Gesture Recognition of EEG Signals Using Wavelet Transform and Artificial Neural Networks

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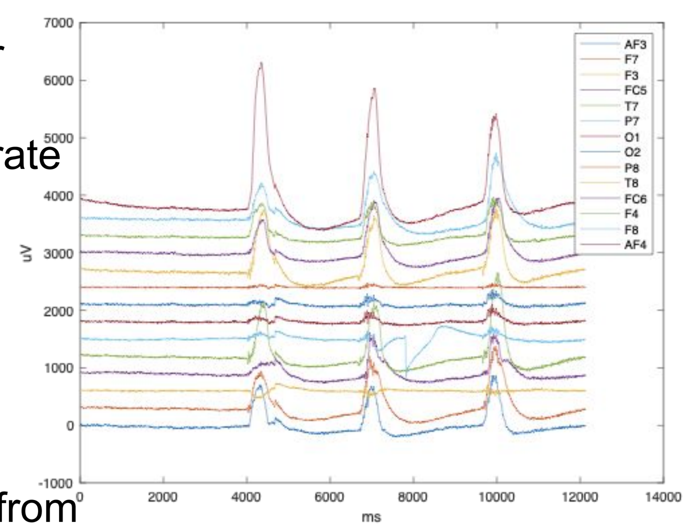
Background: Electroencephalogram (EEG) Brain-Computer Interface (BCI)

- EEG signals provide a non-invasive way of constructing Brain-Computer Interfaces.
- Different brain data travels on separate frequency bands,which consist of:
  - Delta Waves (0.5 to 3Hz)
  - Theta Waves (3 to 8 Hz)
  - Alpha Waves (8 to 12 Hz)
  - Beta Waves (12 to 38 Hz)
  - Gamma Waves (38 to 42 Hz)
- In this project, samples were taken from commercial-grade, 14-channel Emotiv EPOC® Headset.



14-Channel raw EEG signal for a smile.

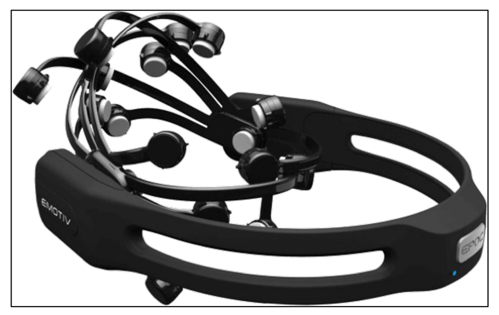
Motivation & Objectives

Motivation

- To improve the accuracy of EEG gesture recognition classifiers that use a commercial grade EEG headset by introducing a robust feature extraction method.

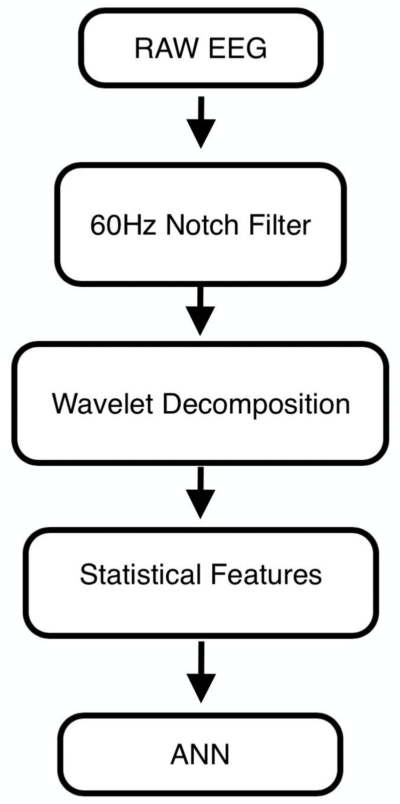
Objectives

- Design a feature extraction and classification system that increases accuracy for EEG gesture recognition of more than one subject by using a 4-level wavelet decomposition prior to classification.


Emotiv EPOC® Headset

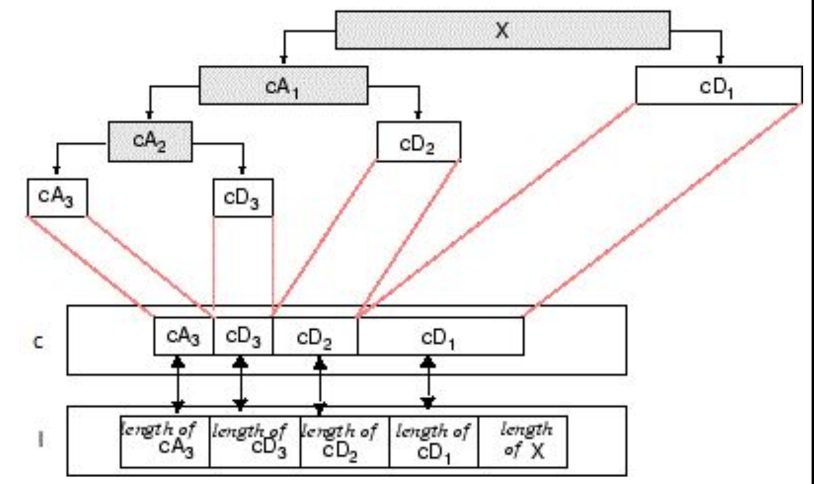
Methodology

- The Gesture Recognition process consists of three stages:
  - Preprocessing: Notch filter at 60Hz to eliminate of wall noise and HPF to rid of DC offset from EPOC® headset.
  - Feature Extraction: Wavelet decomposition and statistical feature calculation
  - Classification: Gesture classification using artificial neural networks (ANN)



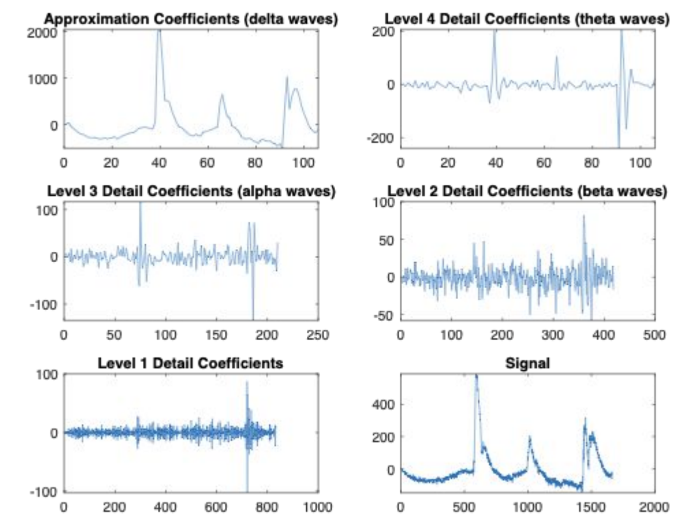
Wavelet Decomposition

- [1] shows positive results in using a 4-level wavelet decomposition for seizure detection on EEG signals.
- 4-level decomposition allows for EEG signal to be split into:
  - Delta Waves (approximation coefficients)
  - Theta Waves (Level 4 Detail Coefficients)
  - Alpha Waves (Level 3 Detail Coefficients)
  - Beta Waves (Level 2 Detail Coefficients)
  - Gamma Waves (Level 1 Detail Coefficients)



Wavelet Decomposition (cont.)

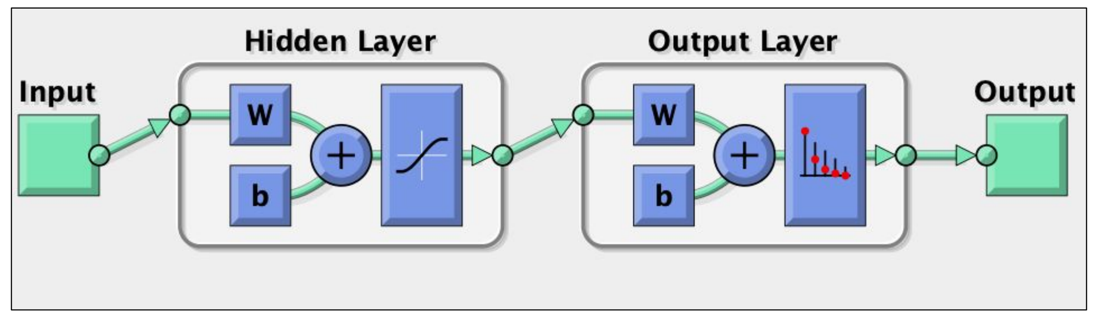
- A 4-level wavelet decomposition using Daubechies 2nd order wavelet was performed on each channel of the EEG signals.
- Once wavelet decomposition is done, statistical features (mean, variance, standard deviation, skewness, kurtosis, magnitude) are calculated for each wavelet coefficient vector per EEG channel. [2]



4-level wavelet decomposition for smile gesture on AF3 channel

ANN Architecture

- A fully connected, two-layer network architecture was used:
  - Sigmoid layer with 150 hidden neurons
  - Softmax output layer.
- Network was trained using scaled conjugate backpropagation.
- Input vector: 6 statistical features x 4 wavelet vectors x 14 eeg channels = 336 points
- Output vector: 6 facial gestures (smile, look left, look right, raise eyebrows, blink, and hard blink)



Results

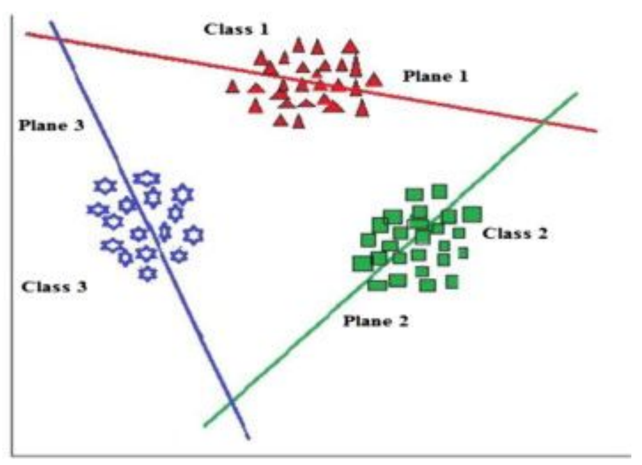
- Classifier exhibits an average of 92% accuracy in training, validation, and testing of ANN.
- Error is evenly distributed throughout the samples, indicating that no gesture was particularly harder to classify than another

All Confusion Matrix

Output Class \ Target Class	1	2	3	4	5	6	
1	66 16.4%	0 0.0%	4 1.0%	1 0.2%	2 0.5%	1 0.2%	89.2% 10.8%
2	2 0.5%	62 15.4%	1 0.2%	0 0.0%	0 0.0%	1 0.2%	93.9% 6.1%
3	1 0.2%	3 0.7%	56 13.9%	0 0.0%	1 0.2%	0 0.0%	91.8% 8.2%
4	0 0.0%	1 0.2%	1 0.2%	65 16.2%	1 0.2%	1 0.2%	94.2% 5.8%
5	4 1.0%	1 0.2%	1 0.2%	1 0.2%	59 14.7%	0 0.0%	89.4% 10.6%
6	0 0.0%	3 0.7%	0 0.0%	1 0.2%	0 0.0%	62 15.4%	93.9% 6.1%
	90.4% 9.6%	88.6% 11.4%	88.9% 11.1%	95.6% 4.4%	93.7% 6.3%	95.4% 4.6%	92.0% 8.0%

Future Work

- Implement classifier design on Brain-Computer Interface for application and use.
- Add more gestures to classification system for greater variety.
- Optimize algorithm for real-time implementation
- Increase sample space (at 402 samples, current sample space is fairly small)
- Test with other classification algorithm, such as a Multiclass SVM and Random Forest algorithm [3]



Multiclass SVM example

References

[1] S. Yasmeen and M. V. Karki, "Neural network classification of EEG signal for the detection of seizure," *2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)*, Bangalore, 2017, pp. 553-558.

[2] P. Jahankhani, V. Kodogiannis and K. Revett, "EEG Signal Classification Using Wavelet Feature Extraction and Neural Networks," *IEEE John Vincent Atanasoff 2006 International Symposium on Modern Computing (JVA'06)*, Sofia, 2006, pp. 120-124.

[3] E. M. Imah and A. Widodo, "A comparative study of machine learning algorithms for epileptic seizure classification on EEG signals," *2017 International Conference on Advanced Computer Science and Information Systems (ICACSIS)*, Bali, 2017, pp. 401-408.