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An Elegant Approach for Diagnosis of Parkinson's disease on MRI Brain Images by Means of a Neural Network

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Abstract

Early diagnosis of Parkinson's disease (PD) is of immense importance, since clinical symptoms do not occur until substantial parts of the substantia nigra(SN) neurons in the brain stem have been irreparably damaged. Furthermore, large parts of the population are affected by this disease and although PD is currently regarded as incurable, the symptoms can be alleviated by the administration of drugs. Neuroprotective drugs could shelter neurons of the SN when used at the beginning of the disease in the preclinical state. Therefore a technology to detect early SN damage is wanted for the identification of individuals at risk for PD. We are presenting an loom for MRI brain slices by means of feature extraction and unsupervised clustering. In which clustering is carried out by means of a self-organizing map (SOM). Then, each pixel is classified according to the identified classes. The number of classes is a priori unknown and the artificial neural network that implements the SOM is used to determine the main classes. The detection of the classes in the SOM is done by using a K-means segmentation. This processing is useful to potential diagnosis of Parkinson´s disease in brain-stem area Principle of this solution is showing morphological operations to detection of pathological defects.

Keywords: Substantia nigra, Parkinson's disease, MRI image

Introduction

With the growing age, there is advancement in each and every field. As far as the medical field is concerned, it also has everyday progress. The medical imaging field in particular, has grown substantially in recent years, and has generated additional interest in methods and tools for the management, analysis, communication of medical image data.

There is a growing need in neuroscience research for computational tools to organize, analyze, and visualize the vast amounts of new information being produced about the structure and the function of the brain. A range of approaches has been proposed for semi-automatic detection of various structures in the head. These approaches usually require manual interaction, even in most practical implementations, to perform the required segmentation and detection. The fully automated segmentation, however, is still under research.

Image processing in modern medicine is very helpful to diagnosis. In our case we work with set of MRI images of brain-stem to potential diagnosis of Parkinson´s disease (PD), which is chronic disease depending on production of dopamine. In ultrasound images is characterized by defects in substantia nigra (SN) area in brain-stem. The goal of this paper is to show an application which has been developed for ROI SN and searching these defects by thresholding and area comparison followed by statistical analysis. This application is helpful for classification of patients who have PD or not. For analysis of these images we are using a two-stage neural network system The first stage is a self-organizing principal components analysis (SOPCA) network that is used to project the feature vector onto its leading principal axes found by using principal components analysis. This step provides an effective basis for feature extraction. The second stage consists of self-organizing feature map (SOFM) which automatically clusters the input vector into different regions.

Substantia Nigra and Parkinson's Disease

A. Substantia nigra in brain stem

Substantia nigra (SN; in English "black substance") is a brain structure[14] which is located in the mesencephalon (midbrain) that plays an important role in reward, addiction, and movement. SN produces an important dopamine for correct function of CNS (Central nervous system). Parkinson's disease (PD) is

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caused by the death of dopaminergic neurons. It is a degenerative disease of basal ganglias inside the brain.
The main symptoms of PD include muscle rigidity, tremors and changes in speech and gait, bradykinesia, sleep disorders and more.1 The following figure shows the position of SN:

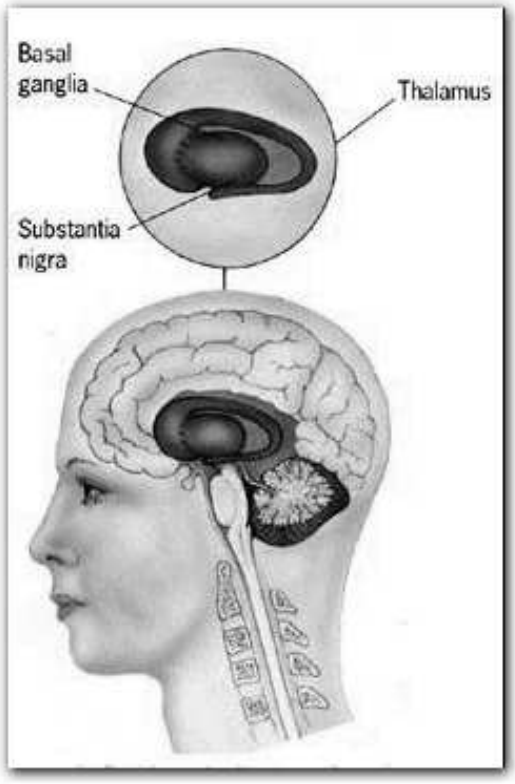

Fig. 1 A position of searched SN in midbrain

B. Parkinson´s disease

Parkinson's disease (PD) is caused by the death of dopaminergic neurons. It is a degenerative disease of basal ganglias inside the brain. PD has been described by James Parkinson in 19th century. The main symptoms of PD include muscle rigidity, tremors and changes in speech and gait and more.

Literature Survey

Actual modern medicine is focused on new progressive technologies for image processing and we encounter with these technologies in many areas of medicine. Nowadays we have not only traditional X-rays but we have a lot of advanced methods to detection and research without real cutting. The development of these methods is very fast and progressive. Modalities US, CT, MRI, X-Rays, PET are nowadays common but indispensable in medicine. This work also well shows interdisciplinary character between medicine and computing. The neural networks are very applicable for image processing problems. Thus we have the different approaches to comparison.

a) ***Image processing of medical diagnostic neuro sonographical images in MATLAB[14]: -*** This paper presents a processing of medical ultrasound images with MATLAB. This processing is useful to potential diagnosis of Parkinson´s disease in brain-stem area. Furthermore introduces DICOM standard for medical imaging and modern 3D/4D scanning for high level and accuracy of diagnoses that is higher than traditionally 2D scanning.

b) ***The image recognition of brain-stem ultrasound images with using a neural network based on PCA[3]: -*** This paper shows how to solve the recognition of ultrasound brain-stem images. Our work is based on PCA method that is very useful and known method for image processing. This paper uses artificial neural networks (ANN) for this problem and we will compare a results. The ANN is generally very usable for image processing. It has been demonstrated with Neuro Solutions software that is very sophisticated simulator of ANN with PCA multilayer (ML) NN topology.

c) ***Classification of MRI Brain Images Using Neuro Fuzzy Model[15]:-*** It is difficult to identify the abnormalities in brain specially in case of Magnetic Resonance Image brain image processing. Artificial neural networks employed for brain image classification are being computationally heavy and also do not guarantee high accuracy. The major drawback of ANN is that it requires a large training set to achieve high accuracy. On the other hand fuzzy logic technique is more accurate but it fully depends on expert knowledge, which may not always available. Fuzzy logic technique needs less convergence time but it depends on trial and error method in selecting either the fuzzy membership functions or the fuzzy rules. These problems are overcome by the hybrid model namely, neuro-fuzzy model. This system removes essential requirements since it includes the advantages of both the ANN and the fuzzy logic systems. In this paper the classification of different brain images using Adaptive neuro-fuzzy inference systems (ANFIS technology). Experimental results illustrate promising results in terms of classification accuracy and convergence rate.

As literature shows there has been much work carried on classification of brain images using neural network. This processing is useful to potential diagnosis of Parkinson´s

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disease in brain-stem area. As we know there are other neural network models that can be used to improve the efficiency of the system.

Proposed Methodology

The work involves the image processing of MRI images of brain[15], feature extraction and finally developing a suitable neural network classifier to classify the normal and abnormal brain images. Images of brain are obtained from MRI and the features are extracted using self organized principal component analysis (SOPCA) technique. These features are used to train the neural network. The artificial neural network model is used for classification. Thus, the proposed work emphasizes on development of Neural Network based method for the classification of MRI brain images. The block schematic diagram shown in figure is the proposed architecture for classification of MRI brain images.

Image Processing: At the first step for every processing is suitable preprocessing for successful application. Thus, the first step is

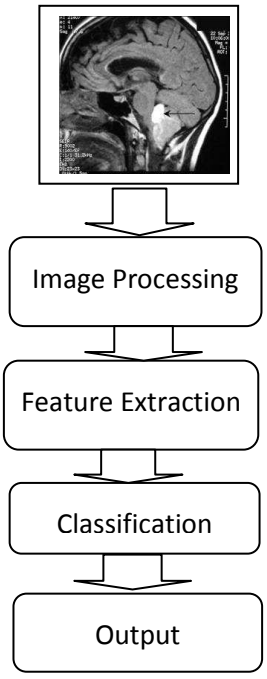

Fig 2: Proposed Architecture

Thus, the first step is cropping of images to window with stem area. It is the first step in algorithm. We considered about influence of a speckle noise that is typical for sonographical data. MRI images are very sensitive to dynamic speckle noise. The speckle noise arises from different tissues and actual position of ultrasound probe. The main problem for reduction is that speckle is not static noise but dynamic in image. If we have these small images then influence is not very considerable despite speckle noise should be reduced.

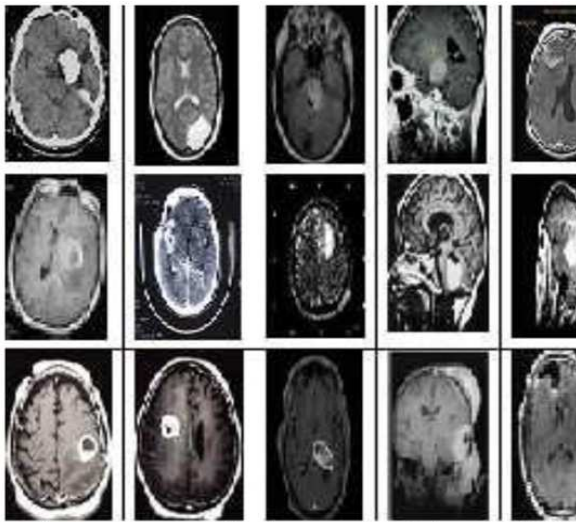

Fig 3: A typical example of the MRI dataset

Feature Extraction: The feature extraction[19] is used to reduce the dimension of the input data and minimize the training time taken by the classifier. Multiple features which include geometrical moments, statistical moments and texture moments are extracted from the region of interest (ROI).

i) Statistical Moments: The basic idea is to characterize the 'content' of an image histogram using some descriptors. Therefore, the following statistical features [16] of the histogram were calculated for quantitative analysis of the gray-level distribution in the ROI. The following statistical features were computed: 1) Mean value, 2) Median value, 3) Standard Deviation, 4) Skewness, and 5) Kurtosis.

ii) Geometrical Moments: Seven moments defined by Hu [17] were computed based on the segmented ROIs. Hu moments have been proven to be invariant to object scale, position and orientation. The moment of inertia is adapted to image processing by interpreting intensity values as inertia values and varies strongly between a uniform and a centrical distribution of the ROI [1].

iii) Texture Features: Gabor filters are effective to extract texture features [18].Given an image I(x, y) with size P × Q, its discrete Gabor wavelet transform is defined by the convolution

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$$G_{mn}(x,y) = \sum_{\xi}\sum_{\eta} I(x-\xi, y-\eta) g^{*}_{mn}(\xi,\eta)$$

where $*$ indicates the complex conjugate of g_{mn}. It is assumed that the local area is spatially homogeneous [8]. The filter mask size is indicated by ξ and η. The other two texture features, average gray level and average contrast were computed.

Feature selection using self-organized principal components analysis

A key problem encountered in statistical pattern recognition [20] is that of feature selection. Feature selection refers to a process whereby a data space is transformed into a feature space, in such a way that the data set may be represented by a reduced number of ''effective'' features and yet retain most of the intrinsic information content of the data. Principal Components Analysis PCA is perhaps the oldest and best-known technique in multivariate analysis Haykin, 1994. The practical value of PCA is that it provides an effective technique for dimensionality reduction. The first stage in two-stage network is a neural network that performs principal components analysis of arbitrary size on the input vector.

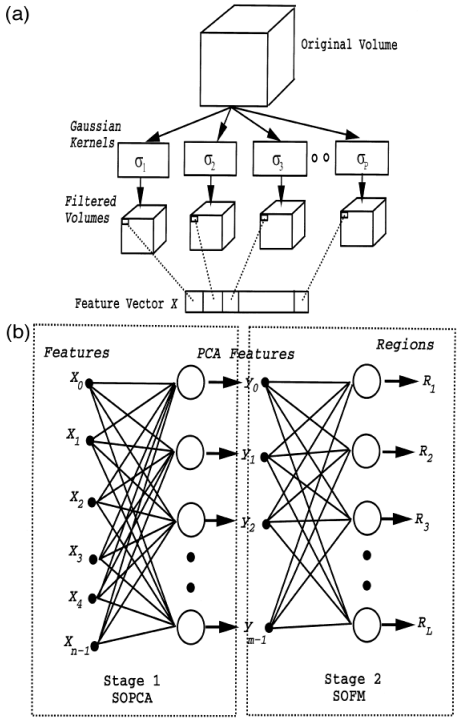

Fig4: a. Feature extraction using differential geometrical invariant features. b. Two-stage network SOFCA–SOFM. for the unsupervised clustering of multi-scale feature vectors.

As shown in Fig. 2, this network is a feed forward network composed of a single layer of linear neurons. The only aspect of the network that is subject to training is the set of synaptic weights $\{w_{ji}\}$ connecting source node i in the input layer to computation node in the output layer, where i=0,1, . . . ,n-1, and j=0,1, . . . ,m-1.

Self-organizing feature-mapping (SOFM)

The principal goal of the self organizing feature mapping (SOFM) network developed by Kohonen 1984. is to transform an incoming signal of arbitrary dimension into a one- or two-dimensional discrete map, and to perform this transformation adaptively in a topological order fashion. Many activation patterns are presented to the network, one at a time. Each input causes a corresponding localized group of neurons in the output layer of the network to be active. The essence of Kohonen's SOFM algorithm is that it substitutes a simple geometric computation for more detailed properties of the Hebb-like rule and lateral interactions. There are three basic steps involved in the application of the algorithm after initialization, namely, sampling, similarity matching,and updating. These three steps are repeated until the map formation is complete.

Classification: The training and classification is done using Neural Network. Neural network technology offers a number of tools such as learning and adaptation, generalization and robustness, feature extraction and distributed representation. The neural network approach has been shown fruitful in solving classification and recognition problems

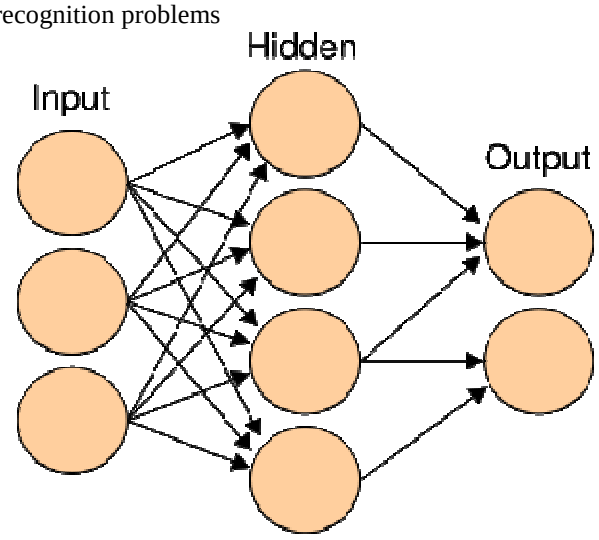

Fig 5 Neural Network Architecture

Conclusion

Diagnosis of Parkinson's disease (PD) is challenging problem and there is still a lot of work that

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needs to be done in this area. Over the past few years, recognition of substantia nigra in brain-stem has received substantial attention from researchers in neurology communities. This common interest in this recognition among researchers working in diverse fields is motivated both by the remarkable ability to diagnose Parkinson's disease. In this paper, a method was proposed for automatic recognition of substantia nigra in brain-stem SOM for feature extraction.

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