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Channel selection for automatic seizure detection

Jonas Duun-Henriksen [a,b,c,*], Troels Wesenberg Kjaer [b], Rasmus Elsborg Madsen [c], Line Sofie Remvig [c], Carsten Eckhart Thomsen [d], Helge Bjarup Dissing Sorensen [a,*]

[a] Technical University of Denmark, Department of Electrical Engineering, Building 349, Oersteds Plads, 2800 Kgs. Lyngby, Denmark
[b] Department of Clinical Neurophysiology, Copenhagen University Hospital, Blegdamsvej 9, 2100 Copenhagen, Denmark
[c] Hypo-Safe A/S, Diplomvej 381, 2800 Kgs. Lyngby, Denmark
[d] Department of Odontology, Copenhagen University, Noerre Allé 20, 2200 Copenhagen, Denmark

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HIGHLIGHTS

- The current study is an evaluation of different methods for channel selection preceding automatic seizure detection.
- When choosing channels for an automatic seizure detection algorithm, best choice is the three channels with the highest variance during training seizures.
- Using the highest variance selection method, the seizure detection performance is similar to when a neurophysiologist chooses the channels he finds best suited.

ABSTRACT

Objective: To investigate the performance of epileptic seizure detection using only a few of the recorded EEG channels and the ability of software to select these channels compared with a neurophysiologist.
Methods: Fifty-nine seizures and 1419 h of interictal EEG are used for training and testing of an automatic channel selection method. The characteristics of the seizures are extracted by the use of a wavelet analysis and classified by a support vector machine. The best channel selection method is based upon maximum variance during the seizure.
Results: Using only three channels, a seizure detection sensitivity of 96% and a false detection rate of 0.14/h were obtained. This corresponds to the performance obtained when channels are selected through visual inspection by a clinical neurophysiologist, and constitutes a 4% improvement in sensitivity compared to seizure detection using channels recorded directly on the epileptic focus.
Conclusions: Based on our dataset, automatic seizure detection can be done using only three EEG channels without loss of performance. These channels should be selected based on maximum variance and not, as often done, using the focal channels.
Significance: With this simple automatic channel selection method, we have shown a computational efficient way of making automatic seizure detection.

1. Introduction

The everyday life of a person with treatment resistant epilepsy can be very frustrating. The unforeseen nature of seizures has a tremendous psycho-social effect (Gilliam et al., 1997). Though many new anti-epileptic drugs have been introduced in the last two decades, the primary outcomes have been towards avoidance of physical and psychiatric adverse effects and prevention of cognitive decline in individual patients (Lundbech and Sabers, 2002). Thus, the percentage of patients with untreatable epilepsy is still approximately 25% as it was 10 years ago (Mormann et al., 2007).

To help this group of patients in whom seizures cannot be prevented, a large group of scientists are investigating the feasibility of predicting epileptic seizures. If epileptic seizures can be predicted successfully, it will make the patient able to prepare and lie down to prevent injury from a fall or by taking a fast acting anti-convulsive drug that will prevent the seizure. Another potential of reliable seizure prediction is the automated electrical stimulation or drug intervention. In this way, a forthcoming seizure

* Corresponding authors. Addresses: Technical University of Denmark, Oersteds Plads, Building 349, Room 109, 2800 Kgs. Lyngby, Denmark. Tel.: +45 6178 9966; fax: +45 4588 0117 (J. Duun-Henriksen), Technical University of Denmark, Oersteds Plads, Building 349, Room 112, 2800 Kgs. Lyngby, Denmark. Tel.: +45 2382 3384; fax: +45 4588 0117 (H.B.D. Sorensen).

E-mail addresses: jhe@elektro.dtu.dk (J. Duun-Henriksen), hbs@elektro.dtu.dk (H.B.D. Sorensen).

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could be avoided completely. Unfortunately, it seems that all currently available methods are still not fully developed (Mormann et al., 2007). Either the prediction performance is not yet satisfactory or the results have been obtained retrospectively, and true performance in an online setting therefore not validated.

As an alternative or addition to anti-epileptic drugs, some patients could benefit from a *seizure alarm*. Warning care takers of an ongoing seizure may lead to closer observation or perhaps relevant intervention (Nicolelis, 2001). Such seizure detection system could provide a significant improvement in quality of life for many patients and their relatives.

The automatic seizure detection can also be used for daily monitoring of a patient to provide an objective, quantitative measure of seizure activity. This may enable physicians to test different medications and assess whether a change in therapy would be beneficial without repeatedly having to admit the patient for EEG monitoring.

Because the characteristics of the electrical activity of the brain change when a seizure strikes, it is reasonable to base an automatic seizure detector on EEG-recordings. One of the first widely applicable automatic seizure detection algorithms was that of Gotman (1982). He used a coefficient of variation as a measure of the duration of half-waves. Multiple studies have applied this method and shown sensitivities of 70–95% and false detection rates (FDR) of 1–3/h (Qu and Gotman, 1993). With increasing computer power more advanced algorithms have been developed and better performances obtained. Osorio et al. (2002) presented a wavelet based seizure detection algorithm that showed perfect sensitivity and only 0.1 false detections per hour. However, in their analysis, they chose to count detections of subclinical seizures as true. Khan and Gotman (2003) improved Gotman's original 1982 detection algorithm to be able to detect 90% of the seizures correctly with an FDR of only 0.3/h.

Based on these reports and other existing automatic seizure detection algorithms, several systems for epilepsy monitoring are on the market (e.g. from Zhongdazhong Medical Equipment, Shenyang City, China, Cadwell Laboratories, Kennewick, USA, Nihon Kohden Corporation, Tokyo, Japan or Natus Medical Inc. (former Stellate Systems Inc.), San Carlos, USA). In general, the automatic seizure detection algorithms function by use of one or several training seizures identified by a neurophysiologist. You can then choose either an automatic or manual channel selection, followed by a seizure classification with the systems algorithm. As mentioned, several researchers have demonstrated strong seizure detection algorithms, but the attention towards the channel selection has been limited. The importance of this can be understood by looking at 50 EEG traces in Fig. 1. Though the patient is affected by the seizures on most of the channels, it is not trivial to assess which channels are optimal for automatic seizure detection. Furthermore, if the selection is based on the assessment by a trained neurophysiologist, it is a subjective and time consuming process.

Some studies describe different ways to select the best features calculated for all channels (Minasyan et al., 2010; Shih et al., 2009). If only a limited number of features are selected, this also means that a reduced number of channels will be used. Unfortunately, it is a computationally very heavy method necessitating feature calculation for all channels during the training period followed by an optimization of feature selection. Shih et al. (2009) found the

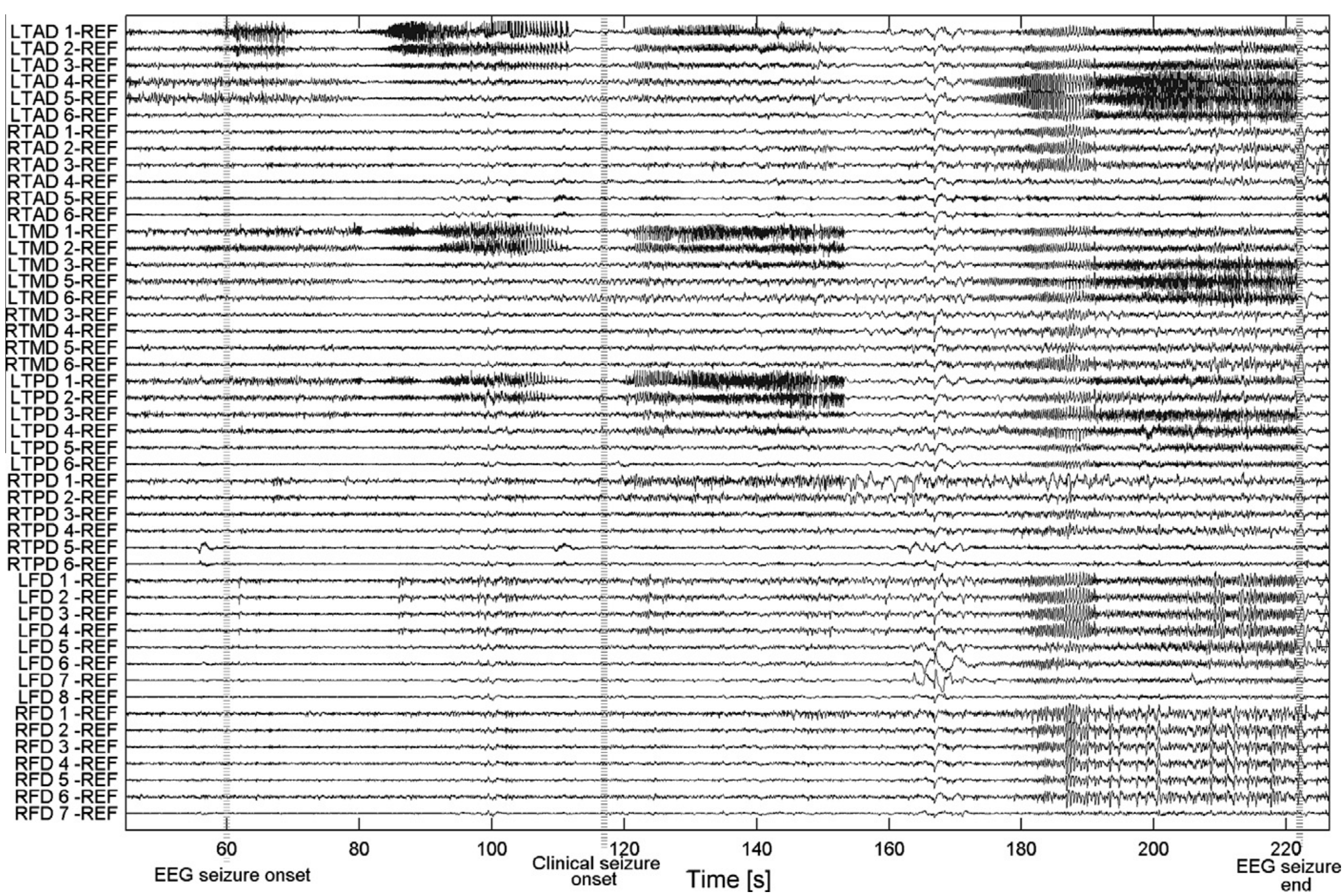

Fig. 1. Fifty intracranial EEG traces during a seizure from the recording of patient 2. Assessing which channels to use for automatic seizure detection is not always trivial. Using all the seizures from the same data set as seen above, a neurophysiologist found the focal channels to be LTAD 1 and 2 and LTMD 1. It is not obvious though, that these channels are also the best for an automatic seizure detection algorithm.