Project Title:

Deep neural network for brain signal (EEG, fMRI) processing

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1. Background and purpose of the project, relationship of the project with other projects

Machine learning techniques have played more and more important roles for signal analysis in many different research fields. Recurrent neural network and support vector machine have been used to learn the representations from Magnetic Resonance Imaging and EEG data in many researches. Convolution neural network (CNN) has achieved very high accuracy in pattern recognition.

For human-body electrical activity signal analysis, machine learning methods have played an important role. Finding effective representation of human-body electrical activity is the key to model cognitive events and for brain machine interface. In this research, we focus on the approaches of presentation of EEG data for deep neural network to generate more accurate classification results.

On the other hand, we also proposed a tensor train approach to improve the previous convolution neural network. In artificial neural networks, the fully connected layers play the role as classifiers, which map the learned features to label space. Because of the redundancy of the parameters, we employ the tensor train (TT) to replace the fully connected layer. In order to optimize the TT efficiently, we introduce the identity mapping as the skip connection in each TT layer.

2. Specific usage status of the system and calculation method

In our research, we proposed two approaches to learn representation from EEG data. In the firstly method, we transform the data into images, the color of images includes the frequency information. Then we will train a convolution neural network to classify the datasets (see Fig 1).

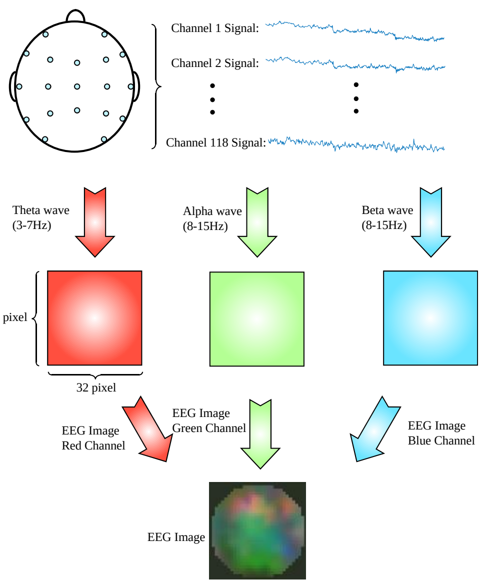

Fig 1. EEG image generation approach.

To detect EEG signals more accurately,

another algorithm was also approved. Firstly, the EEG signals was transformed into the time domain, frequency domain, channel domain tensor with using Morlet wavelets. Then we apply residual deep convolution neural network to classify different patterns in Motor Imagery EEG signals.

We benchmark our models on CIFAR-10 classification task. By introducing TT layers in deep neural networks, the number of parameters and computational cost only slightly increase, but the accuracy is substantially improved.

Image		
3×3 conv, 16		
3×3 conv, 16		$\times2m$
3×3 conv, 32		$\times2m$
3×3 conv, 64		$\times2m$
resTT	inp:$[4,4,4,4,4,4]$	$\times n$
	rank:$[r,r,r,r,r,r]$	
	out:$[4,4,4,4,4,4]$	
average pooling		
fully connected		

Fig 2. The structure of our residul TT neural network

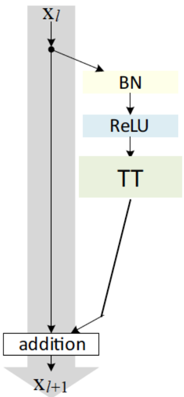

Fig 2. The structure of the residual TT unit

3. Result

The accuracy of EEG image genrate approach can achieve around 80% (Fig 3) but with construction of the 3-D tensor the accuracy is about 93%.

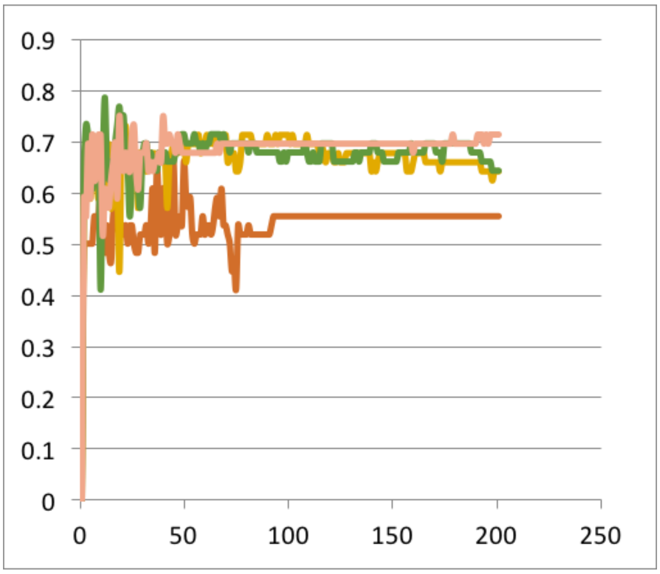

Fig 3. Detection accurary of four subjects based on the EEG image genration approach.

m	n	r	CIFAR-10(%)
5	0	-	6.8
5	2	4	5.7
63	0	-	5.1
63	2	4	4.4

Fig 4. Comparison of test error: with or without TTs (CIFAR-10 dataset).

4. Conclusion

We proposed two approaches for the representation of EEG data and they implemented accurate pattern recognition. The EEG image generation algorithm can process quickly of EEG signals. Since EEG images lost temporal information, So the method construction of time, frequency, channel 3-D tensor can identify EEG patterns more accurately.

We also presented a study on employing residual TT layers in deep residual neural networks. We insert TT layers where fully connected layers are placed in conventional CNN models. The representation of fully connected layer by TT layer greatly reduces the number of parameters. For various of CNN models, employing TT layers substantially improves the performance comparing to the corresponding models without TT, while the number of parameters and computational cost only slightly increased.

5. Schedule and prospect for the future

In the work of neural network for EEG classification, we will use much more dataset to verify the effectiveness of our method. Moreover, we use our neural network to develop a brain machine interface system to control the robots such as walking support robot.

In the work of residual neural network, the ranks for all core tensors in a TT are fixed to be the same value. However, determining the optimal ranks to balance the preservation of expressive power and the reduction of redundant parameters is still an open problem.

Moreover, it is also interesting to explore the performance of employing tensor networks other than TT in deep neural networks. We leave these tasks for future study.