1. Lecture 1.1 – What is a Brain Computer Interface?
   1. The traditional definition of BCI
      1. The goal of BCI was to give significantly paralyzed people another way to communicate, a way that does not depend on muscle control.
   2. New definition
      1. A system which takes a biosignal measured from a person and predicts (in real time / on a single-trial basis) some abstract aspect of the person’s cognitive state.
   3. Three different BCI Subtypes
      1. Active BCI
         1. The driving force behind the BCI is generated from the user, independently form external events, for controlling an application
      2. Reactive BCI
         1. Driving force is from an external stimulation
      3. Passive BCI
         1. Just sort of monitors the brain
   4. Brain Signals
      1. EEG
         1. All you need is a couple electros with EEG
      2. fNIRS
         1. Functional Near-Infrared Spectroscopy
         2. Shines light and deduces what happened
      3. MEG and fMRI
         1. Big and millions of dollars
   5. Non-Brain Signals (used for cleaning up EEG)
      1. SensoMotoric Instruments
      2. Motion Capture and Eye Tracking, super helpful for cleaning up EEG
      3. EMG, ECG, and EOG
      4. Variables in your program
         1. Stimulus presented?
         2. Current vehicle speed
      5. Environmental signals
         1. Line noise
   6. Aspects of Cognitive State
      1. Any aspect of the physical brain state that cn be measured with sufficient single-trial reliability
      2. Tonic State
         1. Degree of “relaxation”, cognitive load, …
      3. Phasic State
         1. Switching attention, type of imagining movement
2. 1.2 Application Areas and Examples
   1. Communication and Control for the Severely Disabled
      1. Severe Disabilities
   2. Now entering an era where BCI is being used for healthy people
   3. Forensics
      1. Lie detection, Brain Fingerprinting, Trust assessment
   4. Entertainment
   5. Health
   6. Neuroscience
      1. Using BCI for the development of neuroscience
3. 1.3 Scientific Challenge
   1. Theory is shared with many other fields
   2. Problems are similar to Computer Vision, Speech Recognition, Pattern Recognition, Timer-Series analysis, Control Systems & Robotics
   3. Why is BCI hard
      1. Processing depends on unknown parameters (person-specific, task-specific, otherwise variable), per-sensor weights
      2. Must adapt to the person to do a good job
      3. Reasons for variability
         1. Folding of cortex differs between any two person
         2. Relevant functions map differs across individuals
         3. Sensor locations differ across recording sessions
         4. Brain dynamics are non-stationary at all time scales
      4. Signal-to-noise ratio is very challenging, so *sensitive* measures are hard obtain
         1. Relevant brain activity is small compared to interfering artifacts and compared to brain background activity
      5. Specific measures are even harder to obtain (with coarse-grained sensing)
         1. Large collections of neurons are involved in many different activities, not just one
      6. Underlying phenomena are also highly diverse and rich and derived measures are still poorly understood – not always clear what to look for.
      7. EEG signals are mathematically complicated to handle since all sensors record almost the same signal (superposition of all brain activity)
   4. Consequences
      1. Sophisticated signal processing is required
      2. All approaches are fundamentally statistical
      3. BCI systems must be calibrates before they can be used
      4. Calibration should entail as much information as available, e.g., example data, prior data
4. 1.4 Available Tools
   1. BioSig
      1. MATLAB toolbox
      2. Open source
      3. Offline processing
      4. Cross platform
   2. BCI2000
      1. Online processing
      2. Data processing
      3. Signal processing
      4. Helps you just get up and running
      5. Written in C++
      6. Lack of advance signal processing and machine learning algorithms
   3. OpenViBE
      1. Also C++, cross platform
      2. Very user-friendly design
      3. For non-programmers
   4. g.BSanalyze
      1. Commercial system developed by g.Tex
   5. BCILAB
      1. Started in 2010
      2. Purpose is to squeeze out the maximum amount of efficiency
      3. MATLAB
      4. Offline, online analysis
      5. Must be very good to mess with the code