An MR Brain Image Classifier System via Particle Swarm Optimization and Kernel Support Vector Machine

Yudong Zhang[1,2], Chuanmiao Xie[1,3], Bradley S Peterson[1,2], and Zhengchao Dong[1,2]

[1]*Columbia University, New York, NY, United States,* [2]*New York State of Psychiatric Institute, New York, NY, United States,* [3]*Department of Medical Imaging & Interventional Radiology, Sun Yat-Sen University, Guangzhou, Guangdong, China*

Introduction

Automated detection of abnormal brain is of importance for clinical diagnosis. Numerous methods were proposed over the last decades to improve the accuracy of the detection of abnormality or the classification of normal and abnormal brains. In this paper, we proposed a novel hybrid system to classify a given MR brain image as either normal or abnormal. The key features of the system are that we introduced the *kernel* support vector machines (kSVMs), which extends original linear SVM to nonlinear SVM classifiers by applying the kernel function to replace the scalar product form in the original SVMs. In addition, we used Particle Swarm Optimization (PSO) to train the kSVM. We hypothesize that these features will help to improve the accuracy of the classification of MR brain images.

Methods

We first used digital wavelet transform to extract features from 2D brain MR images and used principal component analysis (PCA) to reduce the dimensionality of the feature space. Then, we constructed a kernel support vector machine (kSVM) with Radial Basis Function (RBF) kernel, because of its excellent properties such computational efficiency and versatility [1]. We then submitted the features to the classifier kSVM. We chose interior point method to solve this quadratic programming problem. To determine the best parameters for the training function of kSVM, i.e., the constraint on Lagrange multipliers and the width of the RBF kernel, we used the particle swarm optimization (PSO), independently proposed by Fei [2] and Zhao et. al. [3]. Based on their work, we introduced cross validation to construct the fitness function used for PSO. A simplified flowchart of the methodology of the proposed classification system is shown in Fig.1. The system was implemented with programs written in Matlab ©.

Experiments and Discussions

The test dataset consists of 90 T2-weighted MR brain images, which were downloaded from the website of Harvard Medical School (URL: http://www.med.harvard.edu/aanlib/home.html). The images are in axial plane and with 256x256 in-plane resolution, acquired with the same parameters. The 90 images consists of 5 normal and 5x17 abnormal brain MR images of the following 17 diseases: Glioma, Metastatic adenocarcinoma, Metastatic bronchogenic carcinoma, Meningioma, Sarcoma, Alzheimer, Huntington, Motor Neuron disease, Cerebral Calcinosis, Pick's disease, Alzheimer plus visual agnosia, Multiple sclerosis, AIDS dementia, Lyme encephalopathy, Herpes encephalitis, Creutzfeld-Jakob disease, and Cerebral Toxoplasmosis. We employed a 5-fold cross validation [4], which made up effectively total 90x5=450 images. After the 5-fold data were trained, we summarized the results on the 450 images.

In each experiment, 4 groups were used for training, and the left 1 group was used for validation. Each group was used once for validation. In total, 360 images were used for training and 90 images were used for cross validation. We compared our PSO-kVSM method with one hidden-layer Back Propagation Neural Network (BP-NN) and RBF Neural Network (RBF-NN), two of the most widely used classification tools. The results (Tab 1) showed that BP-NN correctly matched 388 cases among total of 450 cases, with 86.22% classification accuracy. RBF-NN correctly matched 411 cases with 91.33% classification accuracy. Our PSO-kSVM correctly matched 440 brain images with 97.78% classification accuracy. Therefore, our proposed hybrid method outperformed the two widely used classification methods.

We also check the abnormal images that are misclassified as normal brain images. Their common features are that they do not have visible lesions.

Tab.1 Confusion Matrix

Algorithm	Confusion Matrix	Sensitivity	Specificity	Classification Accuracy
BP-NN	374 11 51 14	88.0%	56%	86.22%
RBF-NN	393 7 32 18	92.47%	72%	91.33%
PSO-kSVM	417 2 8 23	98.12%	92%	97.78%

Conclusion

In this study we developed a novel hybrid classification system (PSO-kSVM) to distinguish between normal and abnormal MRIs of the brain. We used RBF as the kernel function of SVM. The experiments showed that the PSO-kSVM method achieved 97.78% classification accuracy for a dataset of the 5-folded 90 images and demonstrated the improved performance of the hybrid classification system as compared to that of the commonly used classification tools such as BP-NN and BRF-NN. It should be noticed that, each of these diseases have grossly visible lesions. The results will not be applicable to psychiatric and neurologic conditions that do not have grossly visible lesions.

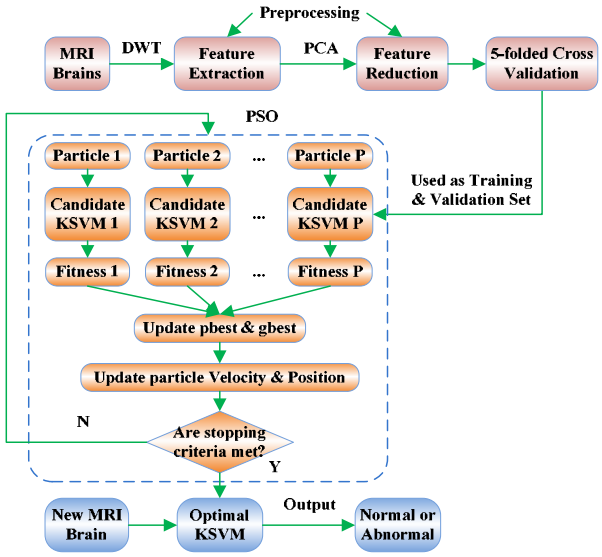

Fig.1 A flowchart of our proposed PSO-kSVM algorithm.

References

1. Park, J. and Sandberg, I. W. Universal approximation using radial-basis-function networks, Neural Comput. 1991; 3: 246–257.
2. Fei, S.-w., Diagnostic study on arrhythmia cordis based on particle swarm optimization-based support vector machine. Expert Systems with Applications, 201; **37**(10): 6748-6752.
3. Chenglin, Z., et al., Fault diagnosis of sensor by chaos particle swarm optimization algorithm and support vector machine. Expert Systems with Applications, 2011; **38**(8): 9908-9912.
4. Kohavi R. A study of cross-validation and bootstrap for accuracy estimation and model selection, in:C.S. Mellish, ed., Proceedings IJCAI-95, Montreal, Que. (Morgan Kaufmann, Los Altos, CA, 1995) 1137-l 143.