Seizure Prediction and Detection

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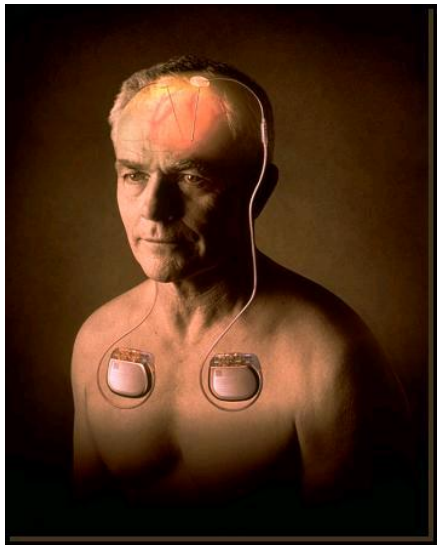
Outline

- Seizure prediction using spectral power features and SVM-classification (Freiburg database)
- Implantable seizure predictor – low-cost/power (2-4 electrodes, battery life > 1 year)
- Seizure detection on large scale data – preliminary results (100+ electrodes)

Overview of Epilepsy

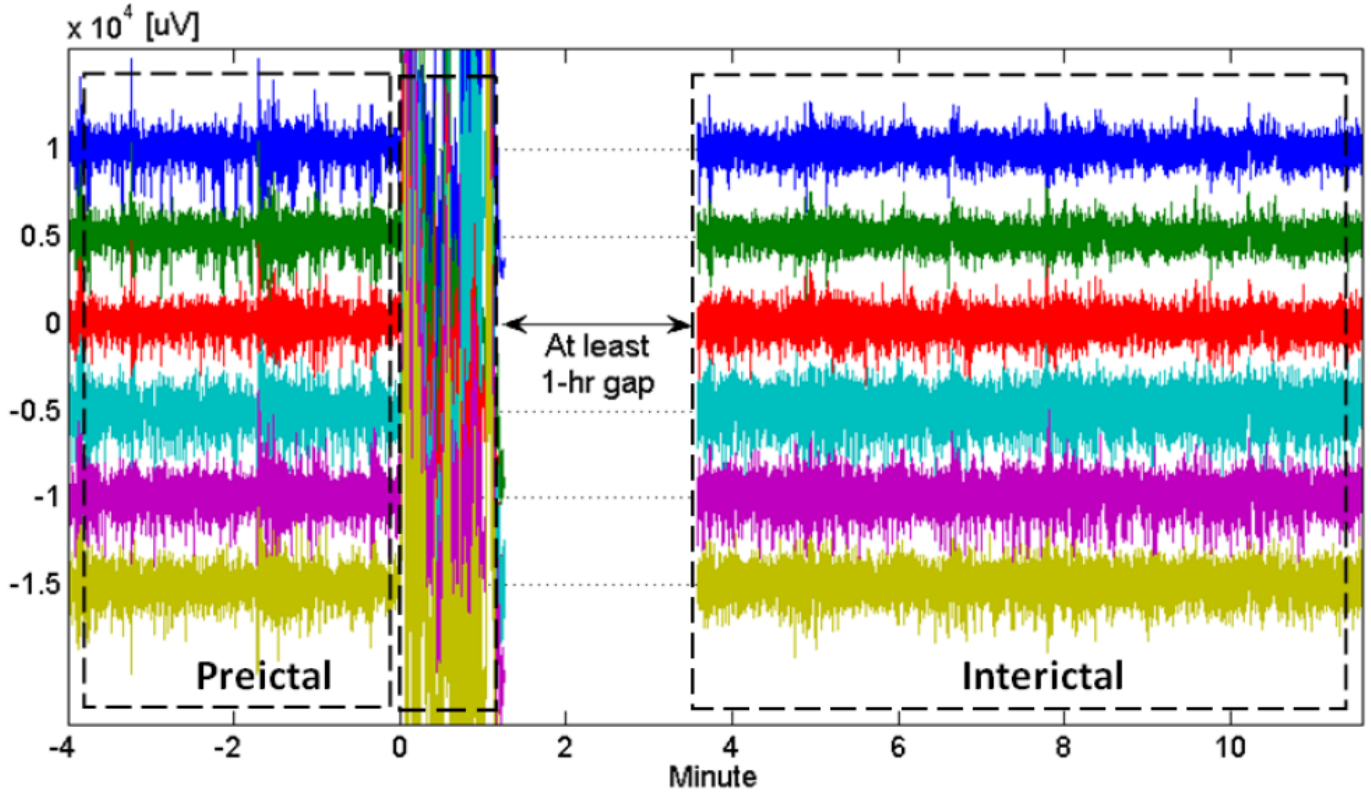
- Epilepsy: 2nd most common neurological disorder
- Affects approximately 1% of US popilation, nearly 3 million
  - 1/3 spontaneously recover
  - 1/3 successfully treated w/ antiepileptic medications
  - 1/3 have intractable seizures
    - 40% successfully treated with surgery
    - **20% continue to have epilepsy after surgery**
    - **40% inoperable**



- $15.5 billion in direct and indirect costs per year in US (Epilepsy foundation, 2005)
- Implantable device provides warnings, and therapy

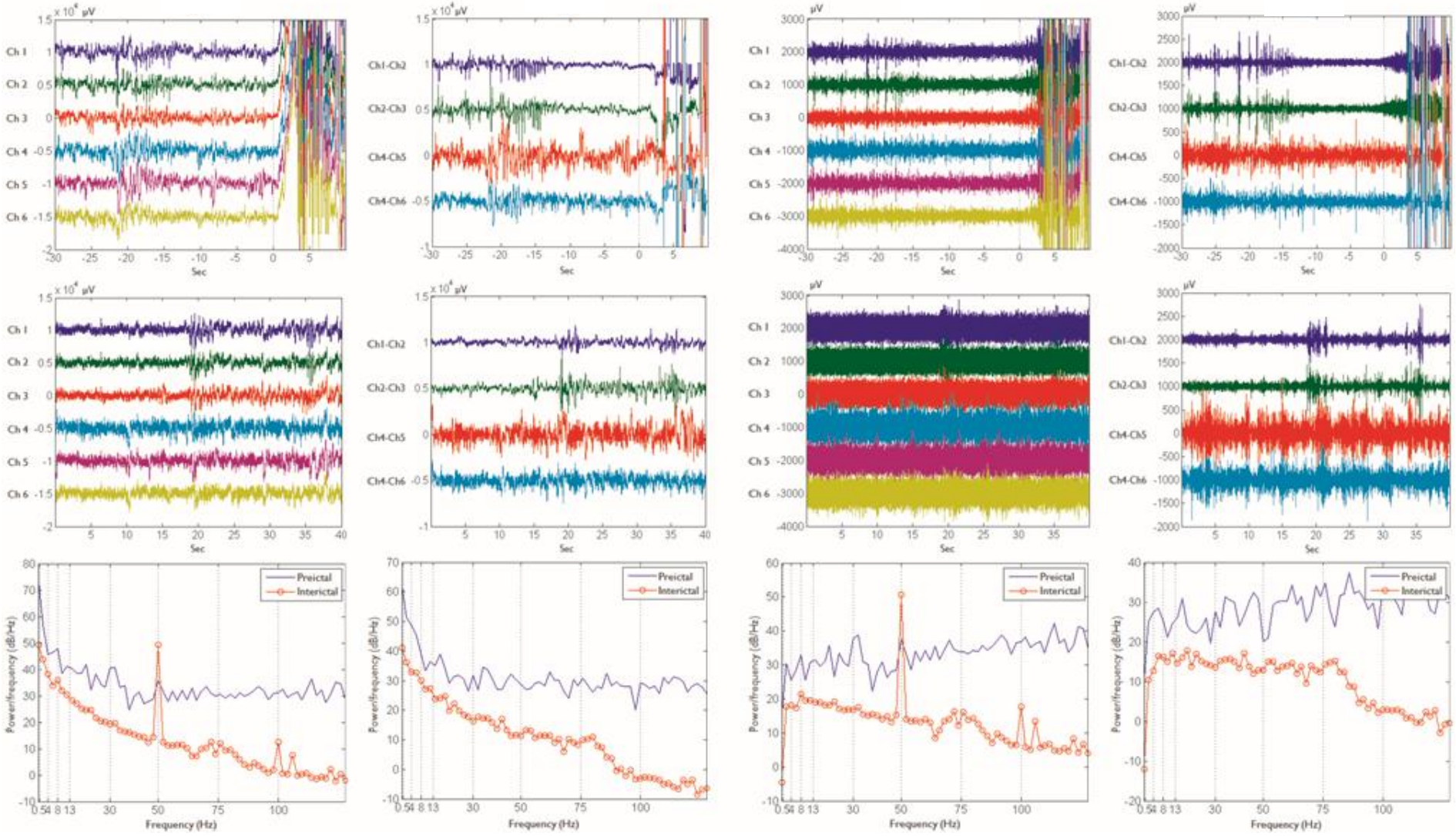
Seizure Prediction based on EEG

- Prediction: classification of **preictal** (prior to a seizure) from **interictal** (between seizures)
- Detection: classification of **ictal** from **non-ictal**



Seizure Prediction Using SVMs

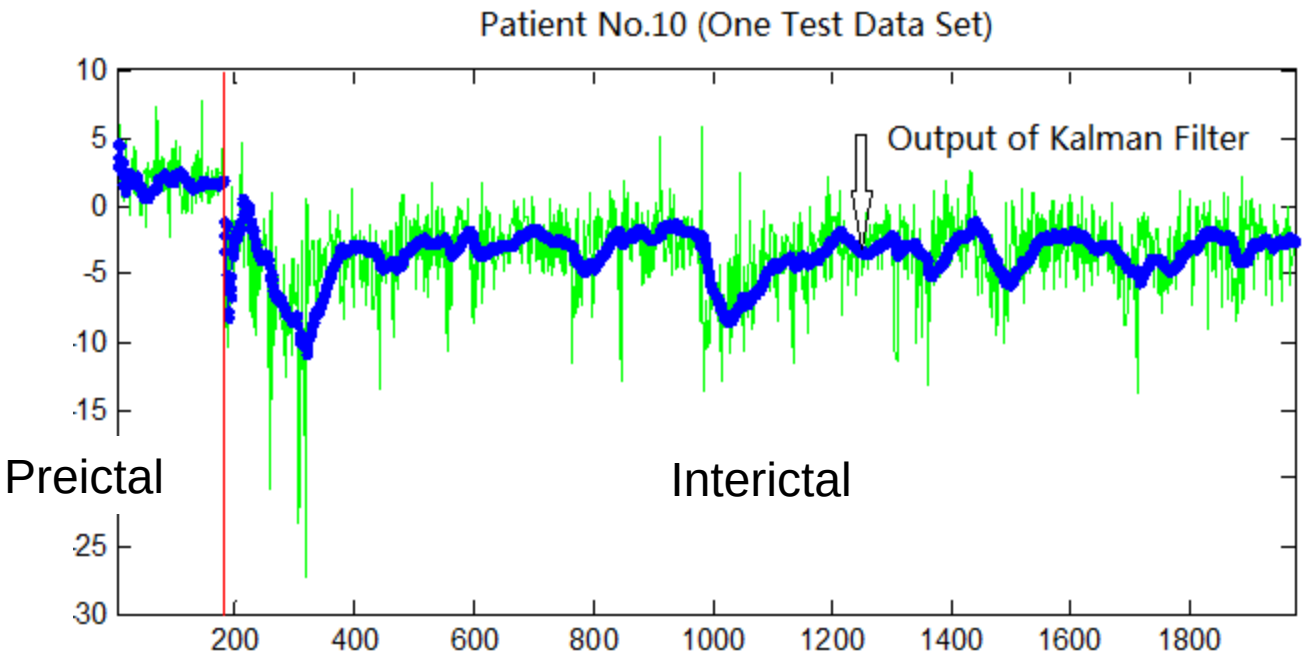
- Mainly consists of **feature extraction** and **SVM-classification**
- Features: **spectral power in 9 bands** from 20-sec-long window
  - δ(0.5-4Hz), θ(4-7Hz), α(8-13Hz), β(13-30Hz), γ(30-50Hz, 50-75Hz, 75-100Hz, 100~Hz), and Total
  - **Bipolar** (space-differential) and/or **time-differential** preprocessing
- SVM-classification with RBF kernel
  - **Cost-sensitive SVMs** for highly unbalanced datasets
- Freiburg EEG database
  - https://epilepsy.uni-freiburg.de/freiburg-seizure-prediction-project/eeg-database
  - 18 of 21 patients selected who have ≥ 3seizure recordings



(A) Raw (B) Bipolar (C) Time-diff (D) Bipolar & Time-diff

Kalman filter for post-processing

- Reduce # of FP while maintaining the sensitivity
- The change rate of two continuous windows should undergo smooth transition → 2nd order Kalman filter



Results

PSD	Sens (%)	FP/hr	FP%
Raw	93.8	0.29	13.7
Bipolar	**97.5**	**0.27**	**13.0**
Time-diff	92.5	0.20	9.49
Bipolar/time-diff	93.8	0.23	10.7

patients = 18, # seizures = 80

Total interictal hours = 437

- Bipolar improves sensitivity; time-diff improves FP rate
- Submitted to Epilepsia in Aug 2010 (under review)

Results' Comparison with Others in Same Freiburg Database

Group	# Pat	# Sz	Interictal hours	Prediction horizon (min)	Sens (%)	FP/hr
Winterhalder, et al., 2003	21	88	509	30	42	0.15
Aschenbrenner, et al., 2003	21	88	509	50	34	0.10
Maiwald, et al., 2004	21	88	509	32	30	0.15
Schelter, et al., 2006	4	20	96	40	70	0.15
Park, et al Submitted 2010 (Epilepsia, under review)	**18**	**80**	**437**	**30**	**97.5 (B)** **92.5 (T)**	**0.27 (B)** **0.20 (T)**

Towards an Implantable Seizure Predictor!

- Features limited to 4-5
- Target power consumption: 50 microwatt
- **Reduce computational complexity: Feature consolidation, Feature Selection by maximizing divergence**

Feature Reduction

- **Feature Consolidation**: Test 1D Henze-Penrose divergence (HPD) of two adjacent power spectrum band features and combine them if 1D HPD of combined bands is greater than or equal to each one of them.
- HPD is based on Minimum Spanning Tree (MST)
- **Feature Selection**: Iteratively obtain 4 features that produce maximum 4D HPD

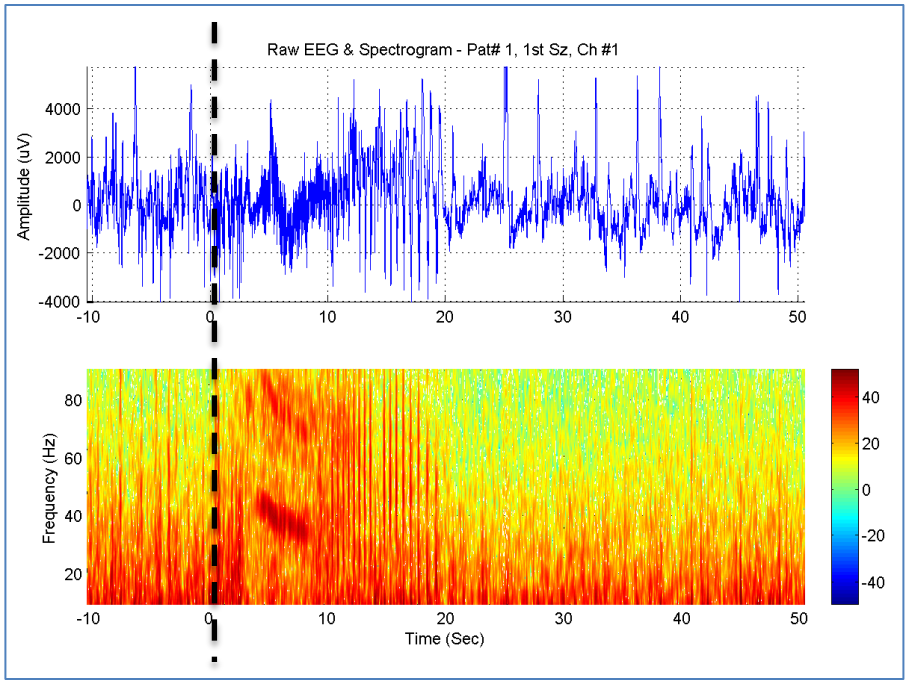
Preliminary Results

- Feature consolidation and feature selection used
- Mean(8-tap) and median (9-tap) filter used for postprocessing

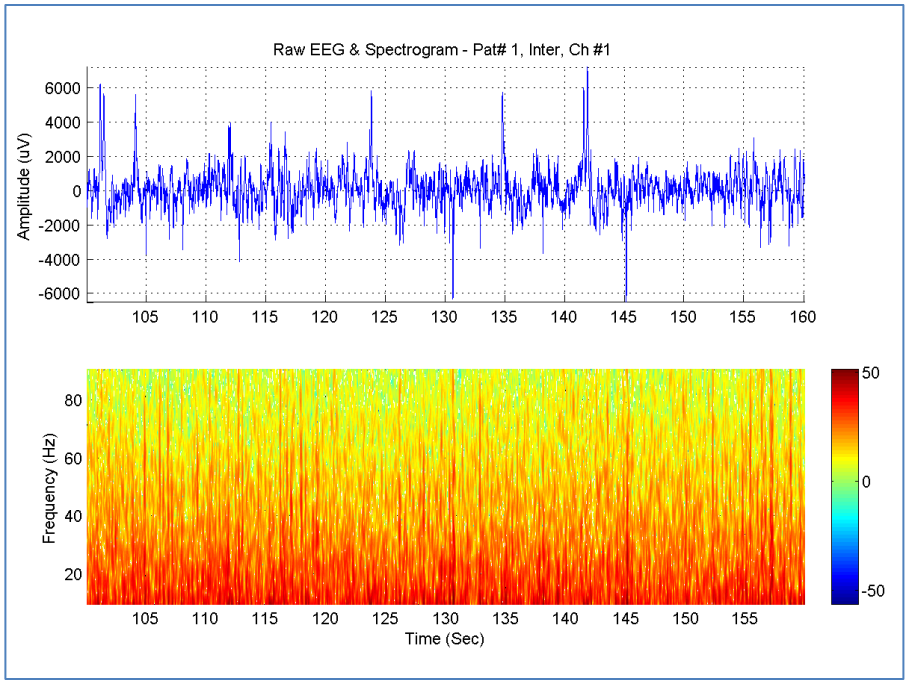
Patient	Predicted	Missed	FP/Hour
1	4	0	0.343
3	3	2	0.133
4	5	0	0.058
5	3	1	0.666
7	3	0	0.444
9	5	0	0.133
10	4	0	0.541
11	3	1	0.614
12	4	0	0.354
15	3	1	0.812
16	3	1	0.406
17	4	1	0.433
18	3	1	0.760
Sensitivity	85.5%	Avg. FPR	0.44/Hour
Full Features	97.5%	Full Features	0.27/Hour

Detection of Epileptic Seizures

- Seizure (onset) detection using linear features of EEG
- Easy to reach high sensitivity but challenging to reduce FP rate



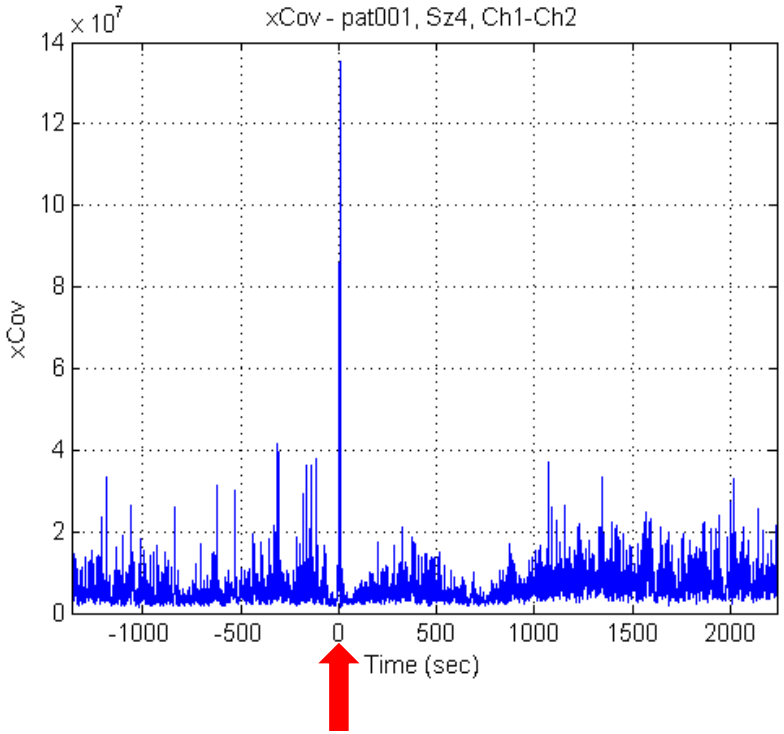
(A) Ictal

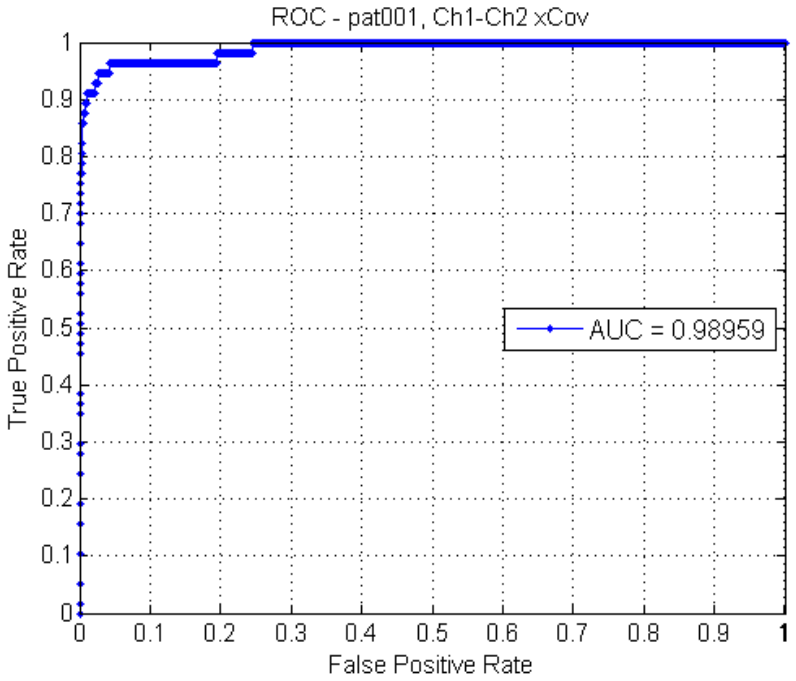


(B) Interictal

Seizure Detection by Cross-Channel Covariance

- Seizure detector with **a few features & simple classifiers**
- Preliminary result using **cross-channel covariance** of **pre-whitened** signals





Conclusion

- Established seizure predictor based on SVM-classification and Kalman filter: **97.5% sensitivity** and **0.27 FP rate** were achieved with bipolar spectral power features
- Implantable seizure prediction device: consolidate and select features using HPD (ongoing)
- Build **seizure detector** with **least number of electrodes, features** and **fusion of simple classifiers (ongoing)**
- Extend our approaches into Mayo database

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