Real-time detection of epileptic seizures in animal models using reservoir computing

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Introduction

In recent years, an increasing number of studies have investigated the effects of closed-loop anti-epileptic treatments. Most of the current research still is very labour intensive: real-time treatment is manually triggered and conclusions can only be drawn after multiple days of manual review and annotation of the electroencephalogram (EEG).

Methods

In this work we propose a technique based on reservoir computing (RC) to automatically and in real-time detect epileptic seizures in the intra-cranial EEG (iEEG) of epileptic rats in order to immediately trigger seizure treatment. This work improves the accuracy of [1] and extends it with the ability to detect the seizures with a low latency. A comparison is made with the state-of-the-art techniques from literature: the off-line technique presented in [1] and the adapted Osorio-Frei algorithm (AOFA) presented by Haas et al. in [2]. The performance of the system is evaluated in two different seizure types: absence seizures from genetic absence epilepsy rats from Strasbourg (GAERS) and limbic seizures from post status epilepticus (PSE) rats. The dataset consists of 452 hours iEEG from 23 GAERS and 2083 hours iEEG from 22 PSE rats. More details will be provided during the presentation of this work.

Results

As shown in the table below, the default set-up of the system detects 0.09 and 0.13 false positives per seizure (FPPS) and misses 0.07 and 0.005 events per seizure (FNPS) for GAERS and PSE rats respectively. It achieves an average detection delay of 1 second in GAERS and less than 10 seconds in the PSE data. This detection delay and the number of missed seizures can be further decreased when a higher false positive rate is allowed. If for example 4 FPPS are allowed, represented by '*' in the table below, the detection delay is reduced to 0.2 and 2.3 seconds respectively.

	GAERS			**PSE**		
	RC	[1]	[2]	RC	[1]	[2]
Delay (s)	1.0	n/a	2.5	9.4	n/a	20
FPPS	0.09	1.0	1.4	0.13	0.26	3.43
FNPS	0.07	0.07	0.18	0.005	0.003	0.03
Delay* (s)	0.2	-	2.1	2.3	-	19
FNPS*	0.001	-	0.16	0.002	-	0.06

Discussion

Our method outperforms state-of-the-art detection techniques and only a few parameters require optimization on a limited training set. It is therefore suited for automatic seizure detection based on iEEG and may serve as a useful tool for epilepsy researchers. The technique also avoids the time-consuming manual review and annotation of EEG and can be incorporated in a closed-loop treatment strategy.

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References

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