlet transform (NSST) in the fusion process. High-frequency sub-bands are fused according to weighted normalized cross-correlation between feature maps, which is given by the extraction part of the CNN, while low-frequency coefficients are combined with the use of local energy. Training and test datasets contain pairs of pre-registered CT and MRI which is taken from the database of Harvard Medical School. Experimental results of visual analysis and objective assessment proved that the proposed deep architecture is better than the state-of-the-art performance in terms of subjective and objective assessment. The proposed CNN's potential for multi-focus image fusion is presented in the part of experiments.

To diagnose many types of heart diseases such as abnormal heartbeat rhythm (arrhythmia), a picture of heart electrical conduction, called electrocardiogram (ECG), is widely used. However, the abnormal ECG characteristics detection is very difficult to perform direct information extraction, because of the nonlinearity and the complexity of ECG signals from one side and the noise effect of these signals from the other side. In the article entitled “Very

Deep Feature Extraction and Fusion for Arrhythmias Detection,” the authors proposed a very deep convolutional neural network (VDCNN), which can distinguish between the normal (NSR) heartbeats and three common types of arrhythmia atrial fibrillation (A-Fib), atrial flutter (AFL), and paroxysmal supraventricular tachycardia (PSVT) without techniques of noise filtering or preprocessing. It uses small filters throughout the network to reduce the noise interference and introduces a method named multi-canonical correlation analysis (MCCA) to learn features of selective adaptive layers which can speed up the training task and make the resulting representations highly linearly correlated. Besides, the algorithm of Q-Gaussian multi-class support vector machine (QG-MSVM) for classification is introduced that performs better on learning and generalization of ECG signals. Experimental results show that this algorithm is better than the state-of-the-art methods.

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