In the name of God



[School of Advanced Technologies in Medicine](http://amt.mui.ac.ir/en)

Brain Computer Interfaces (BCIs)

Autumn 2018

**Course Overview**

**Instructor:** Zahra Amini

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**Lectures**: 10-12, Saturday and 14-16, Sunday

**TA:**

**Email:**

Office hours will be announced in class.

**Website:** <https://app.schoology.com/>

**Access code:**

This password protected web site will serve as the mechanism for information exchange in this course. That is, all course notes, projects, problem sets, solutions, and any other handouts will be made available through this web site. Class announcements will also be made through the web site. Thus, the course web page should be frequently visited throughout the semester.

**Course Description:**

Recent advances in neural interfacing and neural imaging technology and the application of various signal processing methodologies have enabled us to better understand and then utilize brain activity for interacting with computers and other devices. In this course, we will explore these technologies and approaches for acquiring and then translating brain activity into useful information. We will also discuss the components of a brain-computer interface system, including invasive and non-invasive neural interfaces, the clinical and practical applications for a variety of users, and the ethical considerations of interfacing with the brain. Students will investigate the benefits and limitations of commonly used signal processing and machine learning methods (which include independent component analysis, Bayesian inference, dimensionality reduction, and information theoretic approaches), and then apply these methods on real neural data. We aim to equip students with the foundational knowledge and skills to pursue opportunities in the emerging field of brain-computer.

**Course Goal**

To equip students with the advanced knowhow in BCI to enable them to further pursue this emerging topic as a career option. The topics covered will include various methodologies and technologies used to collect information from the brain and learn about their applications.

**Course Objectives**

* Identify and analyze various brain signals for BCIs
* Identify and analyze various types of BCIs
* Use and compare many different signal processing methods to design and analyze BCIs

**Prerequisites**

Basic knowledge of linear algebra, probability and statistics.

MATLAB knowledge is strongly recommended.

**Syllabus and Course Sessions:**

* Introduction (Session 1)
* Basic Neuroscience (Session 2)
  + Neurons
  + Rest and Action potentials
  + Brain Organization, Anatomy, and Function
* Recording/Stimulating the Brain (Session 3)
  + Recording Signals from the Brain
    - Invasive Techniques
    - Non invasive Techniques
  + Stimulating the Brain
    - Invasive Techniques
    - Noninvasive Techniques
* Signal Processing
  + Spike Sorting (Session 4)
  + Frequency Domain Analysis (Session 4)
  + Wavelet Analysis (Session 5-8)
  + Time Domain Analysis
    - Hjorth Parameters, Fractal Dimension, AR modeling (Session 9)
    - Bayesian Filtering (Session 10)
    - Kalman Filtering (Session 11-13)
    - Particle Filtering (Session 14)
  + Spatial Filtering
    - General Filters, PCA, ICA (Session 15-16)
    - Common Spatial Patterns (CSP) (Session 17-18)
  + Artifact Reduction Techniques (Session 19)
* Machine Learning
  + Classification Techniques
    - LDA, SVM, Neural Networks (Session 20)
    - Ensemble Classification techniques, Multi class Classification (Session 21)
    - Evaluation of Classification Performance (Session 22)
  + Regression
    - Linear Regression, Artificial NN, RBF networks (Session 23)
    - Gaussian Process (Session 24)
* Major Types of BCIs
  + Invasive BCIs (Session 25-26)
  + Semi-Invasive BCIs (Session 27-28)
  + Noninvasive BCIs (Session 29-30)
* Applications of BCIs
  + Medical Applications (Session 31-32)
  + Nonmedical Applications (Session 33)
* Ethics of BCI (Session 34)

**Assignments:** There will be several homework and assignments. These will be available on the course website.

**Final Project:** Each student must implement a recently published paper in BCI field (recent journal paper or well-known conference paper). The mentioned paper should be confirmed before 97/9/15. Students will be expected to make a report and a presentation of their work and the grades will be based on implementation, clarity of the report, justification of the results, depth of analysis and discussion. The projects should be presented one month after the final exam.

**Final Exam:** Wednesday 96/11/3

**Final Grade:**

* Homework assignments: 30%
* Final Project: 30%
* Final Exam: 50%

**Useful Textbooks: (available in the library or can be downloaded from** [**http://gen.lib.rus.ec**](http://gen.lib.rus.ec)**)**

* Brain-computer interfacing: an introduction, Rao RPN, New York: Cambridge University Press, 2013.
* Brain-Computer Interfaces: Principles and Practice, Jonathan Wolpaw, Elizabeth Winter Wolpaw, Oxford University Press, USA, 2012.
* Brain-Computer Interfaces 1: Methods and Perspectives, [Maureen Clerc](http://eu.wiley.com/WileyCDA/Section/id-302479.html?query=Maureen+Clerc), [Laurent Bougrain](http://eu.wiley.com/WileyCDA/Section/id-302479.html?query=Laurent+Bougrain), [Fabien Lotte](http://eu.wiley.com/WileyCDA/Section/id-302479.html?query=Fabien+Lotte), Wiley-ISTE, July 2016.
* Brain-Computer Interfaces 2: Technology and Applications, [Maureen Clerc](http://eu.wiley.com/WileyCDA/Section/id-302479.html?query=Maureen+Clerc), [Laurent Bougrain](http://eu.wiley.com/WileyCDA/Section/id-302479.html?query=Laurent+Bougrain), [Fabien Lotte](http://eu.wiley.com/WileyCDA/Section/id-302479.html?query=Fabien+Lotte), Wiley-ISTE, July 2016.
* Towards Brain-Computing Interfacing. Cambridge, Dornhege, G. Millán, J.d.R., Hinterberger, T., McFarland, D.J., and Müller, MA: MIT Press, 2007.
* EEG SIGNAL PROCESSING, Saeid Sanei and J.A. Chambers, Centre of Digital Signal Processing, Cardiff University, UK, John Wiley & Sons Ltd, 2007.
* Guger, C., Allison, B. & Edlinger G. (Eds.) (2013). Brain-Computer Interface Research: A State-of-the-Art Summary 4. New York, NY: Springer.
* Guger, C., Allison, B. & Edlinger G. (Eds.) (2017). Brain-Computer Interface Research: A State-of-the-Art Summary 5. New York, NY: Springer.

### Tools:

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| EEGlab toolbox | <https://www.mathworks.com/matlabcentral/fileexchange/56415-eeglab>  https://sccn.ucsd.edu/eeglab/index.php |
| BCILAB | https://sccn.ucsd.edu/wiki/BCILAB |
| OpenViBE | <http://openvibe.inria.fr/> |