A Virtual Reality (VR)-based Brain-Computer Interface Development

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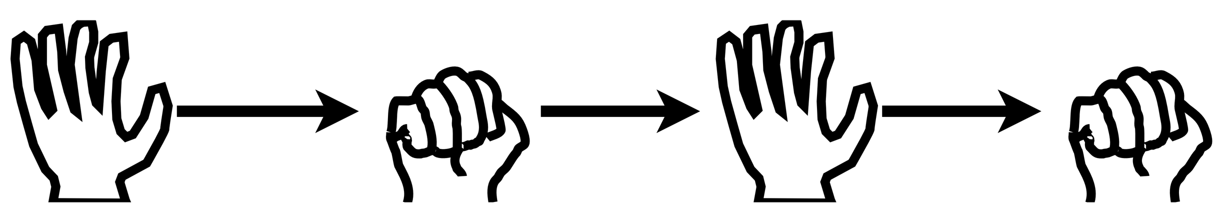
Introduction

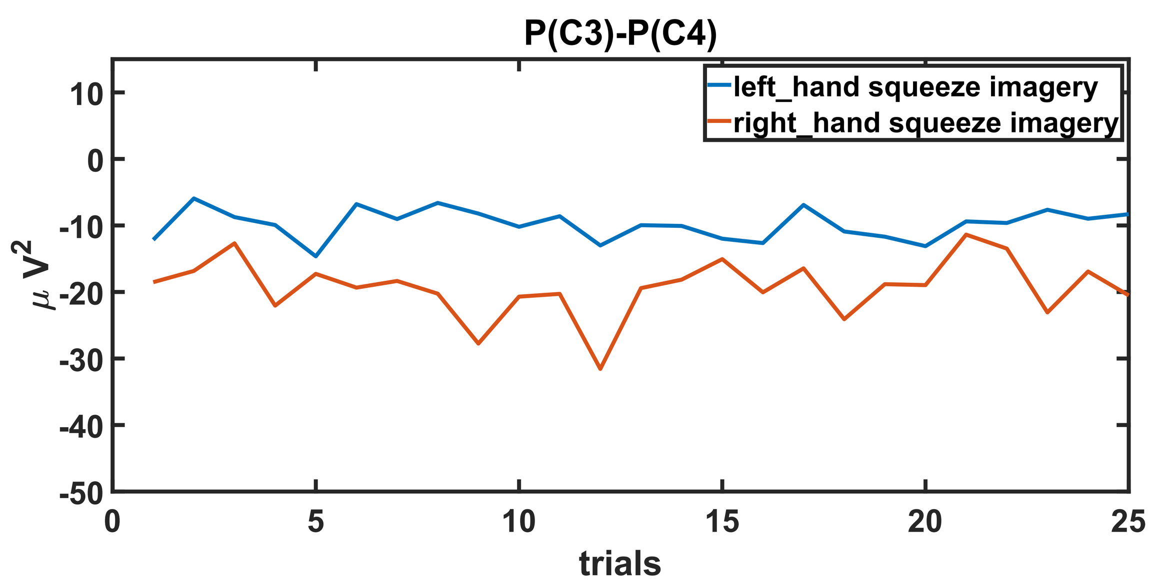
- **Brain-Computer Interface (BCI)** provides non-muscular channels for the brain to communicate with the external world. patients who suffer from paralysis may use a BCI to control prosthetic devices. (ref 1)
- **scalp-eletroencephalogram (S-EEG)** based BCIs are non-invasive and portable. (ref 1)
- **Virtual Reality (VR)** has become a popular compoment in modern BCIs as it can provide an immersive environment for prototyping and testing BCI systems at relatively lower costs.

Objective

- Control virtual robot arm using decoded S-EEG signals to perform tasks in VR program
- 2 DOF to navigate to a virtual object on a 2D table.
- 1 DOF to pick up or release the object.

MI/action

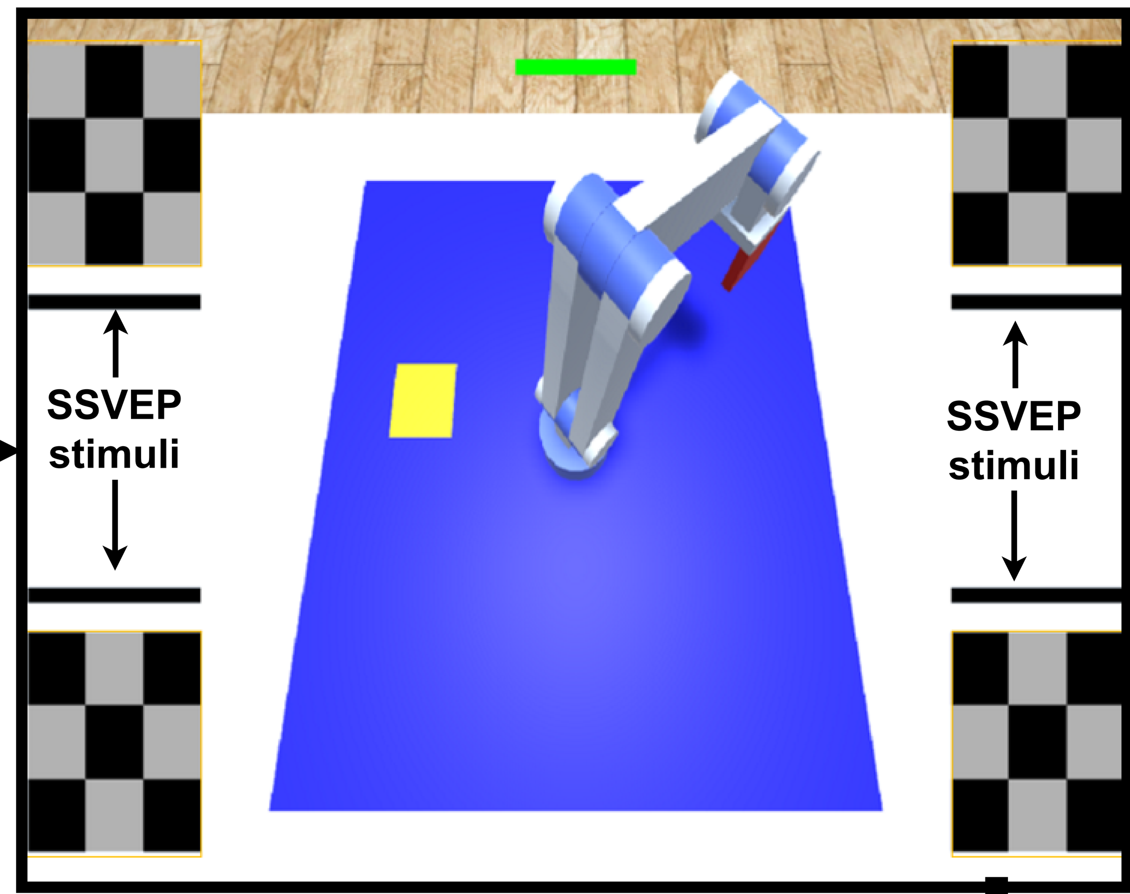




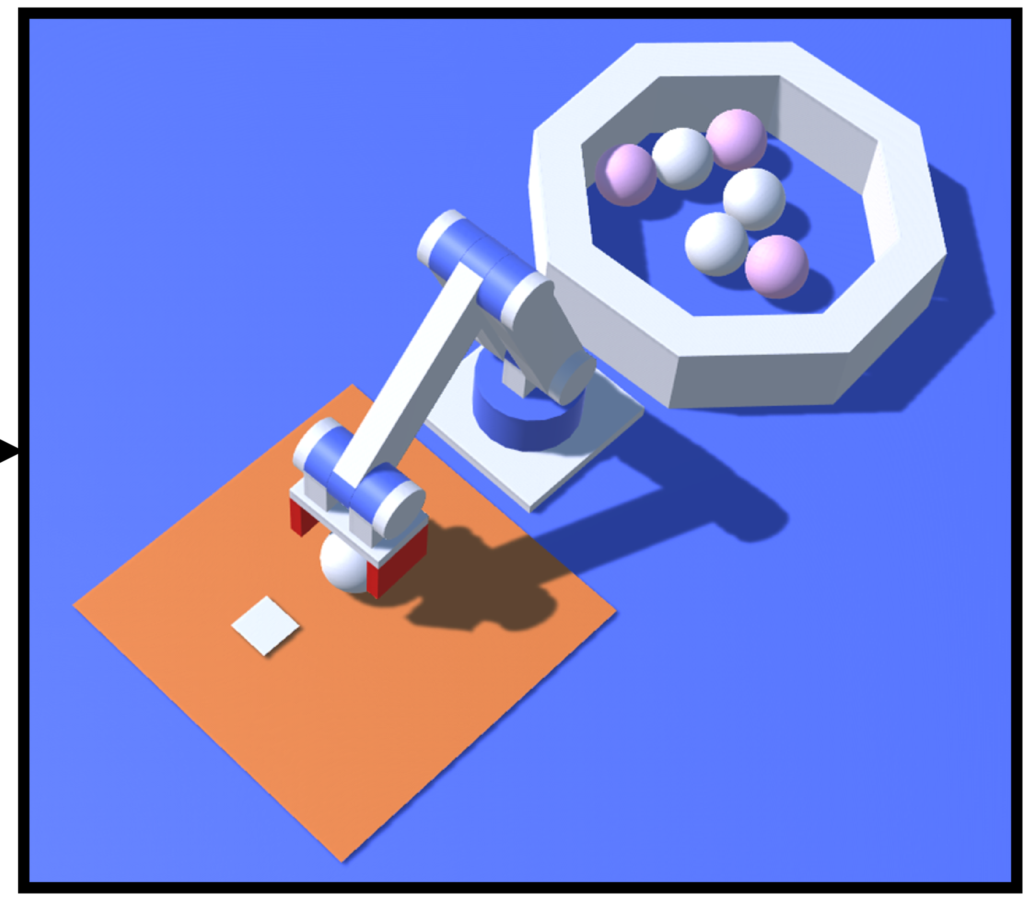
beta frequency power difference between c3,c4 during MI

- **Imagination of movement (MI)** or actual actions produce responses around the motor cortex. (ref 2.)
- **Event Related Synchronisation (ERS)**: Frequency power in **beta (12-30Hz)** increases during imagination and action around relevant areas of motor cortex. (**C3, C4 for hands**).
- Frequency power difference in beta (12-30Hz) can differentiate left hand and right hand squeeze action or imagery. The accuracy is about **70%** for a 5 seconds time window.

g.tec g.GAMMAsys EEG cap & Oculus Rift VR

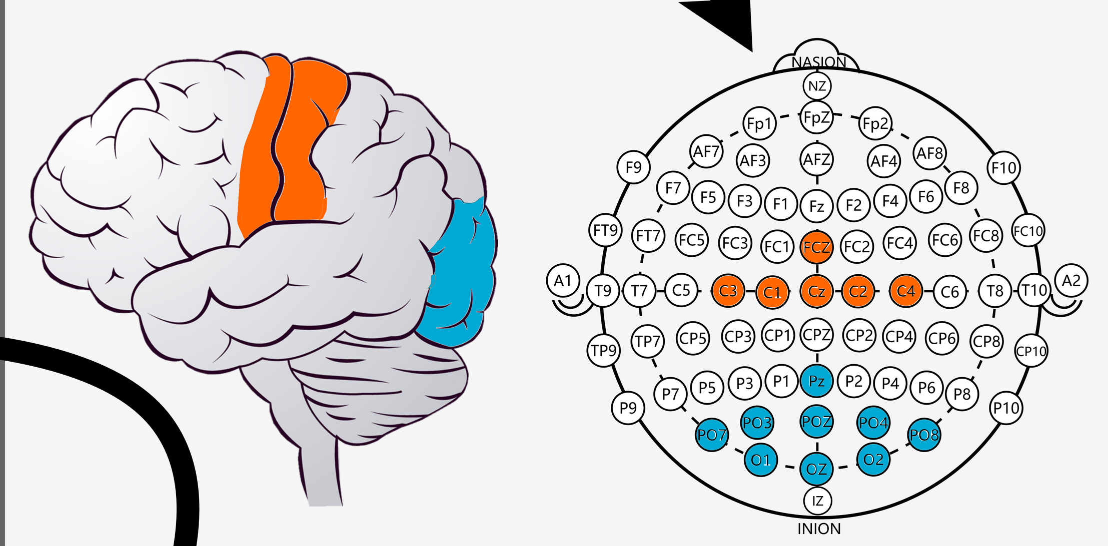


Unity robot 2-D plane navigation control



Unity robot grab/release command

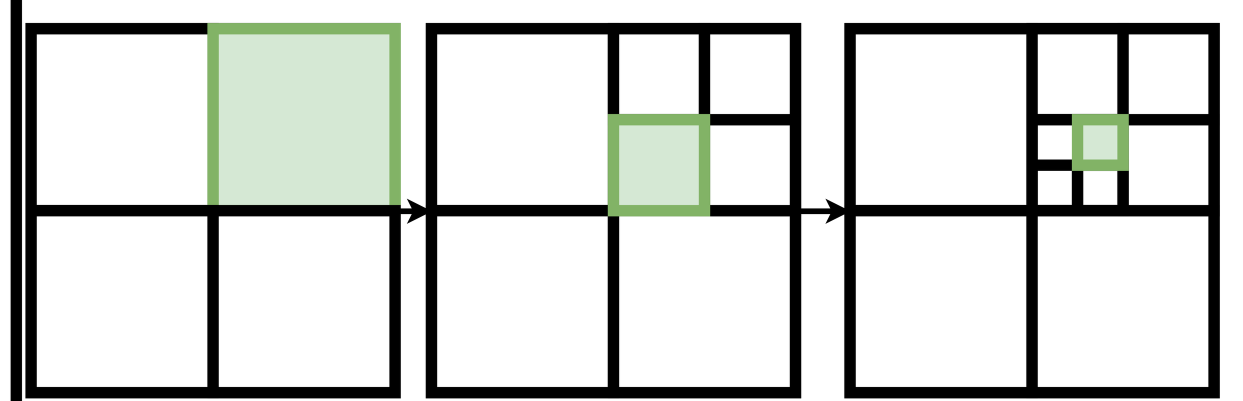
- An object appears at a random location within an 8X8 grid system
- User needs to nagivates the cursor to the correct position and perform a pick-up
- Signals are decoded in Simulink and transferred to Unity via UDP for commands



Motor cortex: planning and control of movements

Occipital Lobe: visual processing center

Unity Interface



- **Navigation can be title by tile of 8x8, or by quadrant**
- **Timing bar** : indicate processing window and rest delays.
- **Cursor** : indicates the current tile/quadrant of choice

Conclusion

- The user can navigate to the object's position via SSVEP controls in both quadrant by quadrant and title by tile control interfaces.
- The user can submit a grab command by motor signal but trade-off between time-window length and robustness is large.
- Electrical and sound noise, as well as physical disturbance can greatly impact on the performance of this BCI.

References

1. Nicolas-Alonso, L. F., & Gomez-Gil, J. (2012). Brain computer interfaces, a review. *sensors*, *12*(2), 1211-1279.
2. Wang, Y., Hong, B., Gao, X., & Gao, S. (2007, August). Implementation of a brain-computer interface based on three states of motor imagery. In 2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (pp. 5059-5062). IEEE.
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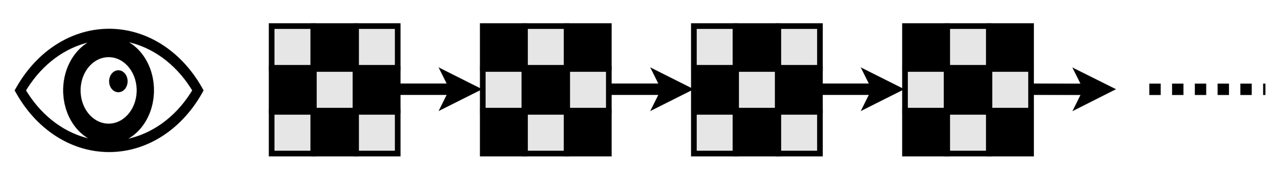
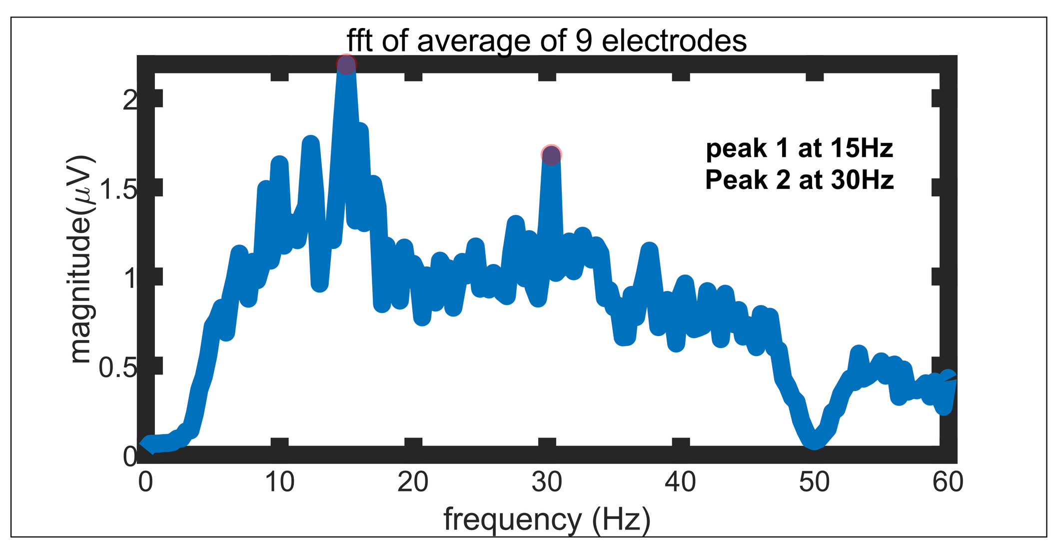
4. Chen, X., Wang, Y., Gao, S., Jung, T. P., & Gao, X. (2015). Filter bank canonical correlation analysis for implementing a high-speed SSVEP-based brain–computer interface. *Journal of neural engineering*, *12*(4), 046008.

SSVEP and correspondant CCA/FBCCA decoder



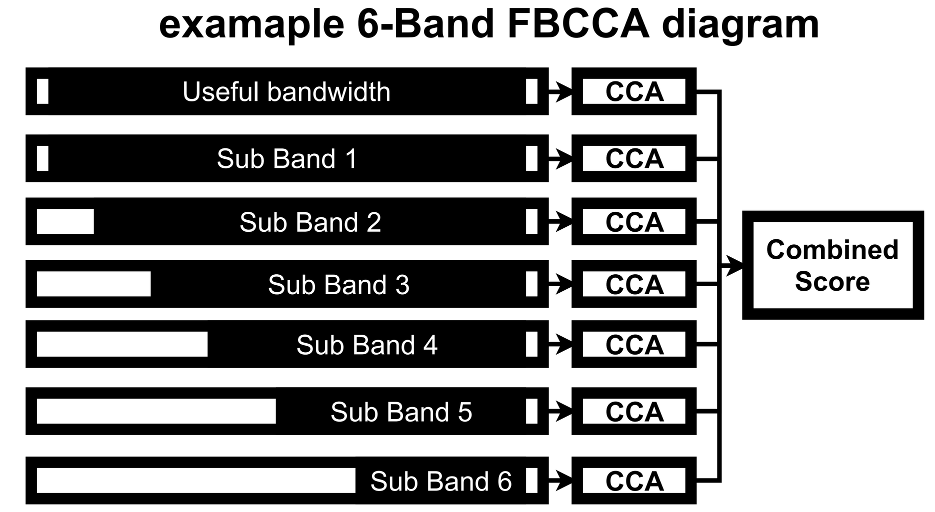
Chessgrid Stimulus in range (8,15Hz)

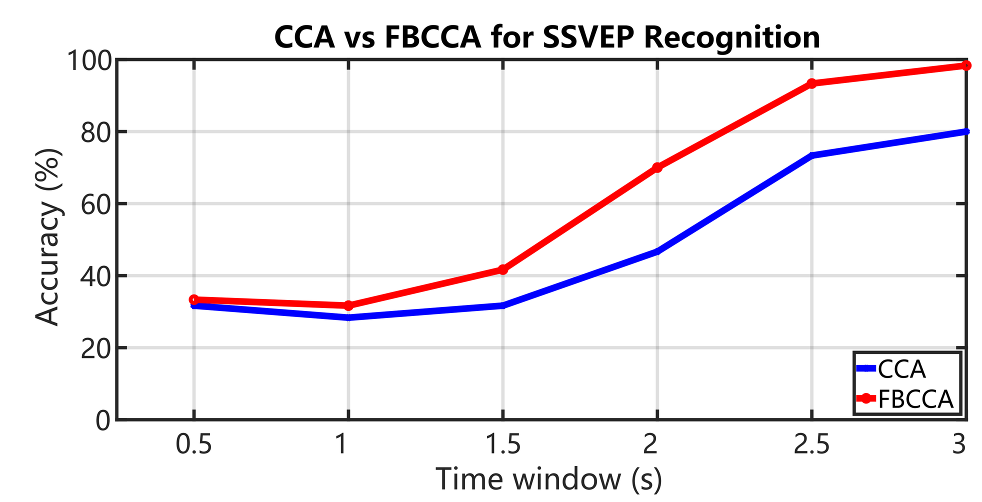


fft plot of filtered measurements during a 3s 15Hz stimulus

- Occipital Lobe can be excited by steady frequency visual stimulus,
- Induced potential has response at the stimulus frequency Fs and subsequent harmonics 2*Fs, 3*Fs, 4*Fs ....
- Stimulus sources that are more comfortable to watch can produce more consistent responses over time.

examaple 6-Band FBCCA diagram





- **Canonical correlation analysis(CCA):** computes the correlation factor between measurements and reference signals corresponding to each stimulus frequencies.
- The reference with the highest correlation factor with the measurements indicates the attended stimulus target.
- **Filter bank CCA (FBCCA) (ref 3,4)** filters the EEG measurements into several sub-bands to produce multiple CCA, where a combined score is obtained to achieve higher accuracy.

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