EPILEPTIC DOGS: ADVANCED SEIZURE PREDICTION

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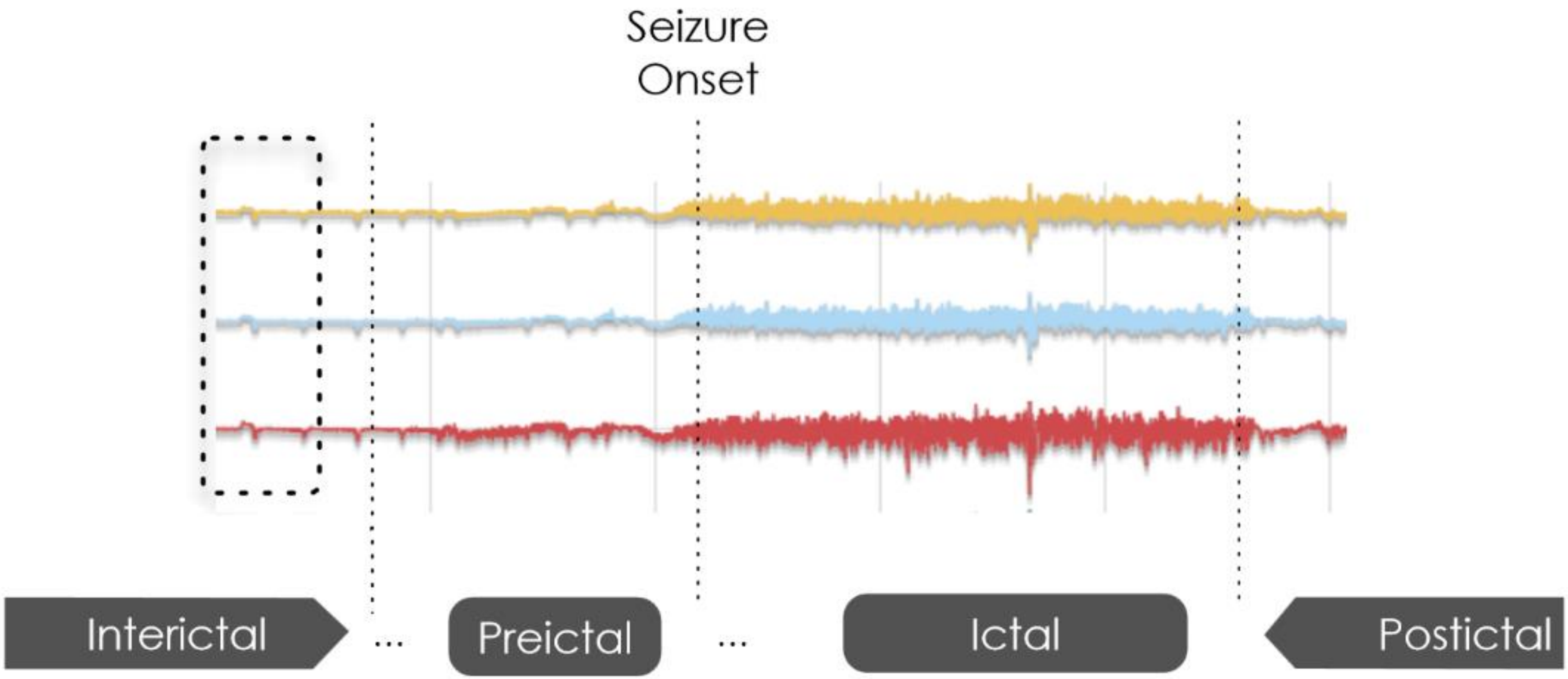
"It’s the variability that really makes it so stressful. You never know when it is going to be chaos again and you’ll have one. Just because this morning is terrific doesn’t mean tonight is going to be terrific, either behavior-wise, medication-wise, or any otherwise. So it is the unpredictability of it that is really nerve-racking to live with."

-Murray Coping with the uncertainty of uncontrolled epilepsy, Seizure 2 (1993) 167–178

SEIZURE PREDICTION CAN IMPROVE QUALITY OF LIFE FOR PATIENTS WITH EPILEPSY

- Epilepsy is a neural disorder characterized by spontaneous seizures
- Severity varies between patients
- Treatment is ineffective for ~30% of patients
- Affects 1% of global population
- Unforeseen seizures can put epileptics at risk during everyday activities
- Prediction allows for smarter decisions and reduced stress


Seizure
Onset
Interictal
...
Preictal
...
Ictal
Postictal

AVAILABLE DATASET

- 5 dogs, 2 humans
- Each dog has ~500 training examples (470 interictal, 30 preictal)
  - ~120 test examples
- Each example is an EEG segment over 10 minutes at 400Hz
  - 240,000 data points across 15-20 channels
- Interictal segments for dogs are taken from +1 week before or after seizure
- Preictal segments can be from 1:05 to 0:05 before seizure onset

“there is not any system usable by patients allowing them to predict a coming seizure and to take action to preserve his (her) safety and privacy, improving substantially his (her) social integration. This is probably because most of the researchers look for a general method and algorithm that would work for every patient. And although several authors propose methods to which they claim a high performance, the considered performance criteria is only partial, neglecting other parts of the problem that prevent them to be used in a clinical environment.“

-V. Ǩurkoví a et al. (Eds.): ICANN 2008, Part II, LNCS 5164, pp. 479–487, 2008.

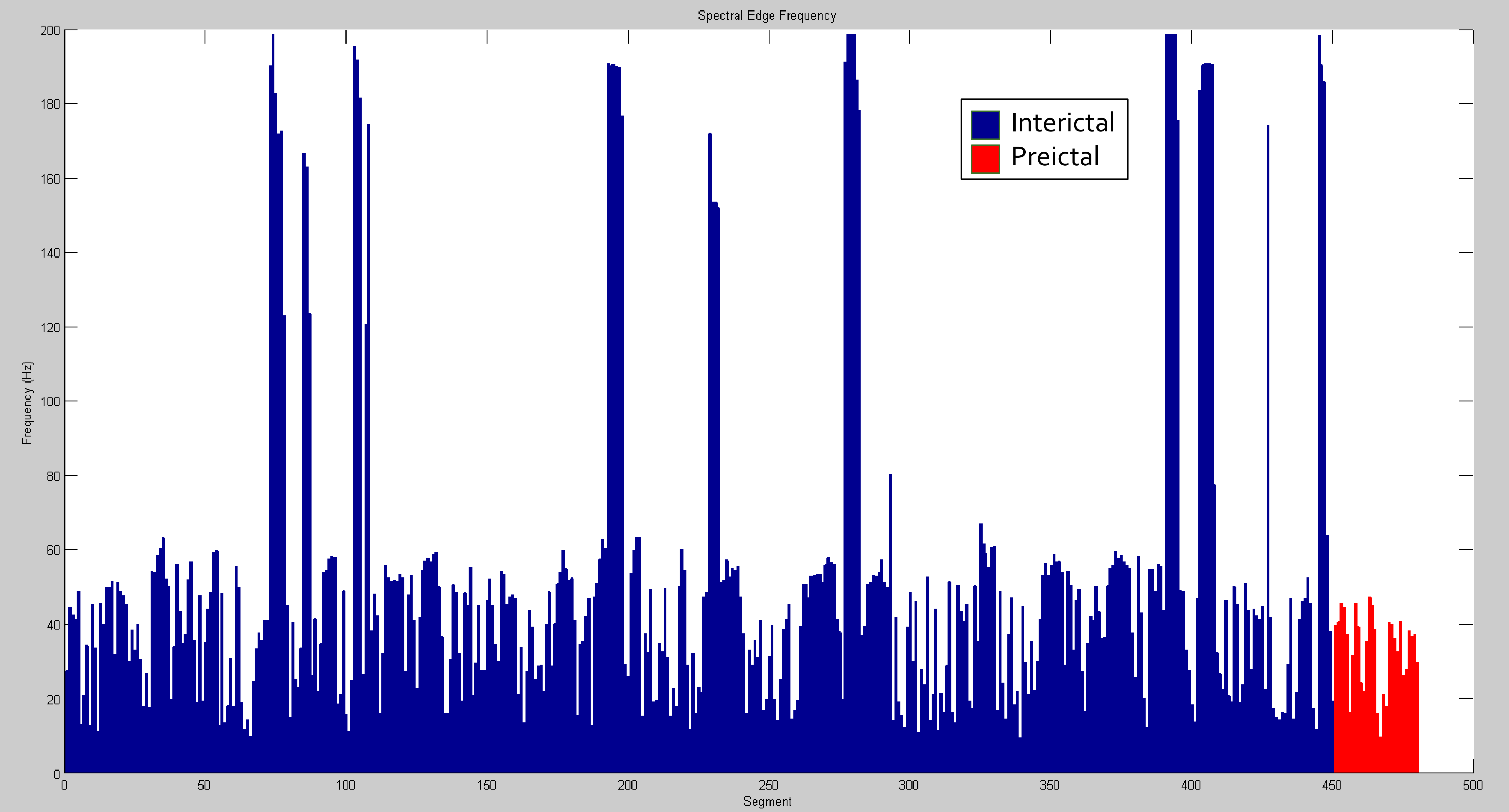
PER-SUBJECT APPROACH

- Reduce each segment into a scalar features using univariate analysis
- Input scalar features into neural network and train
- Use trained weights in neural network to classify test data

FEATURE GENERATION (CURRENT)

- Spectral Edge Frequency
  - Uses FFT to generate power spectrum
  - Finds frequency at which 90% of spectral power lies below

- Signal Power
  - Uses FFT to generate power spectrum
  - Finds max power (and frequency of max power) for each brain wave
    - Theta, delta, alpha, beta, gamma waves

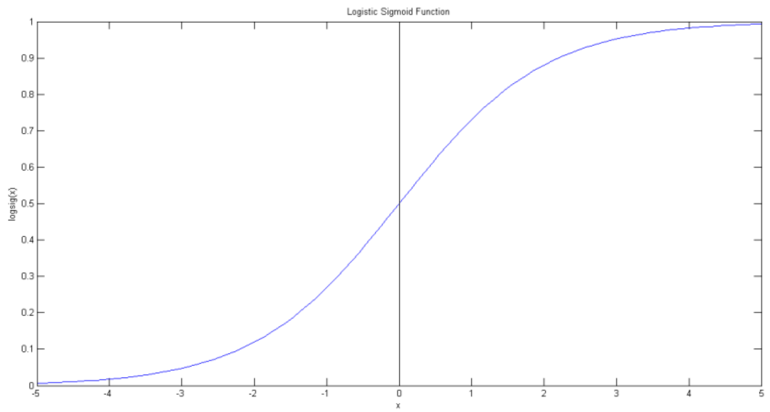

Spectral Edge Frequency
Frequency (Hz)
Segment
Interictal
Preictal
0
20
40
60
80
100
120
140
160
180
200
0
50
100
150
200
250
300
350
400
450
500

FEATURE GENERATION (FUTURE)

- Wavelet Transform (decomposition)
- Increments of Accumulated Energy
- Effective Correlation Dimension
- Spectral Entropy

NEURAL NETWORK

- Feedforward, Dense, Neural Network
- Backpropagation
- Logistic Sigmoid Activation Function



- Positive Tests on XOR function

NEURAL NETWORK

$\Delta W = -\alpha \delta^{(i)} \hat{o}$

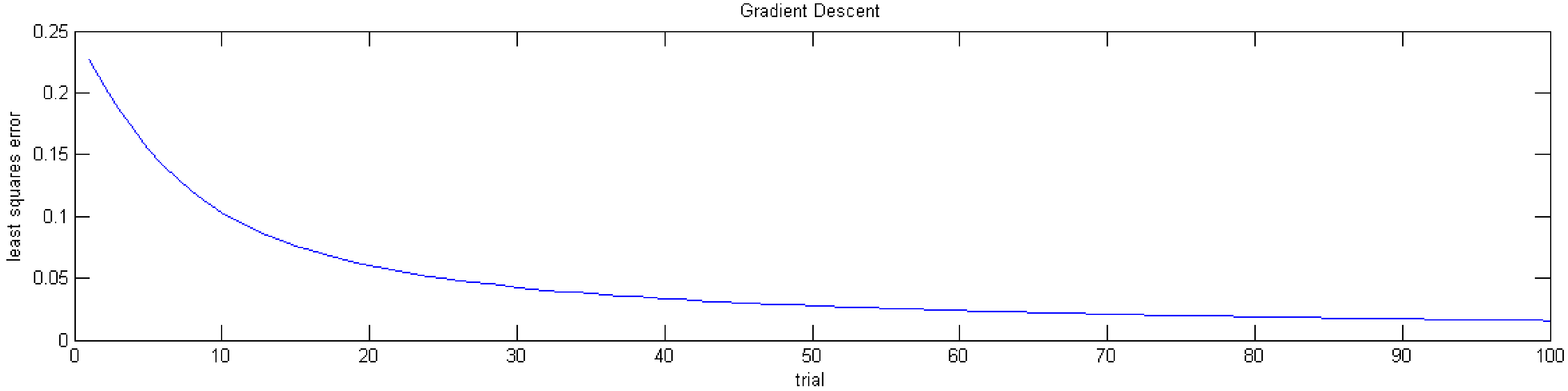
where

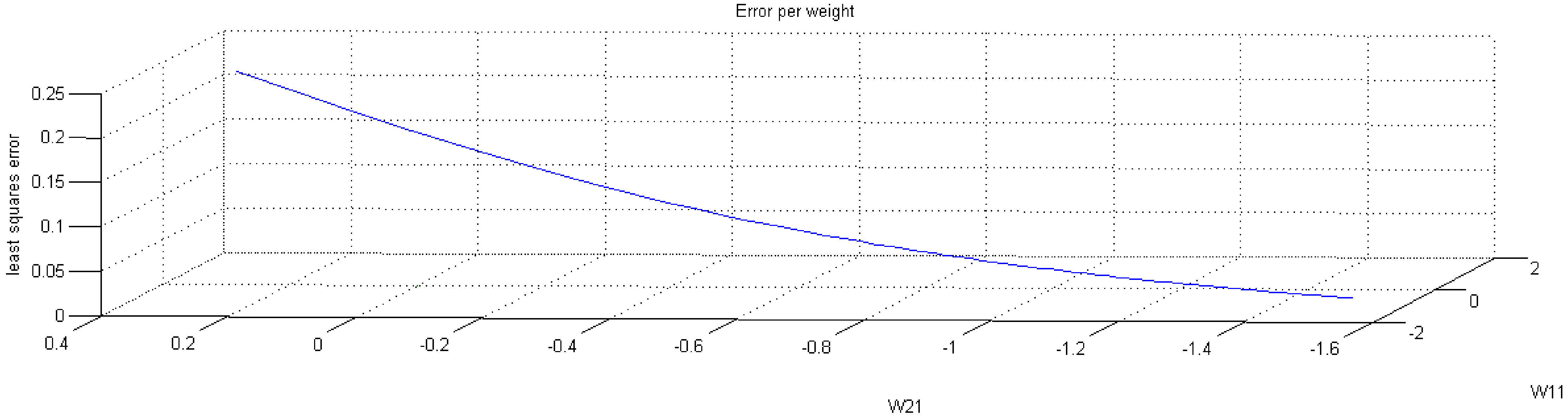
$\hat{o}$ is the input to a given layer

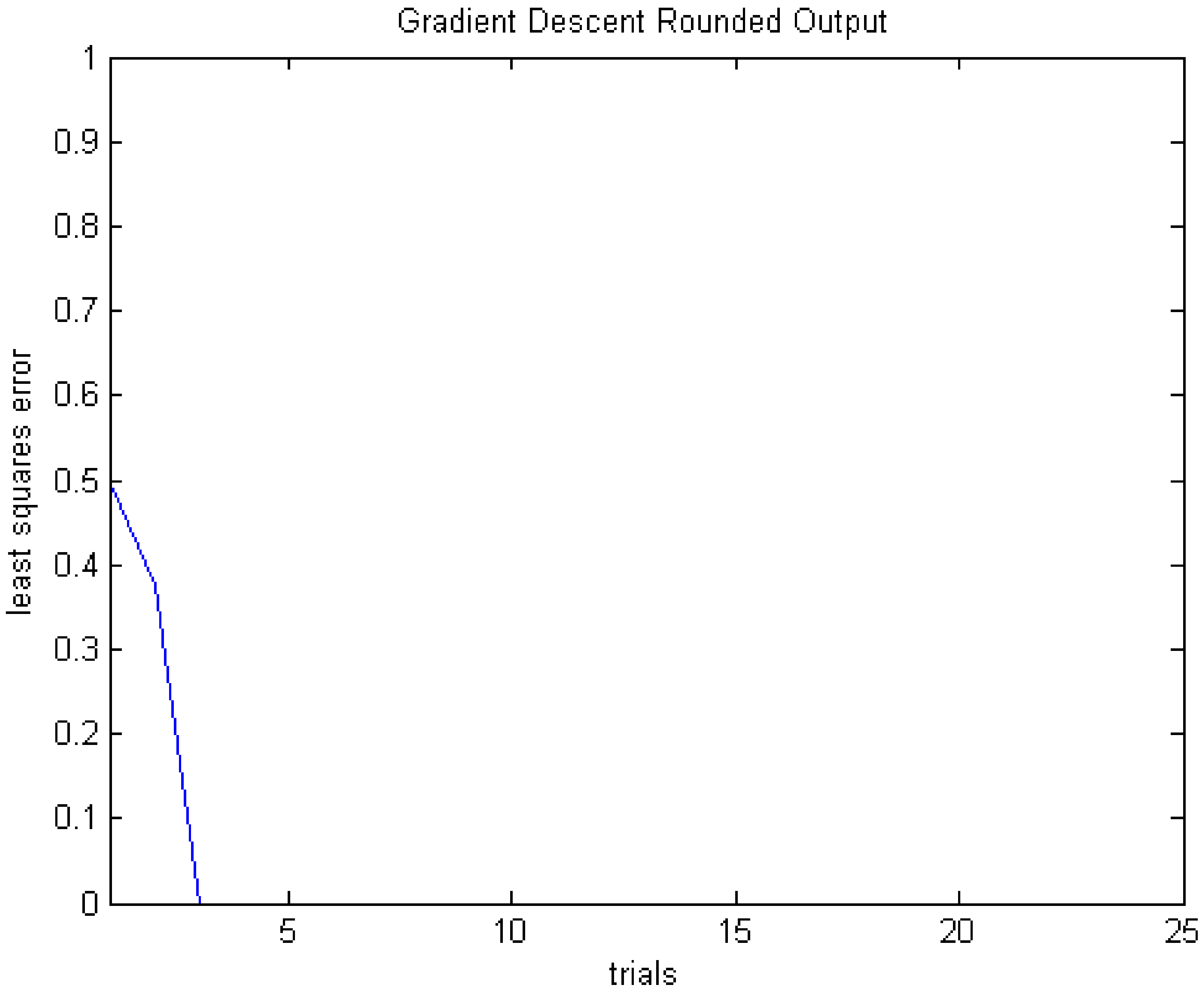
$\delta^{(l)} = D_l e$ base case (output layer)

$\delta^{(i)} = D_i W_{i+1} \delta^{i+1}$ recursive case (hidden layer)

D is diagonal derivative matrix of activation function

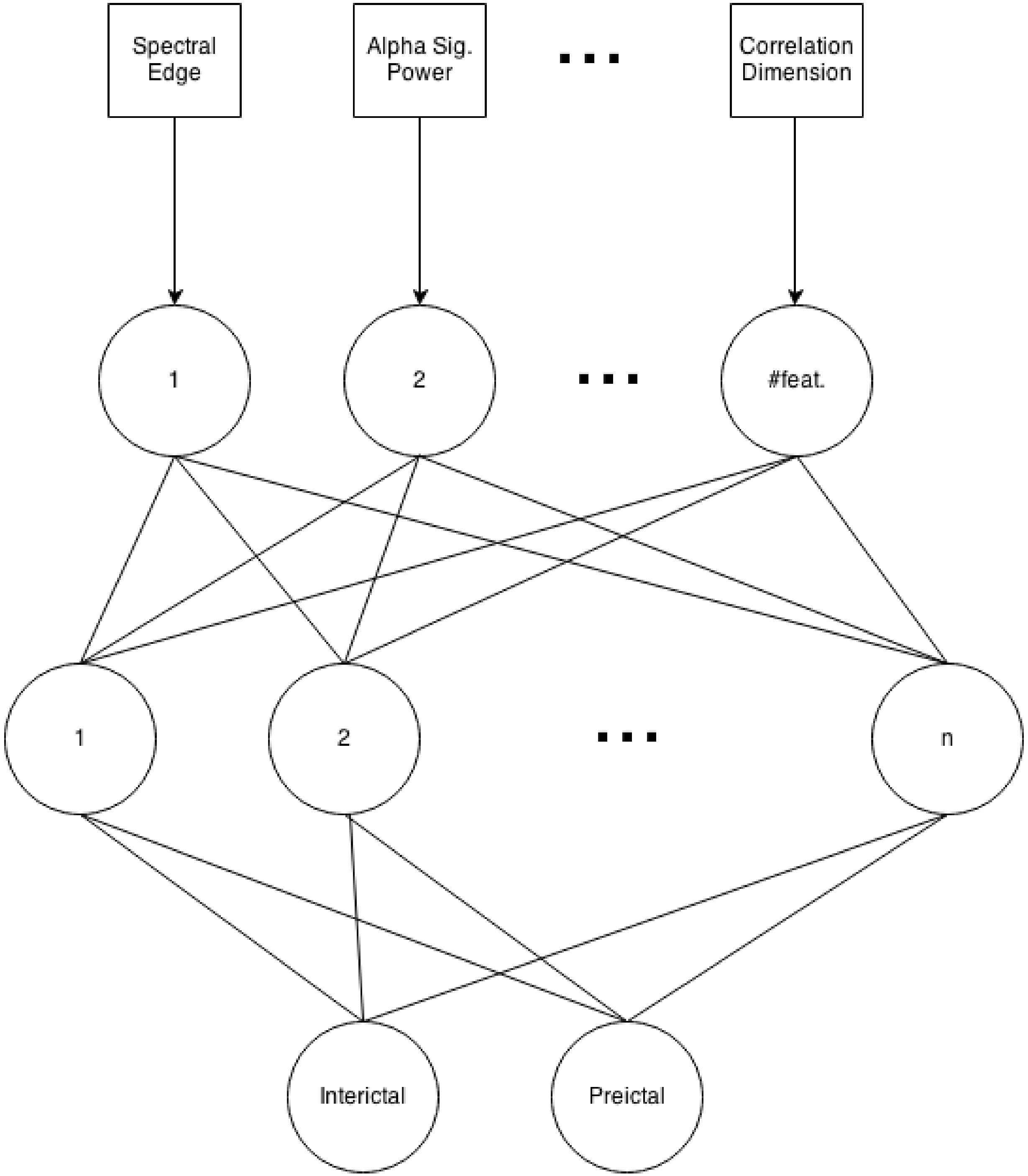

Gradient Descent
least squares error
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
80
90
100
trial


Error per weight
least squares error
0.25
0.2
0.15
0.1
0.05
0
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
W21
2
0
-2
W11


Gradient Descent Rounded Output
least squares error
trials
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
10
15
20
25

NEURAL NETWORK NEXT STEPS

- Finalize Feature selection
- Learning Rate selection
- Seeding Function to reliably initialize the network
- Pruning Method to optimize performance
- Experiment with Recurrent Networks


Spectral Edge
Alpha Sig. Power
...
Correlation Dimension
1
2
...
#feat.
1
2
...
n
Interictal
Preictal

JUDGE OF QUALITY

- Sensitivity: how many preictal segments can we correctly classify?
  - maximize
- False Positive Rate: how many interictal segments are incorrectly classified?
  - minimize

LIMITATIONS

- Current features do a poor job of handling multiple channels, do not cross-correlate any channels
- Initial dataset is huge
  - Takes ~25 minutes to load on smallest dog
  - Must be partitioned when generating features due to memory constraints
  - Storage is difficult
- Seeding of neural network is basic

REFERENCES

- Maiwald, Thomas, et al. "Comparison of three nonlinear seizure prediction methods by means of the seizure prediction characteristic." Physica D: nonlinear phenomena 194.3 (2004): 357-368.
- Howbert JJ, Patterson EE, Stead SM, Brinkmann B, Vasoli V, Crepeau D, Vite CH, Sturges B, Ruedebusch V, Mavoori J, Leyde K, Sheffield WD, Litt B, Worrell GA (2014) Forecasting seizures in dogs with naturally occurring epilepsy. PLoS One 9(1):e81920.