CLASSIFIER CASCADE TO AID IN DETECTION OF EPILEPTIFORM TRANSIENTS IN INTERICTAL EEG

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INTRODUCTION

- Epileptiform transients (ET) or interictal epileptiform discharges (IED) occur between seizures in the scalp EEG of patients with epilepsy.
- Agreement among experts regarding which waveforms are epileptiform is imperfect.
- Automated IED detection offers benefits of increased speed and uniformity in EEG interpretation.
- A large amount of data is needed for training and evaluating the performance of an effective IED detection system.
- Interictal EEG contains mostly background waveforms.
- Current ET detection methods suffer from insufficient precision and high false positive rates
- The main objective in ET detection is to determine whether any ETs exist in a patient's EEG, and if so to find their channel locations
- We establish a method to exclude as much background data as possible from EEG recordings by applying a classifier cascade.
- We aim to develop our algorithm to lower the false positive rate and increase the precision.

EEG DATASET

- Scalp EEG Data from the Massachusetts General Hospital (MGH)
- 93 epileptic patients, and 53 healthy subjects.
- 156 subjects with a total length of 4454.2 hours 18,164 IEDs
- Cross-annotated by two neurologists from MGH.
- 5-fold cross-validation
- Average length of each EEG is 28.5 minutes

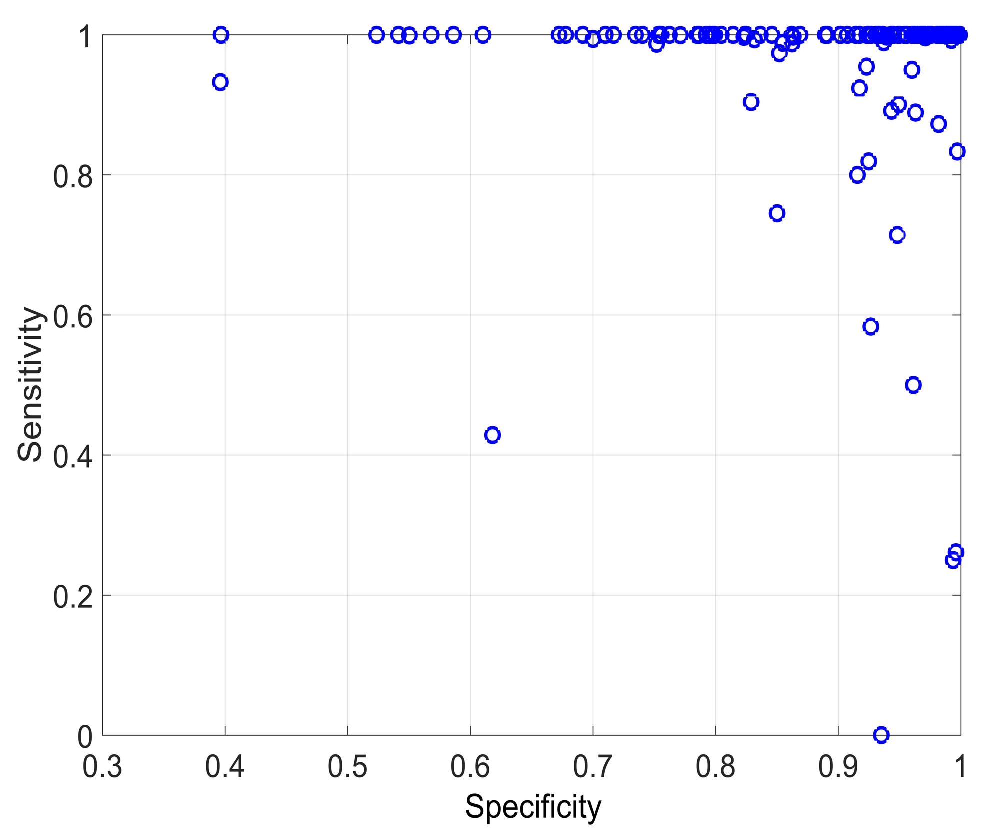
CLASSIFIER CASCADE

Training:

- Sample one background waveform for each ET
  - Balanced training
- Train classifiers using each background set (from each EEG in training set) and all ETs
  - Around 125 SVMs for each fold, and 624 for all folds
- All trained SVMs are applied on the whole training set
- Adjust the threshold on the output scores such that sensitivity ≥0.999
- The classifier having the highest specificity is selected, and is applied on the whole training set
- All classifiers are again applied on the new training waveforms labeled "ET" in the previous step
- The same procedure is repeated

Testing:

- Apply the classifier cascade to all the EEG waveforms in the test set
- For the majority of subjects the sensitivity and specificity values are high



Sensitivity versus specificity for each subject after a 10-stage classifier cascade

CLASSIFIER CASCADE

Sensitivity of the classifier cascade after each step

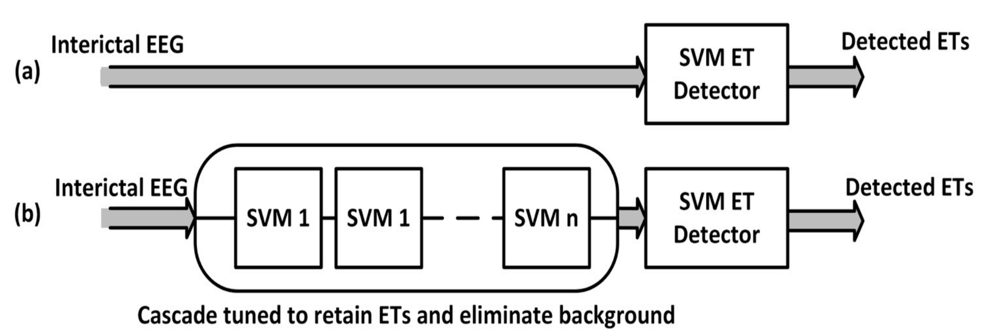
Stage	Fold 1	Fold 2	Fold 3	Fold 4	Fold 5	Average
1	0.999	0.982	1	1	1	0.996
2	0.996	0.971	0.998	0.998	0.908	0.974
3	0.973	0.962	0.991	0.986	0.908	0.964
4	0.97	0.962	0.991	0.985	0.852	0.952
5	0.962	0.849	0.991	0.97	0.848	0.924
6	0.959	0.847	0.991	0.97	0.824	0.918
7	0.93	0.847	0.984	0.962	0.795	0.904
8	0.907	0.843	0.984	0.953	0.794	0.896
9	0.904	0.842	0.952	0.953	0.789	0.888
10	0.904	0.841	0.952	0.948	0.771	0.883

Specificity of the classifier cascade after each step

Stage	Fold 1	Fold 2	Fold 3	Fold 4	Fold 5	Average
1	0.533	0.784	0.323	0.577	0.586	0.561
2	0.738	0.848	0.408	0.73	0.754	0.696
3	0.836	0.888	0.556	0.828	0.792	0.78
4	0.851	0.908	0.668	0.861	0.843	0.826
5	0.875	0.915	0.72	0.886	0.866	0.852
6	0.887	0.927	0.762	0.904	0.879	0.872
7	0.903	0.933	0.792	0.918	0.896	0.888
8	0.91	0.94	0.825	0.927	0.915	0.904
9	0.914	0.945	0.828	0.934	0.923	0.909
10	0.925	0.95	0.851	0.941	0.93	0.919

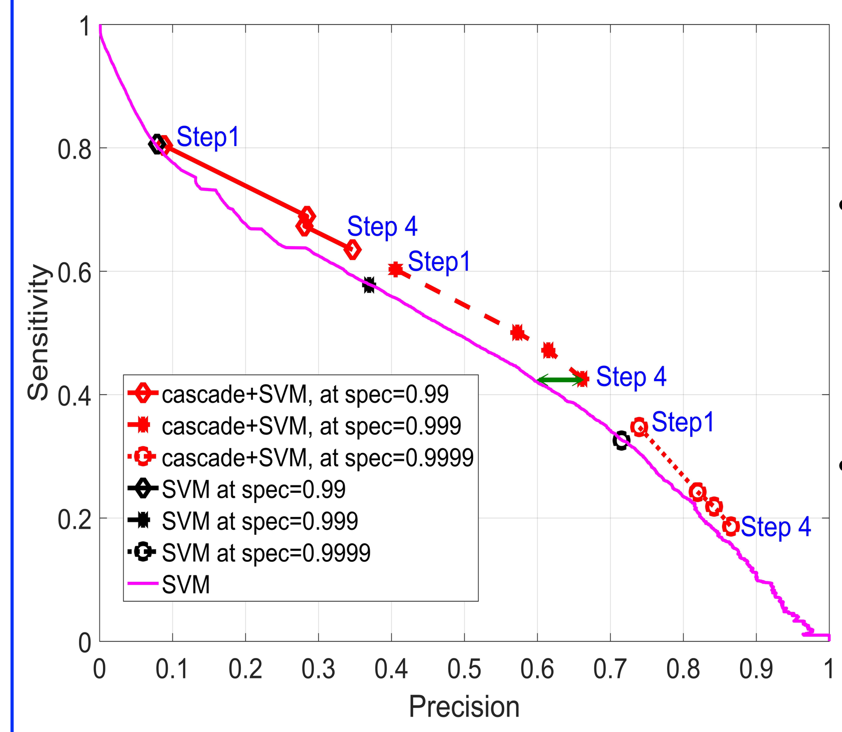
COMBINING THE CASCADE WITH AN ET DETECTOR

- Test a single SVM as benchmark and compare it to the classifier cascade followed by the same SVM



Two approaches for ET detection: (a) One single SVM detector (b) An SVM cascade followed by one SVM detector

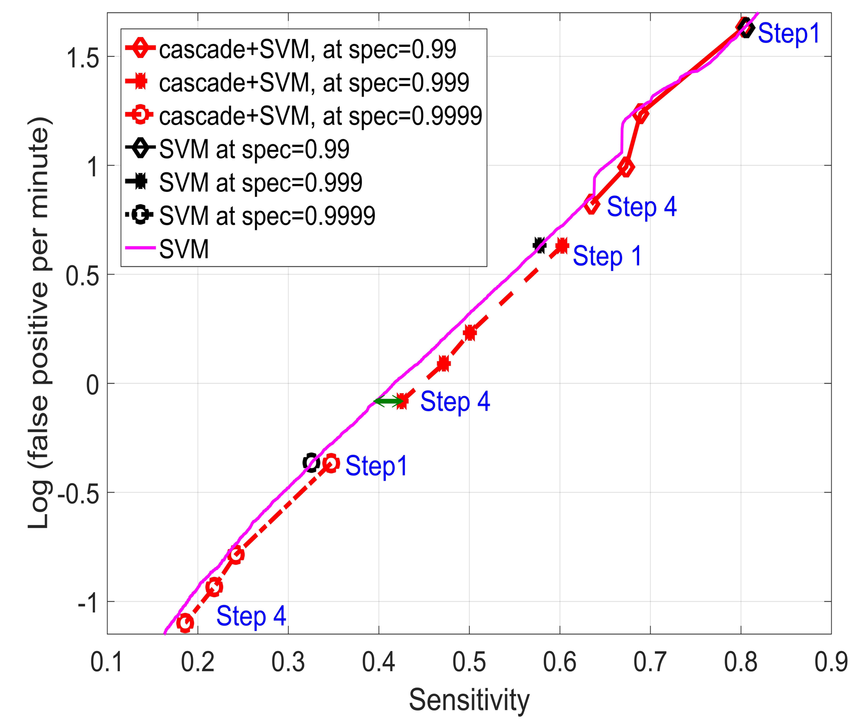
RESULTS



Precision versus sensitivity at certain specificity values, with and without the classifier cascade

- For a fixed sensitivity of 42.53%, precision is increased from 59.38% to 66.16%
- A total increase of 6.78% in precision

- For a fixed false positive rate of 1.2 per minute (-0.081 in logarithmic scale), sensitivity is increased from 39.70% to 42.53
- A total increase of 2.83% in sensitivity



False positive rate versus sensitivity at certain specificity values, with and without classifier cascade

Overall performance of ET detection by applying SVM with and without the initial classifier cascade

Method	Specificity=0.99			Specificity=0.999			Specificity=0.9999		
	Sensitivity	Precision	FPR	Sensitivity	Precision	FPR	Sensitivity	Precision	FPR
SVM detector	0.806	0.078	40.786	0.577	0.369	4.089	0.325	0.715	0.412
SVM detector+ SVM cascade stage 1	0.803	0.088	41.047	0.602	0.405	4.079	0.347	0.739	0.410
SVM detector+ SVM cascade stage 2	0.689	0.284	16.455	0.501	0.572	1.626	0.242	0.819	0.156
SVM detector+ SVM cascade stage 3	0.673	0.280	9.367	0.471	0.615	1.175	0.218	0.842	0.110
SVM detector+ SVM cascade stage 4	0.634	0.346	6.327	0.425	0.661	0.789	0.186	0.865	0.075

CONCLUSIONS

- Precision and false positive rate improve significantly by incorporating a classifier cascade before ET detection
  - Sensitivity declines
  - Precision is increased
  - false positive rate per minute is reduced
- At a fixed sensitivity, precision was improved by 6.78%
- At a fixed false positive rate, the sensitivity improved by 2.83%
- We plan to process the waveforms that are retained after the cascade by using other machine learning algorithms

REFERENCES

1. E. Bagheri, J. Dauwels, B. C. Dean, C. G. Waters, M. B. Westover, and J. J. Halford, "Interictal epileptiform discharge characteristics underlying expert interrater agreement," Clinical Neurophysiology, 2017.

2. E. Bagheri, J. Jin, J. Dauwels, S. Cash, and M. B. Westover, "Fast and efficient rejection of background waveforms in interictal eeg," in 2016 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), March 2016, pp. 744–748.

3. J. Jing, J. Dauwels, T. Rakthanmanon, E. Keogh, S. Cash, and M. Westover, "Rapid annotation of interictal epileptiform discharges via template matching under dynamic time warping," Journal of neuroscience methods, vol. 274, pp. 179–190, 2016.

4. J. J. Halford, "Computerized epileptiform transient detection in the scalp electroencephalogram: Obstacles to progress and the example of computerized fECGg interpretation," Clinical Neurophysiology, vol. 120, no. 11, pp. 1909 – 1915, 2009.

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