ON THE ANALYSIS OF SEIZURE ONSET IN THE EEG: THE APPLICATION OF CONSTRAINED ICA

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Abstract: **Epileptic seizures are commonly studied using the electroencephalogram (EEG) for the measurement of brain electrical signals, which often show characteristic seizure waveforms. The automatic extraction of this seizure waveform from the recorded data has many implications, including the possibility of a real time system to warn the patient of an impending seizure. Such detection has hitherto proved difficult because of the non-stationarity of seizure waveform and corruption of the EEG signals by artifacts and other waveforms present in the measurements. We demonstrate the use of the recently published constrained independent component analysis (cICA) algorithm for the extraction of seizure waveform from EEG recordings, from time periods prior to the clinical onset of the seizure.**
Keywords: **electroencephalogram, EEG, seizure onset, ICA, constrained ICA.**

Introduction

Epilepsy is a condition characterised by the recurrence of epileptic seizures, which are often studied by the measurement of brain electromagnetic signals using the EEG. These recorded signals often show characteristic seizure waveforms which appear in the recordings before the clinical onset of the seizure. The automatic extraction of these waveforms may allow the origin of the seizures to be identified for possible seizure treatment. If this extraction can be performed in real time, the possibility of a system to warn patients of impending seizures is raised.

Materials and Methods

The application of the cICA algorithm [1] to the analysis of electromagnetic brain signals is introduced elsewhere [2]. This iterative algorithm has the aim of extracting the single statistically independent source which is closest, in some sense, to a supplied reference signal. In this application, the input data are the pre-whitened EEG measurements and the reference signal is a crude approximation of the desired source, derived from the original data. Correlation is used by the algorithm as the closeness measure between the output at each iteration and the reference signal. It is therefore important that the frequency and phase of the reference signal are similar to the actual underlying source; as described below, this was achieved by matching with an epoch of known seizure waveform.

Results

Figure 1 shows an example of the use of the cICA algorithm for the extraction of seizure waveform from time periods prior to the clinical onset of a seizure. A reference signal which was similar to the seizure waveform was obtained by selecting a two-second period of clear seizure waveform from the EEG (in this case after the seizure has developed) and generating a square wave with the same frequency and phase as the seizure waveform in that period. The cICA algorithm was then used, with this reference, to extract seizure waveform from two-second time periods prior to the clinical seizure onset. The topographic maps obtained from the cICA mixing vector for each extraction approximately match the focus of the seizure, which appears to be in the right temporal lobe – the earliest appearance of seizure waveform in Figure 1(a) is on channels such as T10, whose electrodes are located near this region.

Discussion

As shown by this example, a crude square wave reference signal allows the cICA algorithm to extract the seizure waveform as an independent source, from time periods prior to the clinical onset of a seizure. The extracted waveform is noisy but temporally consistent. The topographies obtained from the mixing vector are quite consistent and physiologically reasonable, with foci in the region of the brain that seems to be the origin of this seizure. For the extraction furthest in time from the clinical onset (Figure 1(b)), the topography shows a movement of the focus slightly towards the back of the head. This might be due to some inaccuracy in the algorithm's output (for instance, some mixing of true underlying sources) or the seizure's actual focus may have moved in this way.

Conclusions

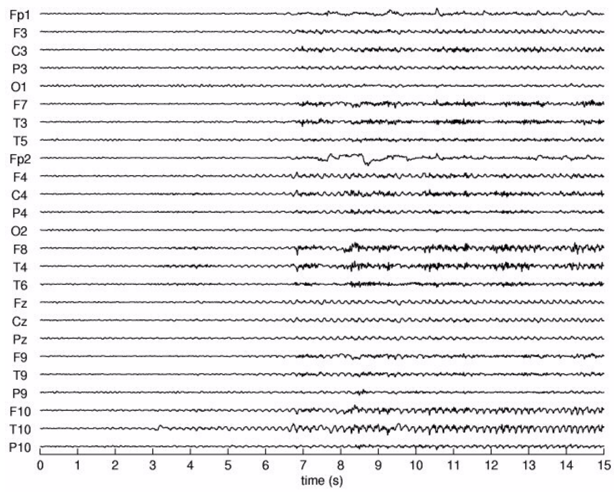
The application of the cICA algorithm to seizure onset analysis in the EEG offers promising results. A crude reference, obtained from a period of known seizure, proves a template which dictates the single underlying source to be extracted.

Work is ongoing to investigate measures of reliability of the algorithm, addressing problems such as the incidence and consequences of false positives. Use of a spatial, rather than temporal, reference is also being studied; this would avoid the assumption made here that the frequency and phase of the seizure waveform are constant during the development of the seizure. A spatial reference, however, requires assumptions about the spatial stationarity of the seizure.

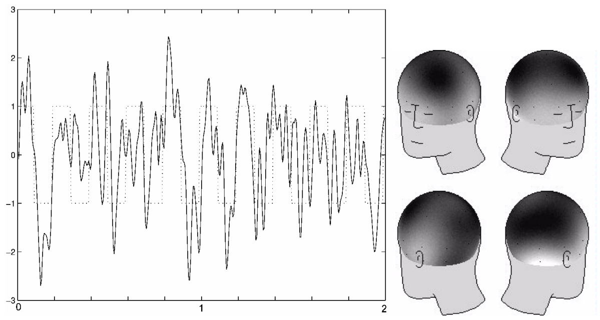
REFERENCES

[1] Lu, W and Rajapakse, J C (2001). "ICA with Reference". Proceedings of Third International Conference on Independent Component Analysis and Blind Signal Separation: ICA2001.

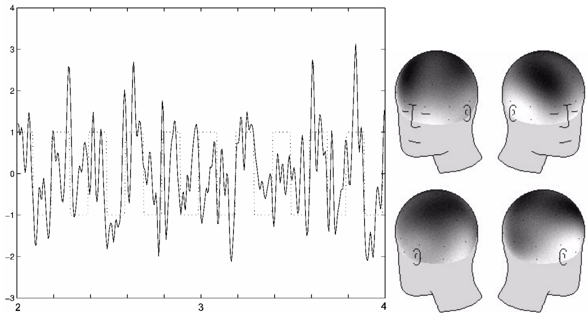
[2] James C J and Gibson O, 2002, "Electromagnetic brain signal analysis using constrained ICA", Proceedings of 2nd European Medical & Biological Engineering Conference EMBEC'02, Vienna, Dec. 04 - 08.



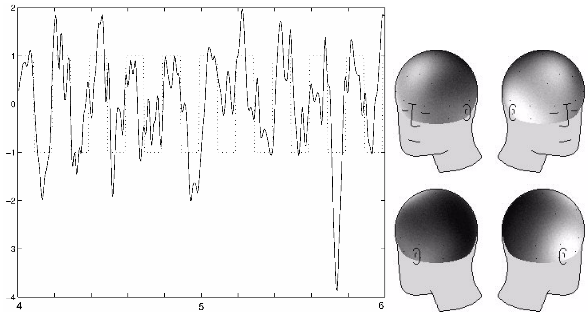
(a) EEG epoch, recorded with a referential montage using FCz as the reference electrode. The standard 10-20 system of electrode placement was used, with a sample rate of 200 Hz.



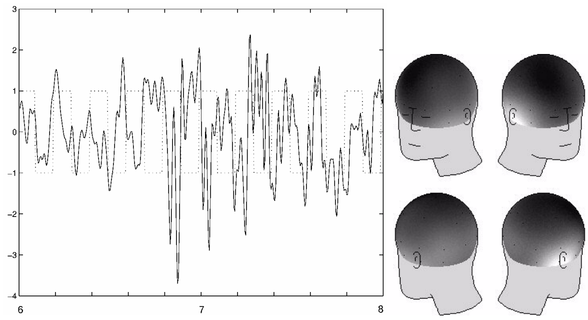
(b) Extraction from t=0 to 2 s.



(c) Extraction from t=2 to 4s.



(d) Extraction from t=4 to 6s.



(e) Extraction from t=6 to 8s.

Figure 1: Seizure onset analysis using the cICA algorithm. The EEG epoch (a) contains a developing seizure with clinical onset at around t = 7s, where seizure waveform is visible on most channels and high frequency muscle artifacts are present. The seizure originates in the right temporal lobe; the earliest clear appearance of seizure waveform is on channels T10, F10 and F8. A reference signal was obtained from a square wave matched in frequency and phase to a section of clear seizure waveform (between t = 13 s and t = 15 s). With this reference, the cICA algorithm was used to extract seizure waveform from two-second epochs prior to the clinical seizure onset. The extracted sources are shown in (b)-(e), with the reference signal superimposed (dotted line) and the corresponding topographic maps obtained from the estimated mixing vector. The components resemble noisy seizure waveform and the topographic maps conform to the spatial location of the seizure onset in the right temporal lobe.