Final Project Proposal
cs527

Abstract

The goal of this proposal is to develop a software system that would automate the process of epileptic spike detection in MEG data. I propose to accomplish this with the use of time delay neural network trained on MEG data with epileptic spikes prelabeled by an expert. The system to be developed could be used as a tool to automate epileptic spike detection presently performed by an expert. Also because of the nature of time delay neural network the software could be adapted to online detection process.

The Problem

Epilepsy is a disorder involving recurrent unprovoked seizures: episodes of abnormally synchronized and high-frequency firing of neurons in the brain that result in abnormal behaviors or experiences. This is a fairly common disorder, affecting close to 1% of the population. The lifetime risk of having a seizure is even higher, with estimates ranging from 10 to 15% of the population. About two million Americans have epilepsy; of the 125,000 new cases that develop each year, up to 50% are in children and adolescents. Older people, in particular those over 65, experience the second highest incidence of first seizures. One common cause is stroke — stroke victims often develop epilepsy prior to their full or partial recovery. Other causes are head injuries, serious infection, alcoholism, tumors, and dementia. Approximately 50% of patients recovering from traumatic head injury develop epilepsy.

Epilepsy can be caused by genetic, structural, metabolic, or other abnormalities. Epileptic disorder could be either generalized, partial (focal) or undetermined. Primary generalized seizures start as a disturbance in both hemispheres synchronously, without evidence of a localized onset. Partial forms of epilepsy start in a focal area of the brain and may remain localized without alteration of consciousness.

One method used to control epilepsy is pharmacological treatment. Antiepileptic drugs are widely used and give good results for 80 to 90% of patients. However many cases of intractable seizures are not responsive to antiepileptic therapy. *Many patients undergoing pharmacological treatment experience serious and sometimes even debilitating side effects.*

Surgical removal of the part of brain that initiates the epileptic activity is a second mode of treatment. In general, patients with partial seizure disorders are the most amenable to surgical intervention. Main question with this kind of treatment is to identify more accurately where seizures originate in the brain and to what extent surgery may affect vital functions, such as sensory/motor functions and linguistic abilities.

For identifying the origin of seizures electroencephalography (EEG) and depth electrodes have been used routinely for decades. Recently magnetoencephalography (MEG) has become more popular especially in Europe for common use in the evaluation of epilepsy patients. Epileptic patients commonly exhibit "spikes" between seizures in their EEG and MEG recordings. Consideration of those spikes and spike patterns in the signal allows an expert to make a decision about the area in which epilepsy foci is localized. *MEG is thought to be better suited for the task because it has greater spatial sensitivity than EEG.*

Conventionally processing of both EEG and MEG data is performed by trained professionals. This task can consume up to 48 working hours per subject and depends heavily on the level of skill. Automation of this process is highly demanded. The first aim would be to reduce the time needed to find spikes in the data. *The potential financial savings and improvement in quality of care due to the automation of experts' work are expected to be high because of the scale of the disease.*

Related Work

The importance of automation of the process of epileptic spike detection has been realized by many researchers and there are many published works on the subject of spike detection. Different methods were proposed by different groups [2,3,4,5]. Though many of them are successful to some extent they are not completely satisfactory for the purpose of epileptic spikes detection. This can be seen from the fact of continuing work on the problem when some novel methods get invented for the task [6]. If we consider working experts in the field (I have some experience with VA hospital in Albuquerque) not many of them trust in existing methods and still use manual recognition techniques without extensive support from automation software. Also a big part of previous work on epileptic spike detection was performed with EEG data though it is believed now that MEG data provides better spatial accuracy for this purpose [1]. In the context of the work done already and being done for epileptic spike detection the work I'm proposing to do is novel in the fact that time delay neural network will be used for spike recognition, which is good because of the online nature of recognition with this tool. Another advantage of this project is using MEG data which will provide better spatial resolution when the data processed by the proposed spike recognition software will go to the next stage of localization.

Methods

I will implement a Time Delay Neural Network, try different preprocessing techniques on the data, train the network and evaluate its performance for spike recognition in MEG data both in individual channel and using information available across all channels at given time point (or interval).

Now I give some background on Time Delay Neural Network, its suggested use for the task and why I believe it should be useful for the epileptic spike detection.

Time Delay Neural Networks (TDNN) is a group of neural networks that have a special topology which is usually used for the *position-independent recognition of features within a large pattern* because of its so-called shift invariant property. Specifically, TDNN use build-in time delay steps to represent temporal relationships; and by sharing the connection weights of the time delay steps, the invariant recognition is realized.

Training in TDNN is performed by a procedure which is similar to back-propagation (BP) algorithm. During the training period, a sequence of MEG raw data (patterns) will be presented to the input layer which have the feature shifted but within the patterns:

- Firstly, a regular forward pass is performed (the activation of each TD neuron is computed by the weighted summation of all activations of predecessor neurons in a input window over time and applying a non-linear functions, such as the sigmoid function to the sum), and the error in the output layer is computed.
- Then, the error derivatives are computed and propagated backward. This yields different correction values for corresponding connections.
- Finally, all correction values for corresponding links are averaged and the weights are updated with this value. This is the same as the forward pass process except it won't compute the error in the output layer.

TDNN has many beneficial properties which fit requirements of spike detection problem:

- First, it has multiple layers and sufficient inter-connections between units in each of these layers, which provides TDNN with an ability to learn complex nonlinear decision surfaces.
- Second, TDNN has the ability to represent relationships between events in time.

- Third, TDNN has the shift invariant property, that is, the actual features or abstractions learned by TDNN are invariant under translation in time.
- Fourth, the learning procedure should not require precise temporal alignment of the labels that are to be learned.
- Fifth, the number of weights in the network is sufficiently small compared to the amount of training data so that the network is forced to encode the training data by extracting regularity.

First the idea of TDNN appeared in Weibel A. et. al [7]. TDNN was used there for-recognition of the phonemes "B", "D" and "G" and achieved recognition rate of 98.5 percent correct which was compared with hidden markov model which had 93.7 percent accuracy. For the task TDNN had three layers and its input was spectrogram of the signal normalized between -1 and +1.

Evaluation

As there are several stages in the project evaluation criteria could also be split. In case of success of the project the most important evaluation criterion would be false-positive, false-negative rates of recognition, ROC curve would also be appropriate and clarifying. If recognition rates are not so promising as I expect them to be the project should be evaluated by the following two objectives: TDNN software and data preprocessing. Software should be evaluated by its performance and possibility to use in other tasks (so generality of the software should be taken into account). Preprocessing techniques should be evaluated by their relevance to the data and to the goal under investigation - i.e. temporal nature of the data and online nature of recognition should be taken into account.

Bibliography

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