Generating Forbidden Region Virtual Fixtures By Classification of Movement Intention Based on Event-related Desynchronization

Isao Sakamaki [a], Mahdi Tavakoli [a], Kim Adams [a,b]

(a) University of Alberta, Canada

(b) Glenrose Rehabilitation Hospital, Canada

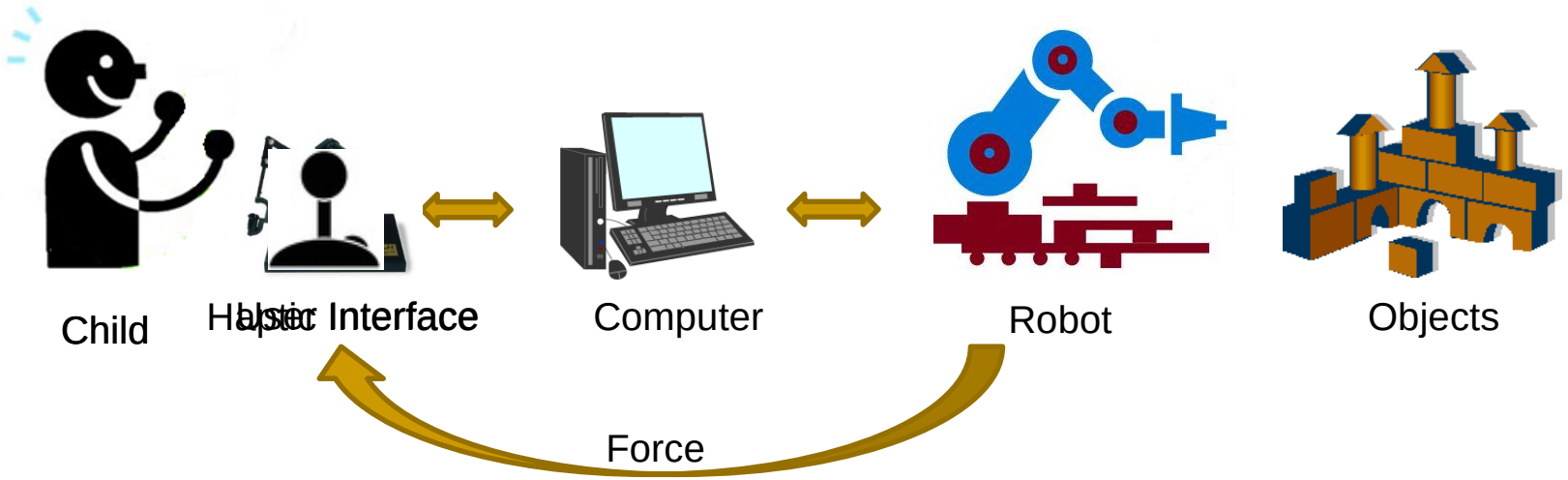
2017 IEEE Global Conference on Signal and Information Processing (GlobalSIP)
Montreal, Canada, November 14-16, 2017

Background - Children's Development through Play

- Play using objects - a means to develop:
  - Physical, language, cognitive, social skills…etc
- If a child has physical impairments then manipulating is limited - resulting in:
  - Isolation, delays and detrimental effects on development

Background – Robots and haptic interfaces

- Robots can be utilized to facilitate object manipulations by children with impairments.
- Robotic systems, including haptic interfaces, have been studied in our preliminary project.



Background – Haptic force feedback

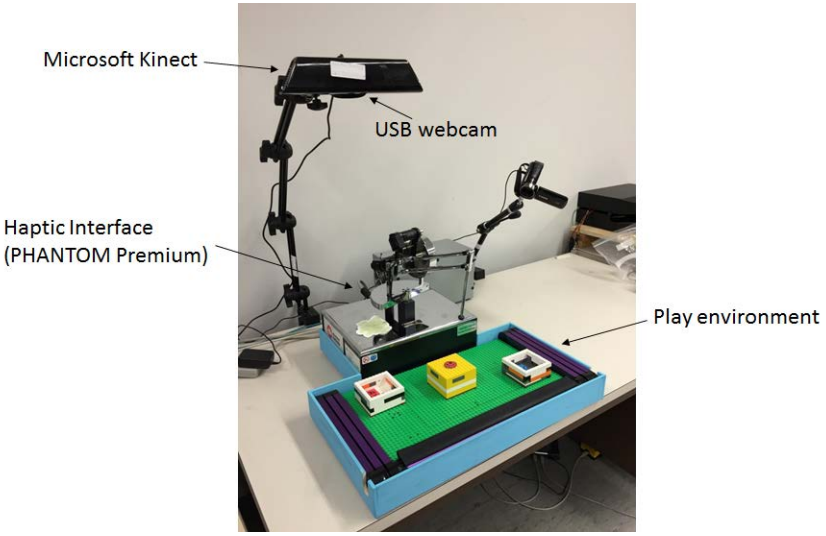
- Haptic force feedback can be used as
  - Forbidden Region Virtual Fixtures (FRVFs)
  - Kinesthetic motion assistance.
- These robotic functions can be beneficial for people with disabilities, especially those who do not have the skills to correctly operate a robot

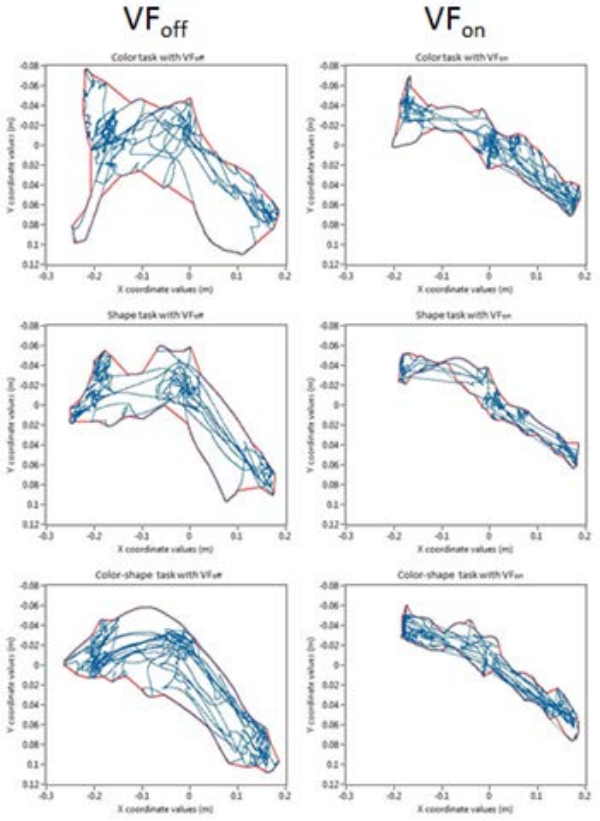
Forbidden-Region Virtual Fixtures

Kinesthetic motion assistance

Background – Previous Work

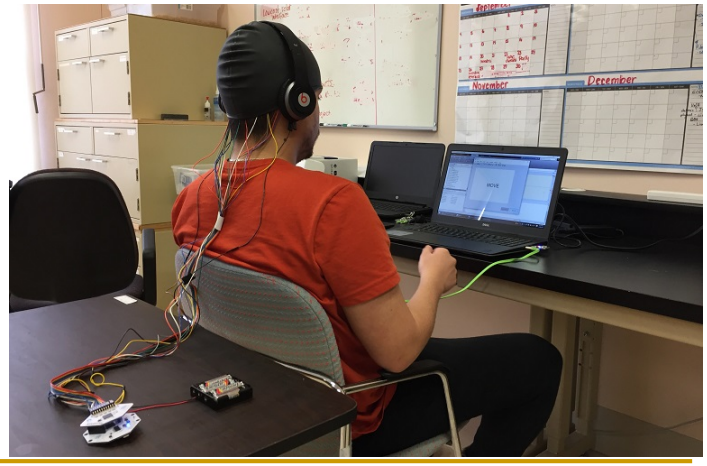
- The FRVF, defined by computer vision, were developed in our previous work





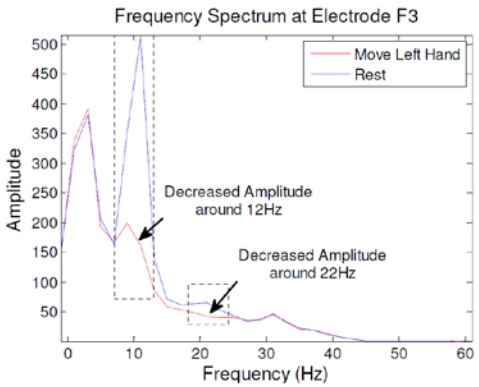
Background – Electroencephalography

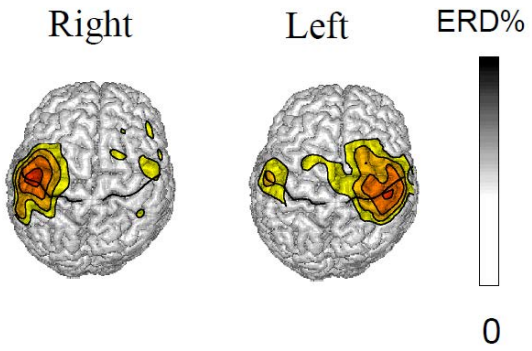
- Using the user's electroencephalography (EEG) signal as an additional input to the system
- Why EEG?
  - Non-invasive brain computer interface (BCI) method
  - No physical motion is required.
  - Consumer EEG-based BCI products are commercially available today.



Background – Electroencephalography

- Event-Related Desynchronization (ERD)
  - μ(8-12Hz) and β(18-25Hz) bands in EEG signals decrease during actual movement or preparation for movement (motor imagery)
  - Possible to find when hand movements are performed according to ERD



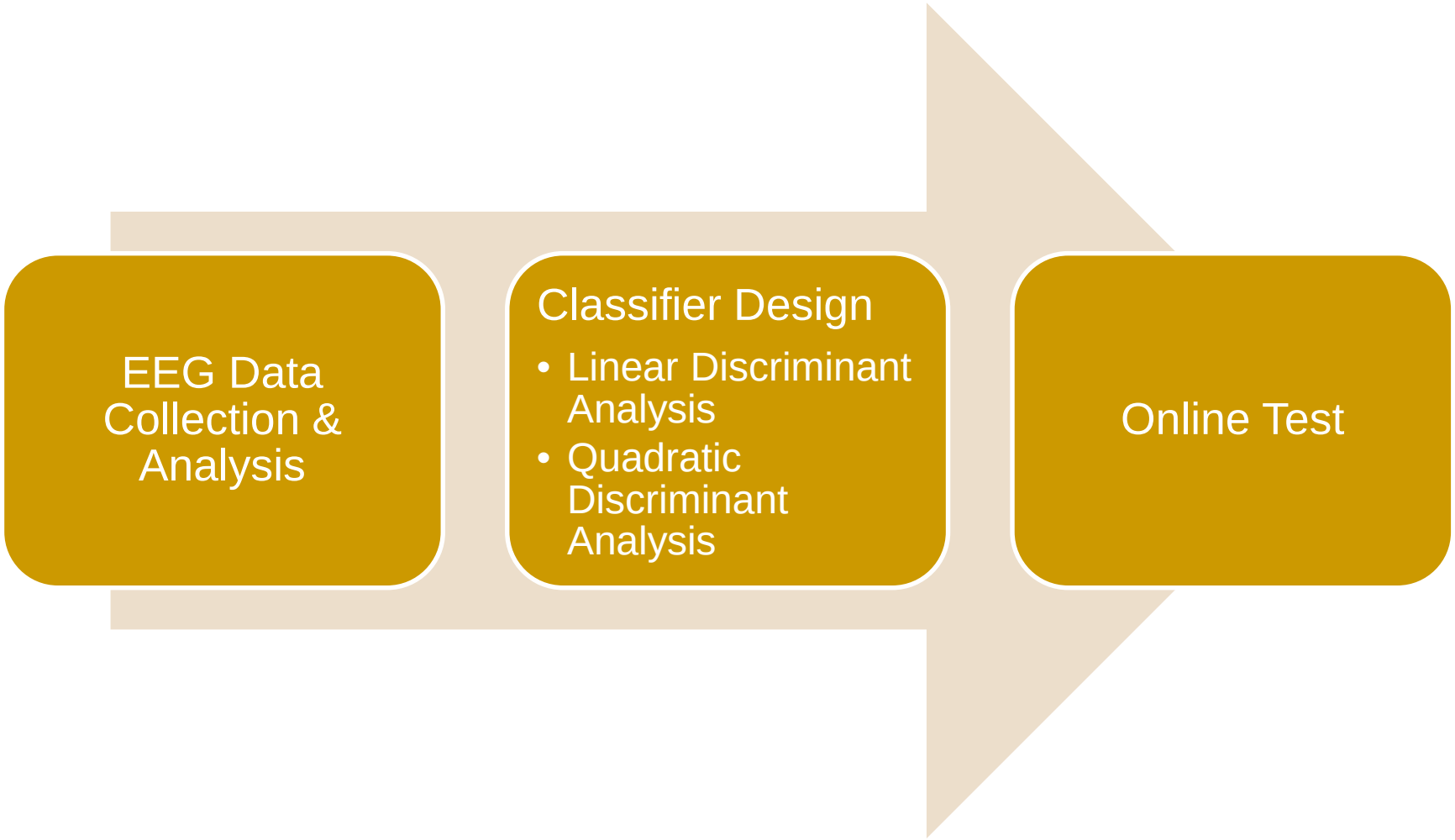


Pfurtscheller, G., Müller-Putz, G. R., Pfurtscheller, J., & Rupp, R. (2005). EEG-based asynchronous BCI controls functional electrical stimulation in a tetraplegic patient. EURASIP Journal on Applied Signal Processing, 2005, 3152-3155.

Objectives

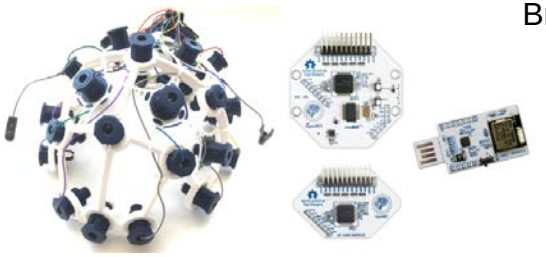
- To develop and a human-robot interface that generate a FRVF triggered by ERD brain response .
- To evaluate the feasibility of the ERD-based FRVF with simple robot operation tasks.

Procedure

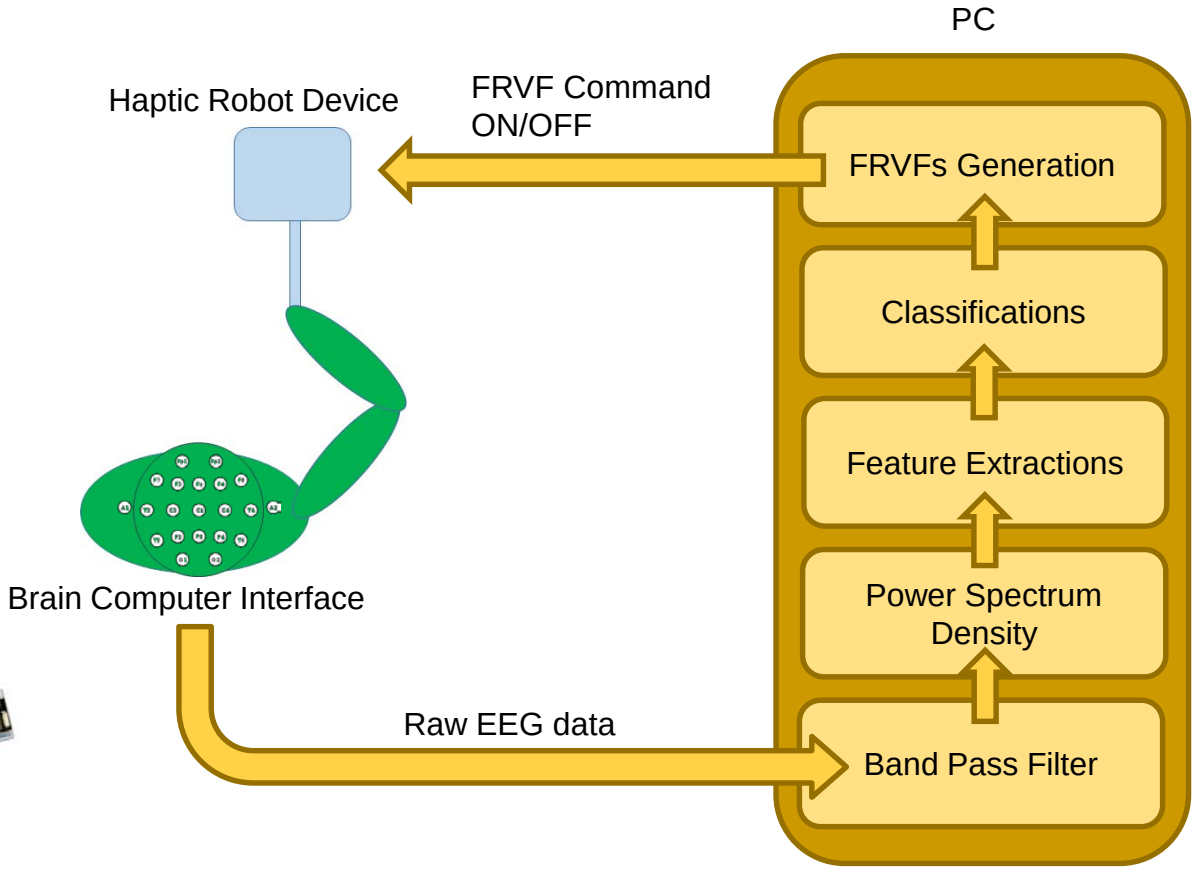

EEG Data Collection & Analysis
Classifier Design
• Linear Discriminant Analysis
• Quadratic Discriminant Analysis
Online Test

Methods

Novint Falcon



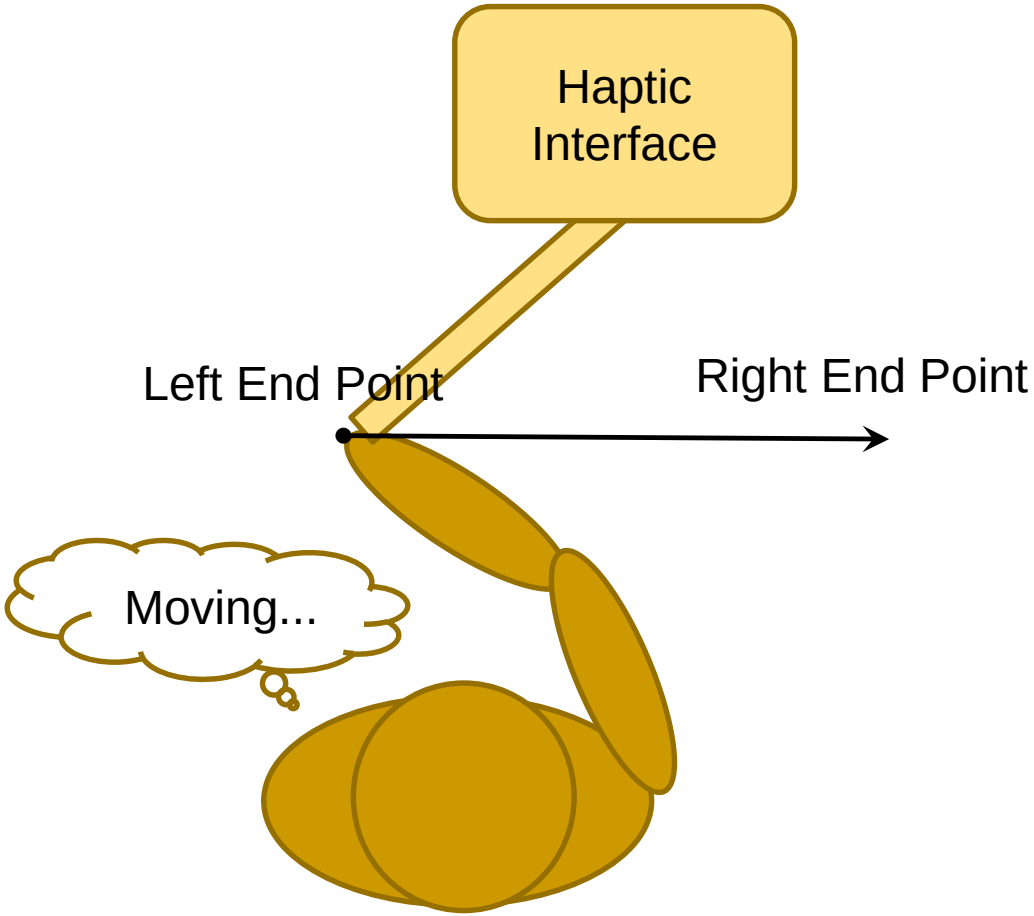
OpenBCI



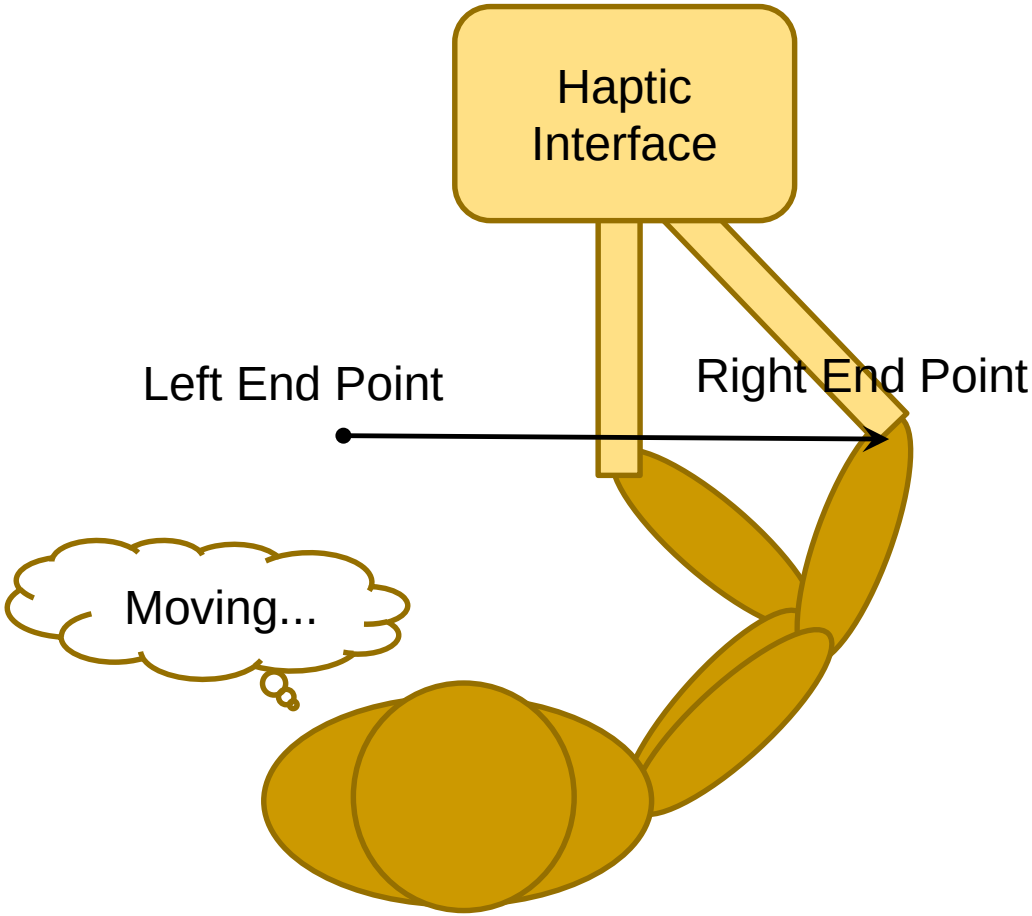
Methods

- Participants
  - Two non-disabled Adults
- Tasks
  - Moving an end-effector of the haptic Interface from the left end point to the right end point of the robot workspace
    - Forbidden Region Virtual Fixture - OFF
    - Forbidden Region Virtual Fixture - ON

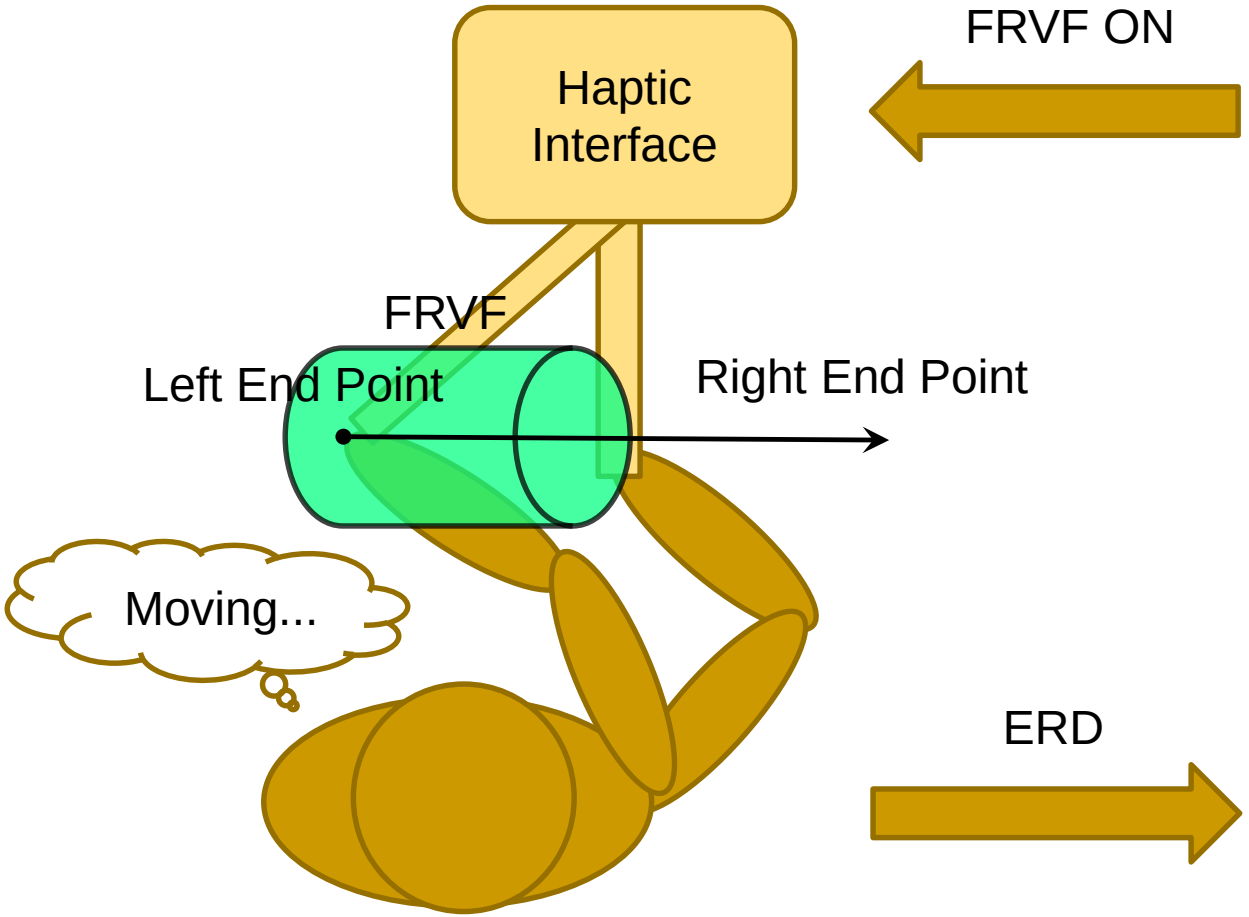
Methods



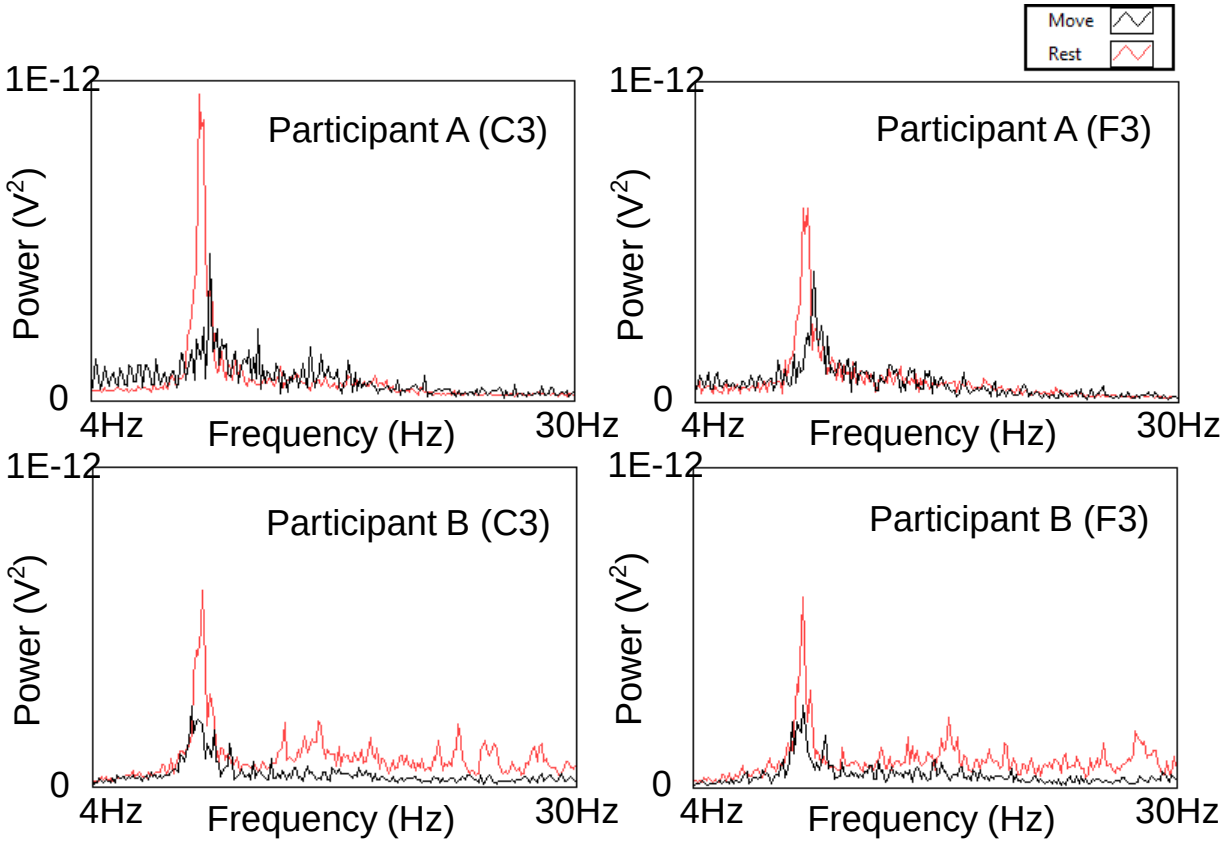
Methods



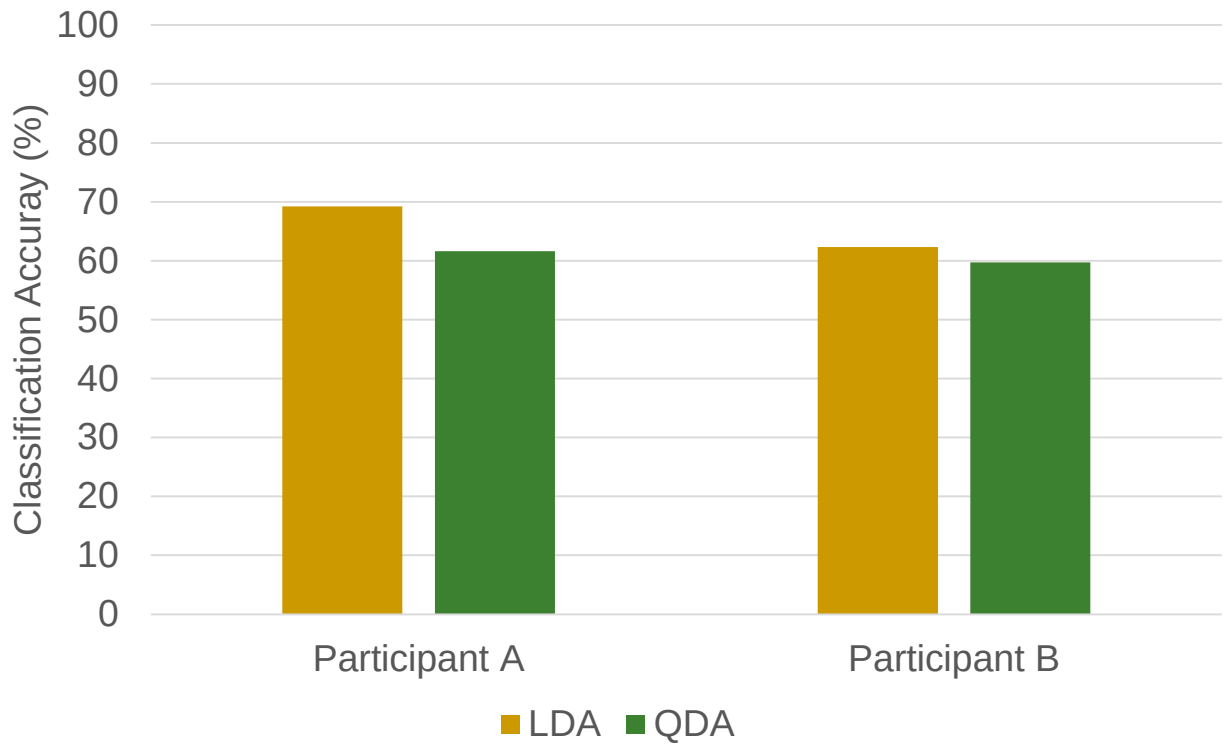
Methods


Haptic Interface
FRVF ON
FRVF
Left End Point
Right End Point
Moving...
ERD

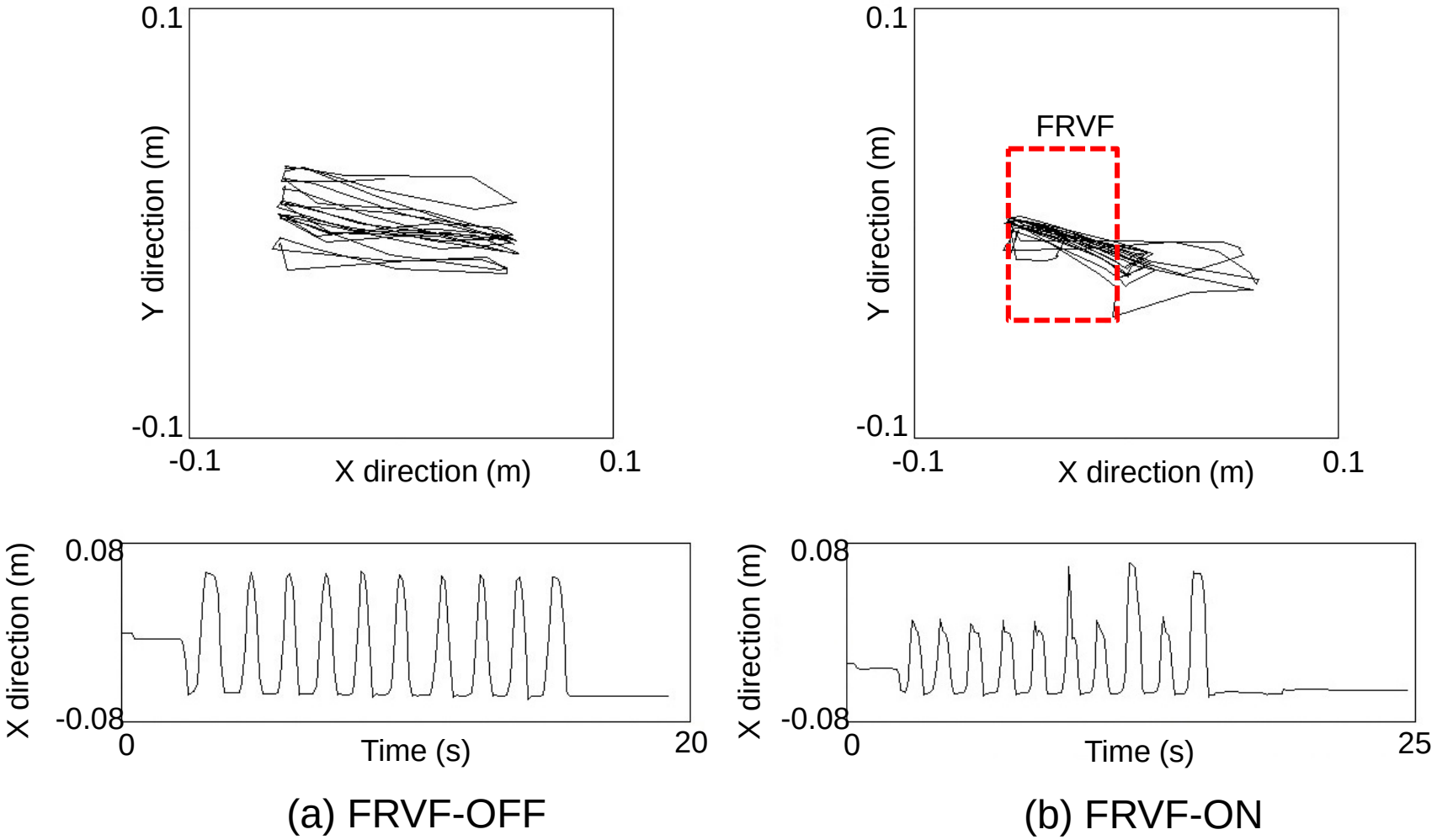
Results - Power Spectrum Density of the EEG



Results – Classification Accuracy



Results – Online Robot Operation Tasks



(a) FRVF-OFF

(b) FRVF-ON

Results – Online Robot Operation Tasks

Trials #	Number of Times the End-Effector Reached the Right End Point			
	Participant A		Participant B	
	FRVF-OFF	FRVF-ON	FRVF-OFF	FRVF-ON
1	10	4	10	3
2	10	4	10	3
3	10	3	10	5
4	10	3	10	3
5	10	1	10	4
Average	10	3	10	3.6

Conclusion

- The Forbidden Region Virtual Fixtures triggered by ERD response were successfully generated.
- However, the classification accuracy was not high and would need to be improved for practical use.
- The system needs to be validated with clinical populations including children with physical impairments.

Acknowledgments

CIHR IRSC
Canadian Institutes of Health Research
Instituts de recherche en santé du Canada
NSERC CRSNG
GLENROSE REHABILITATION • HOSPITAL FOUNDATION

Assistive Technology Labs

Faculty of Rehabilitation Medicine, University of Alberta, and
Alexandar Kostov Assistive Technology Lab, Glenrose Rehabilitation Hospital

http://www.rehabresearch.ualberta.ca/assistivetechnology/

Relevant References

- E. J. Gibson, " Exploratory Behavior in the Development of Perceiving, Acting, and the Acquiring of Knowledge," Annual Review of Psychology, vol. 39, p. 1, 1988
- A. M. Cook and J. M. Polgar, Assistive technologies :principles and practice: St. Louis, Missouri :Elsevier/Mosby, [2014], 2014.
- D. J. McFarland and J. R. Wolpaw, "Brain-Computer Interfaces for Communication and Control," Communications of the ACM, vol. 54, pp. 60-66, 2011.
- E. López-Larraz, L. Montesano, Á. Gil-Agudo, and J.Minguez, "Continuous decoding of movement intention of upper limb self-initiated analytic movements from premovement EEG correlates," Journal of NeuroEngineering & Rehabilitation, vol. 11, pp. 1-28, 2014.
- M. A. Tansey, "EEG sensorimotor rhythm biofeedback training: some effects on the neurologic precursors of learning disabilities," International Journal Of Psychophysiology: Official Journal Of The International Organization Of Psychophysiology, vol. 1, pp. 163-177, 1984.
- Z. Vamvakousis and R. Ramirez, "Towards a Low Cost Mu-Rhythm Based BCI," presented at the Fifth International Brain-Computer Interface Meeting 2013,California, 2013.
- T. Solis-Escalante, G. Müller-Putz, C. Brunner, V. Kaiser, and G. Pfurtscheller, "Analysis of sensorimotor rhythms for the implementation of a brain switch for healthy subjects," Biomedical Signal Processing and Control, vol. 5, pp. 15-20, 2010.

Thank you

Contact Information:

Isao Sakamaki- isao@ualberta.ca
Kim Adams- kdadams@ualberta.ca