Project LexiCon

Building a Brain Computer Interface

Rohak Singhal
BEng (CE) Year 4

Outline

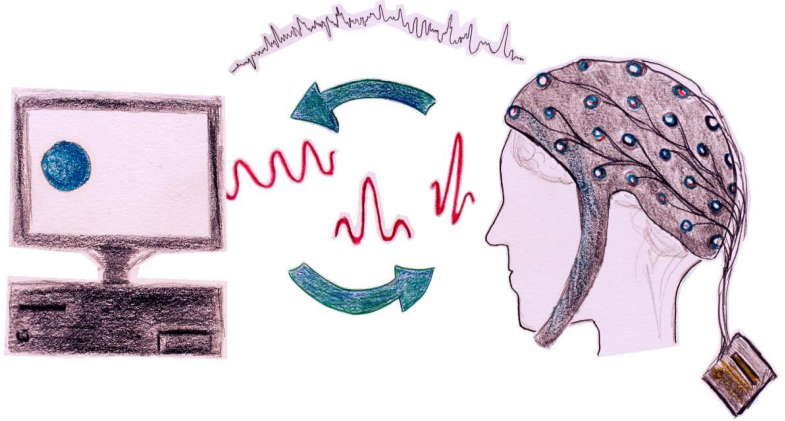
1. Introduction
2. Apparatus
3. Methodology
4. Architecture
5. Results and Performance Measure
6. Conclusion

RECAP

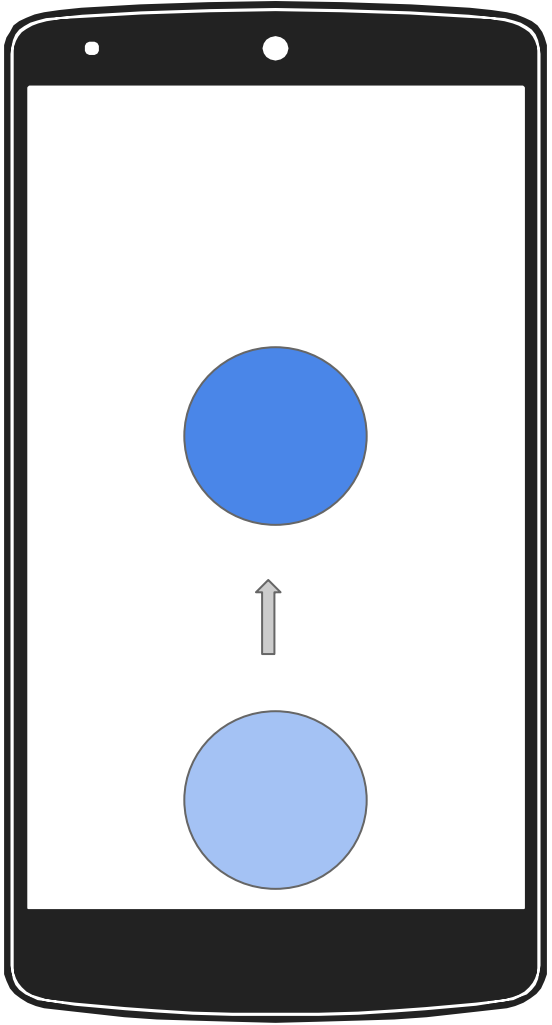
Introduction

What is a Brain Computer Interface (BCI)

- Brain produces electrical activity in performing its functions.
- Electrical activity can be recorded using electrodes on the scalp.
- BCI recognises patterns from data extracted from the brain.
- Patterns then associated with commands.



UP!



Project Aims and Significance

1. Establish a well documented process to develop a BCI system from scratch.
   - **To help university students to continue research in this field.**
2. Build a simple real time BCI application.
   - **To demonstrate the capabilities of the BCI system.**
3. Analyse if the low resource BCI hardware can be used to extract meaningful mental information.
   - **To reduce cost of development.**

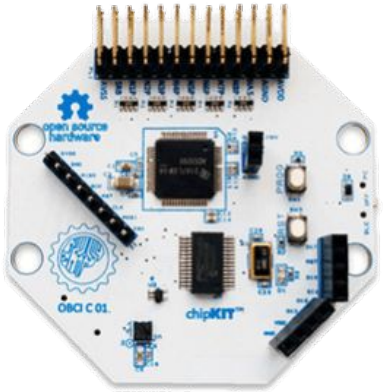
Revised Objectives

- Focus on building a better model for real-time command classification
  - Application not the focus
  - Machine Learning
- Use thoughts or “motor imagery” instead of physical movement
- Demonstrate the application in real-time

Apparatus

Hardware: OpenBCI Cyton and Daisy

- Total of 16 channels from the combined boards
- Greater accuracy and brain coverage
- Compatible with most BCI software libraries

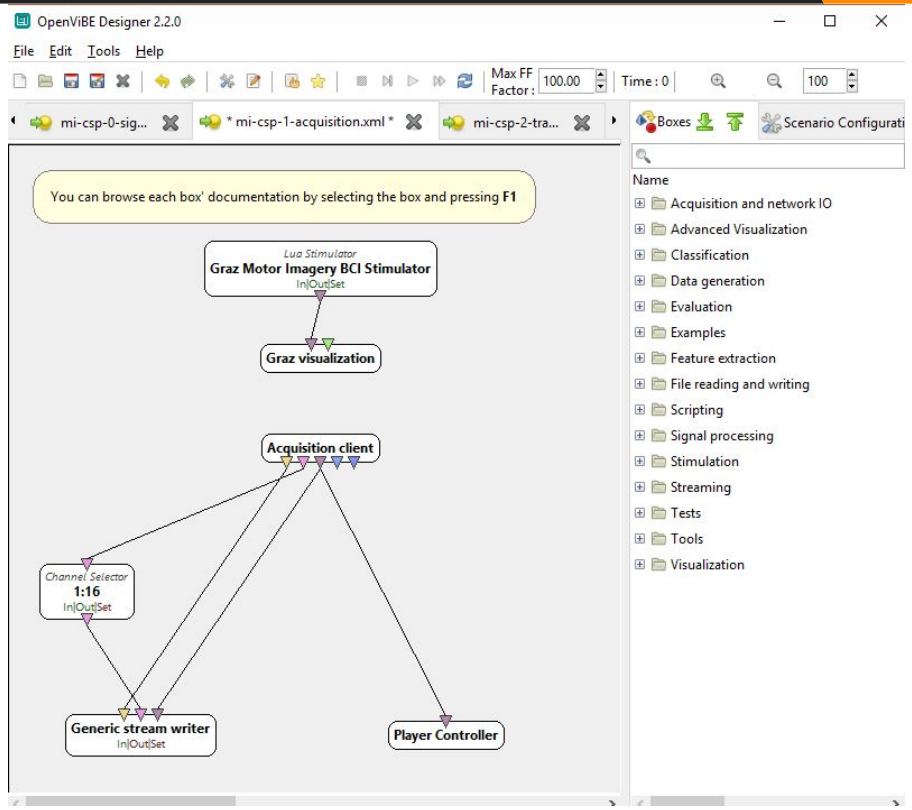


OpenBCI 32-bit Board Kit

OpenBCI 16-channel R&D Kit

Software: OpenVibe Designer

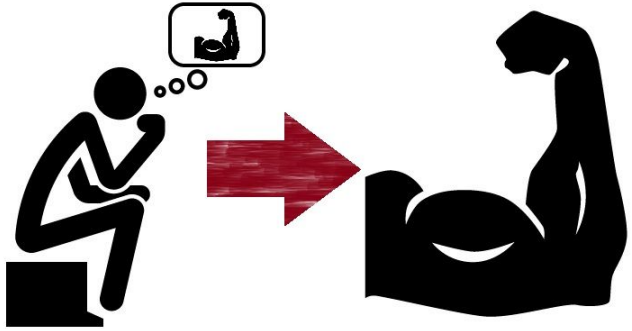
- Modules can be configured, edited, chained and used
- Best for rapid prototyping

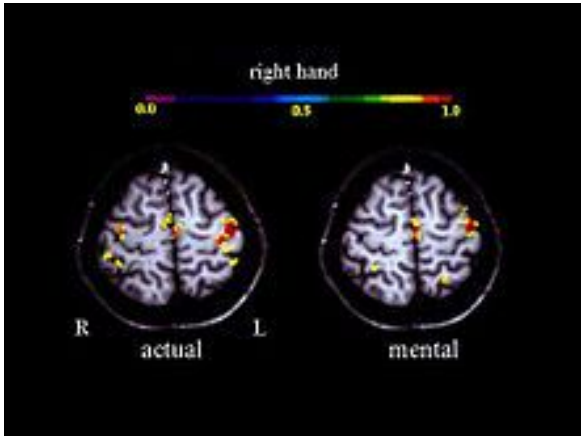


Methodology

Mapping Principle: Motor Imagery

- Performing an action and thinking of the same action
  - Activate same areas in the brain
- Thus thinking of left or right hand should give results similar to moving them
- First classify arm movement
  - Attempt motor imagery

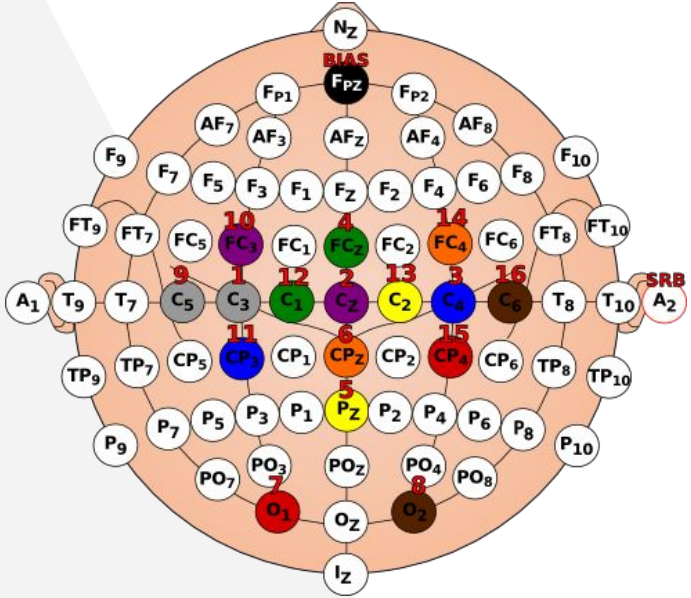




Process Flow

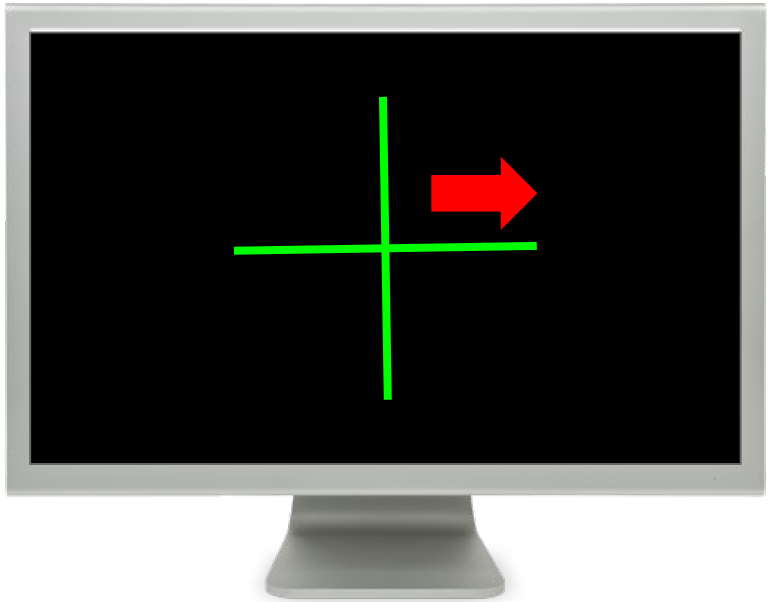
Signal Acquisition: Electrode Placement

- Used international 10-20 standard of placement
- Used brain areas known for movement and discrimination between left and right body areas



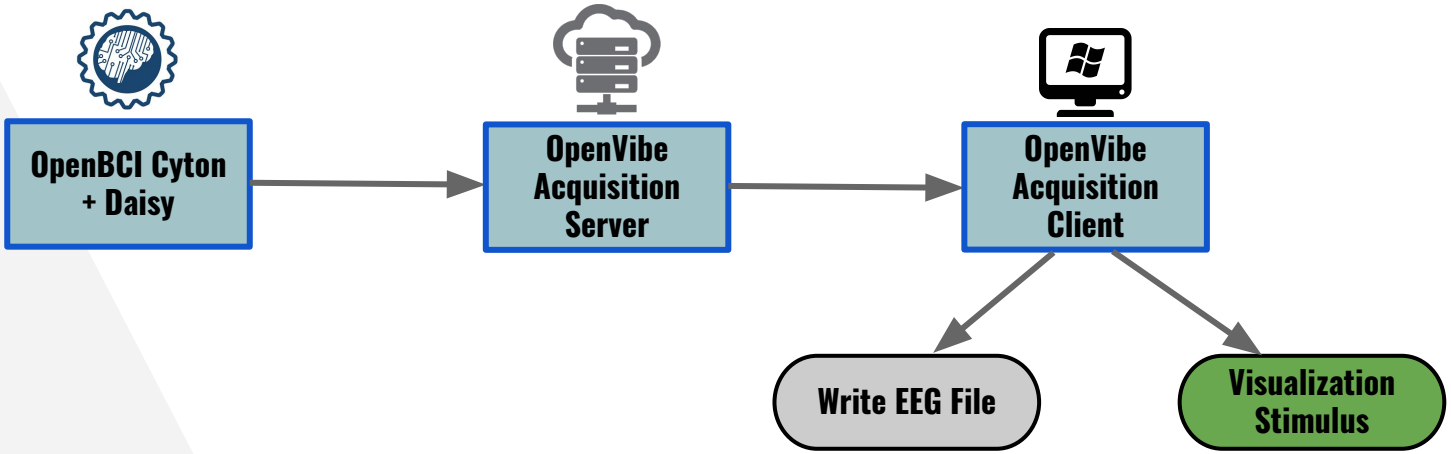
Data Acquisition: Stimulation

- Stare at blank screen for 30s
  - Allow brainwaves to settle
- Green Cross indicates user to get ready
- Arrow direction indicates
  - Which side to move/think (left vs right)
- 3 Separate Tasks
  - Moving Arms
  - Moving Fingers
  - Motor Imagery
- 20 trials for each side (left and right)



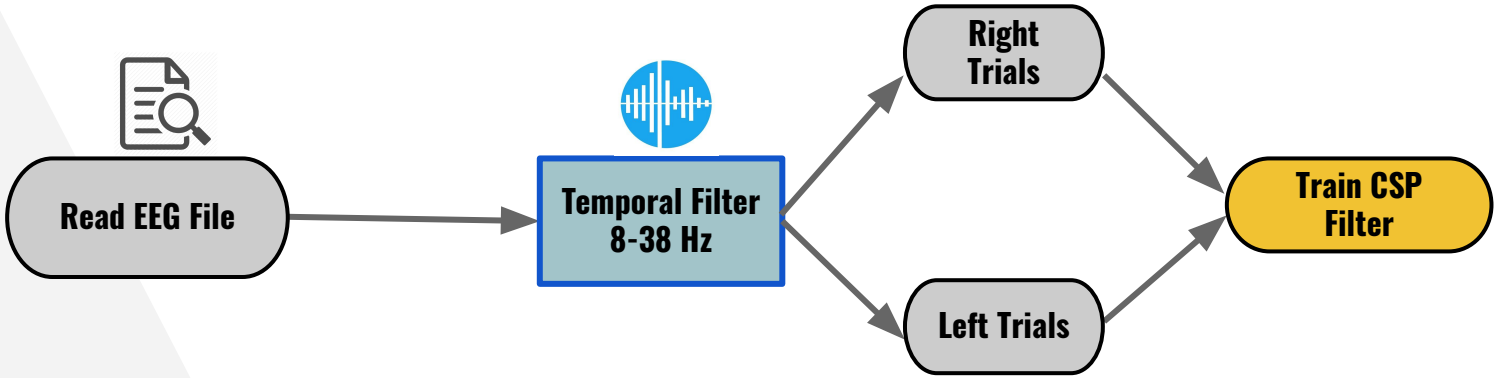
Architecture and Implementation

Data Acquisition: Process



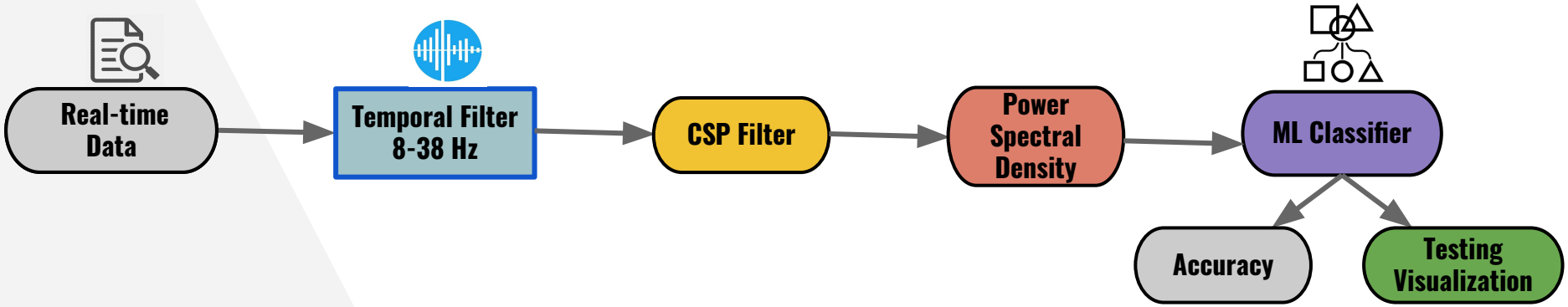
- Stimulation shown to user
- Data recorded to file as user responds

Signal Processing and Feature Engineering



- Temporal Filter extracts frequencies in the alpha and beta region (8-30Hz)
- CSP Filter produces features by linear combination of EEG data
  - Maximize class variance for 1st class
  - Minimize for 2nd class

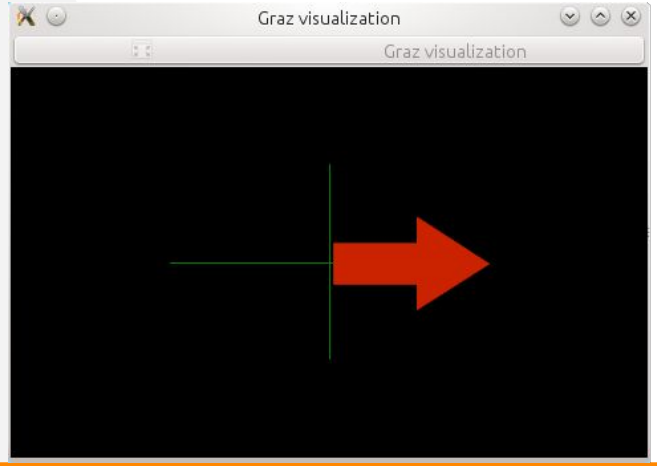
Classification

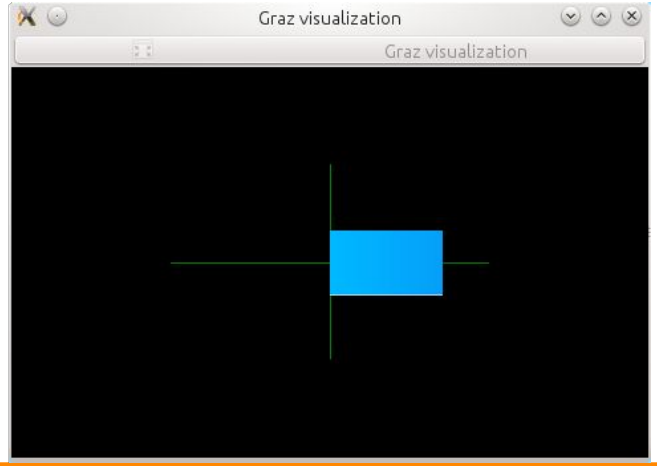


- Power Spectral Density estimates the total magnitude (power) of the signal
- Calculates the power associated with the signals captured from the different regions of the brain while performing an action

Testing Visualization

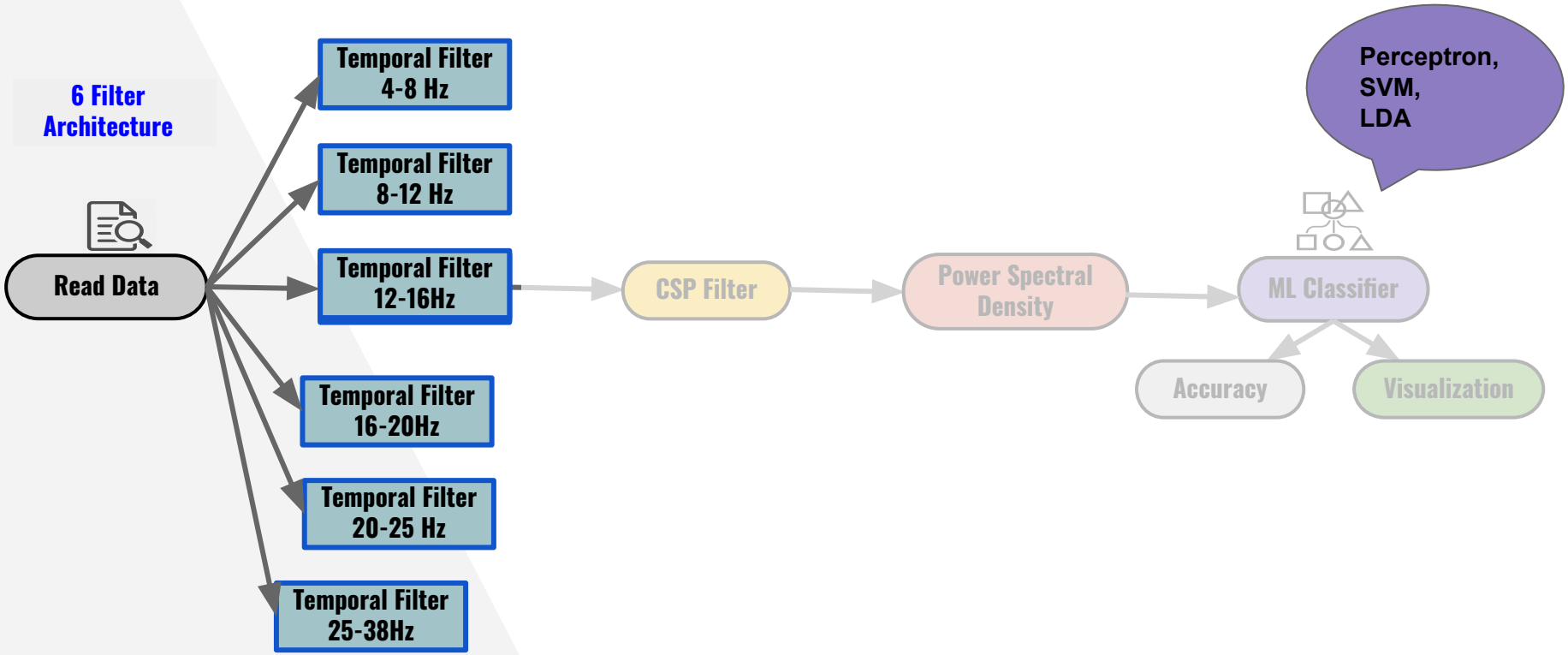
- **Red Arrow**
  - Direction to move/think of moving
- **Blue Bar**
  - Which side is detected (left/right)
  - Length denotes confidence





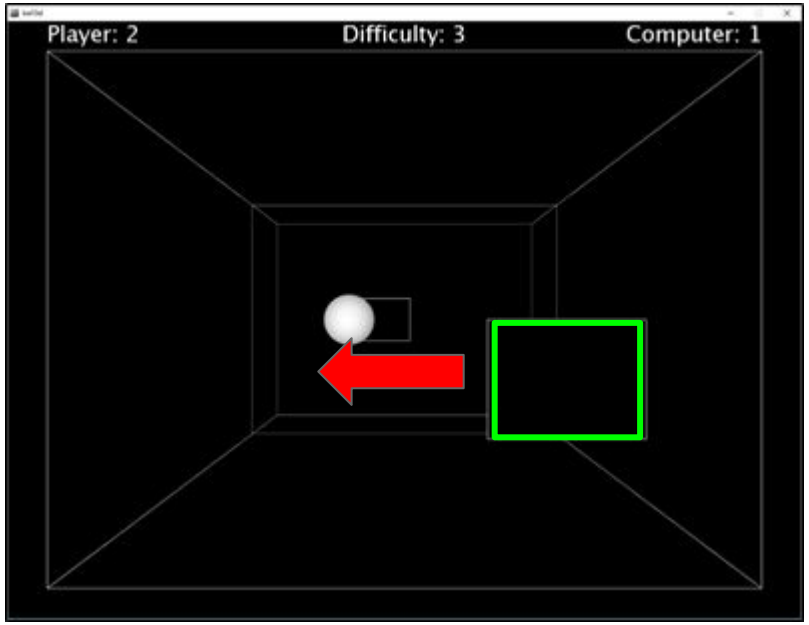
Testing Demo

Model Improvements and Variations



Application Development

- 3D Game written in Processing framework
  - Arcade version of pong
- Paddle controlled by command from model
- Goal is to hit the ball back towards the opponent



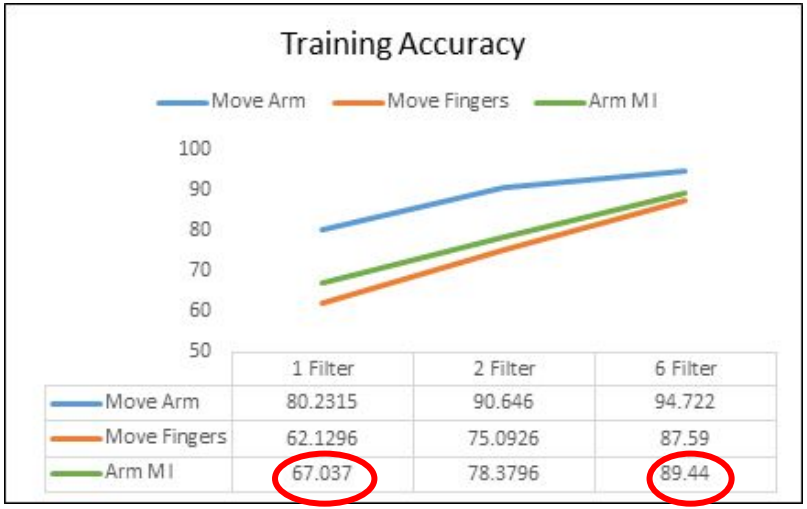
3d Pong in Processing

Game Control Demo

Results and Analysis

Performance Measure

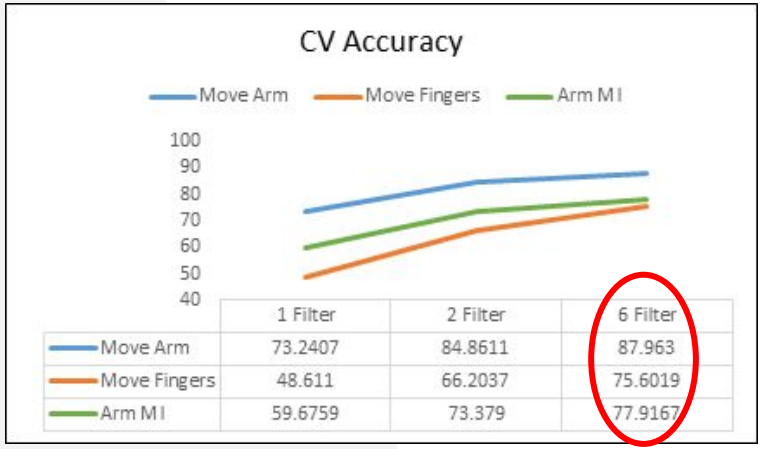
- Measure classification rate
- Comparing architectures and responses (movements)
- Significant improvement in 6-filter approach
- Arm MI improved significantly from **67% to 89%**



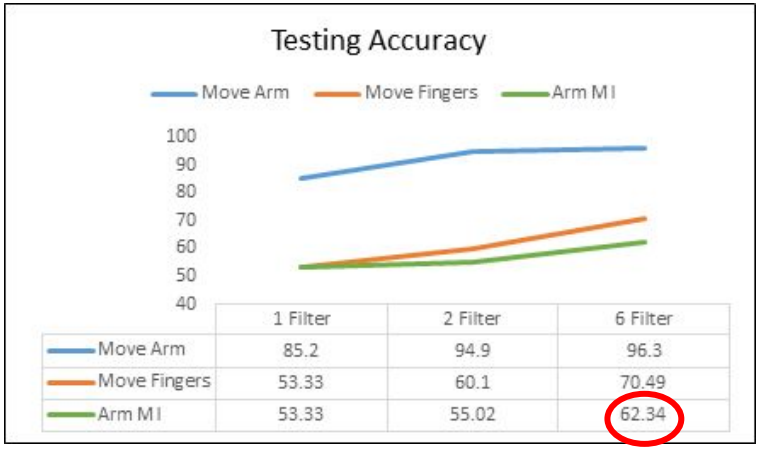
	1 Filter	2 Filter	6 Filter
Move Arm	80.2315	90.646	94.722
Move Fingers	62.1296	75.0926	87.59
Arm MI	67.037	78.3796	89.44

Testing Accuracies

- **Testing Accuracy for Arm Motor Imagery (MI) is 62% with 6 Filters**
  - Possible that user cannot generate strong enough motor imagery
  - Fair degree of control observed in gameplay
- **Accuracy of Moving Arm > Arm MI > Moving Fingers**



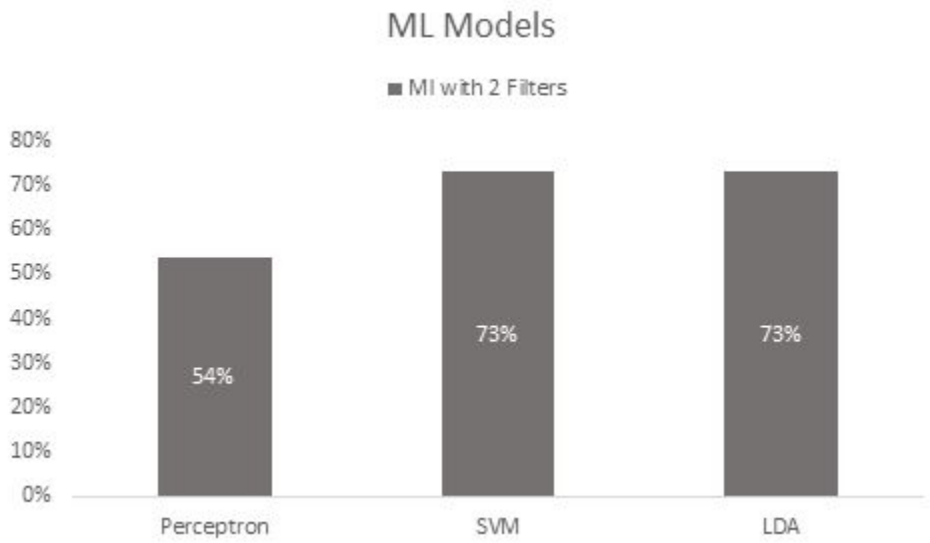
	1 Filter	2 Filter	6 Filter
Move Arm	73.2407	84.8611	87.963
Move Fingers	48.611	66.2037	75.6019
Arm MI	59.6759	73.379	77.9167



	1 Filter	2 Filter	6 Filter
Move Arm	85.2	94.9	96.3
Move Fingers	53.33	60.1	70.49
Arm MI	53.33	55.02	62.34

Model Comparison

- LDA and SVM give similar performance.
  - Fig shows 2 filters
  - Best with 6 filters
- Perceptron performs very poorly compared to the others



Conclusion and Future Direction

Significance and Contributions

- Built an end-to-end real time BCI system
  - **Demonstrated its power using a 3D video game**
- System is well documented, easy to modify and can be reproduced from instructions
  - **Promote research interest in student and maker community**
- Improved classification accuracy of current BCI models
  - **Established a baseline for future research**

Challenges and Limitations

- **Accuracy affected by both model and human error**
  - More training fatigues user thus ineffective
- **Several unknown variables**
  - Noise affected by nearby electromagnetic fields, sweat etc
- **Lack of comprehensive information**, documentation and support.

Conclusion: Key Points

- **LexiCon can recognize user's thoughts and classify them in real time.**
- **Commands provide enough control to play simple video games.**
- **Significant accuracy improvements were made**
  - Can try to improve further by varying architecture or training the user

Future Applications

- Multiplayer video games
- Rehabilitation therapy
  - People with lost limbs can train their body for prosthetic attachment
  - Controlling wheelchair

THANK YOU!

Any Questions?

References

[1] J. J. Shih, D. J. Krusienski and J. R. Wolpaw, "Brain-Computer Interfaces in Medicine," Mayo Foundation, March 2012.

[2] J. R. Wolpaw, N. Birbaumer, D. J. McFarland, G. Pfurtscheller, and T. M. Vaughan, “Brain–computer interfaces for communication and control,” *http://www.cs.cmu.edu/~tanja/BCI/BCIreview.pdf*. [Online]. Available: http://www.cs.cmu.edu/~tanja/BCI/BCIreview.pdf

[3] "Ganglion Board (4-channels)," [Online]. Available: https://shop.openbci.com/products/pre-order-ganglion-board?variant=13461804483. [Accessed 30 October 2018].

[4] OpenBCI, “OpenBCI/OpenBCI_GUI,” *GitHub*, 19-Aug-2018. [Online]. Available: https://github.com/OpenBCI/OpenBCI_GUI. [Accessed: 30-Oct-2018].

Demo