BCIs: Improving Spatial Resolution and Spatial Filtering Algorithms

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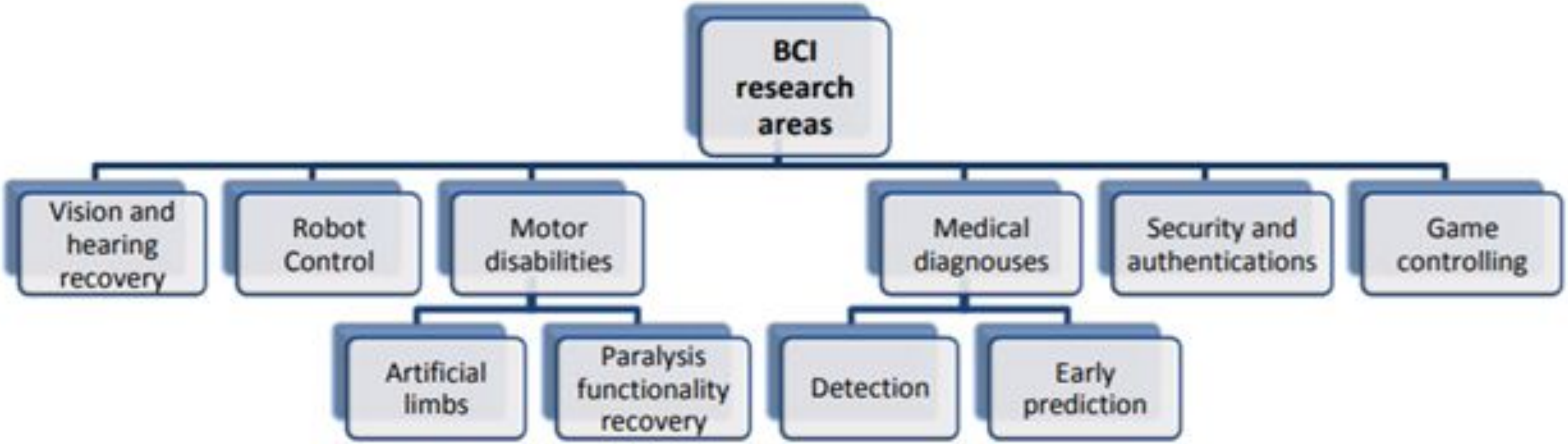
Overview on BCIs

- ★ Interpret brain signals into intention which is translated in the real world
- ★ Began mostly in the biomedical space
  - Helping disabled people with mobility or communication
  - Still a lot of research being done in this space
- ★ Early BCI project: two dimensional cursor movement to targets
- ★ Passive BCI
  - Using information gained involving mood, attentiveness, and sleep state
  - Tracking motion sickness to prevent car accidents

Overview on BCIs



How do BCIs work generally?

- ★ Signal Acquisition
- ★ Signal Preprocessing
  - Noise
  - Artifacts
- ★ Feature Extraction
  - Finds parts of the signal that are of interest
    - Response to stimuli
    - Change in user state
    - Decreases size of data needing to be classified
- ★ Classification
  - Actionable device commands

Signal Acquisition

- ★ Invasive
  - Biocompatibility of materials
  - Rejection
  - Degradation of quality of data
  - Irreplaceable
  - Not worth the risk to able-bodied people
- ★ Non-invasive
  - Electroencephalogram or EEG
  - Low health risk with regards to the instrument itself
  - Portable and relatively easy to place
  - Good for large consumer market

EEG

- ★ Utilize electrodes on different parts of the scalp to look at voltage fluctuation
- ★ Can place electrodes on area of interest
  - Different parts of the brain are more active with different activities
- ★ Artifacts
  - Muscle movement
  - Variation and incorrect placement of the electrodes
  - Eye movement
  - Pulse, heart beating
  - Tongue movement

EEG

Downsides

★ Training time
★ Brain is non-linear
★ High dimensionality to preserve as much spatial data as possible
★ Feature extraction reduces dimensionality
    ○ Removing artifacts of signal acquisition is important so feature extraction can work well
    ○ Saves the “features” of the signal that are of interest, reduces others

Temporal and Spatial Resolution

- ★ Small signal to noise ratio
- ★ Low spatial resolution
  - ○ Skull has low conductivity
  - ○ Can only record signal when a dime sized section fires
  - ○ Signals from nearby regions are picked up by the electrodes
- ★ High temporal resolution
  - ○ Can track the signal thousands of times per second
- ★ Theoretical temporal resolution isn’t reached because spatial resolution isn’t the greatest
  - ○ They are interdependent
  - ○ Burle et al. uses the surface laplacian (spatial filtering algorithm) to prove

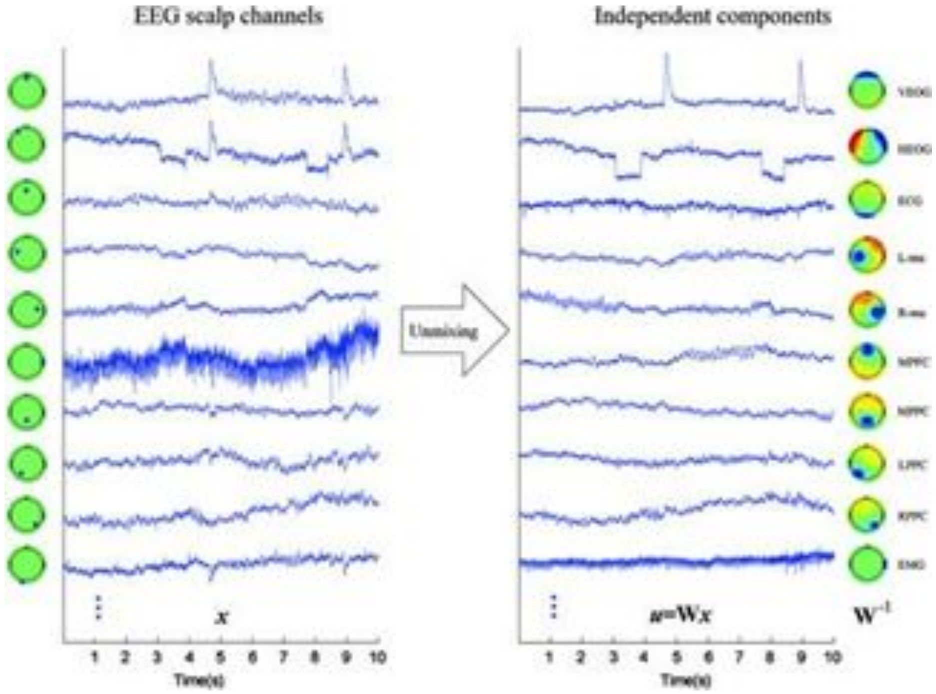
Improving Spatial Resolution

- ★ Up to 256 electrodes
- ★ 10-20 orientation
- ★ Spatial filters

Independent Component Analysis (ICA)

- ★ Finds the parts of the signal that are the most different from each other
- ★ Separating the signal into different sources
  - Different parts of the brain
  - Artifacts
  - Feature extraction
  - Weights different electrodes differently
- ★ Use in combination with other algorithms

ICA



EEG scalp channels
Independent components
Unmixing
x
u=Wx
W-1
1 2 3 4 5 6 7 8 9 10
Time(s)
1 2 3 4 5 6 7 8 9 10
Time(s)

Common Spatial Pattern (CSP)

- ★ Seen most in motor imagery research
  - Variability between subjects
- ★ Epoched EEG data
- ★ Band-pass filter
- ★ Seperates into subcomponents by most variability
  - ICA separates by most independent projections

Basic Spatial Filters

- Laplacian filter
- Common Average Reference
  - Subtracts average potential from all electrodes
  - Doesn’t weight electrodes differently
  - Gets rid of DC bias
    - How much wave is offset
- Allonso et al. classification accuracy
  - Laplacian: 81.5%
  - Common Average Reference: 79%

Next Steps

- ★ Better documentation of spatial filter algorithms and consolidate information on each one
- ★ Algorithms are constantly being improved
  - ○ Nothing is commercially available that super works
- ★ Use algorithms in combination with each other