Modeling Brain-Body Dynamics using EMG Source Imaging

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Abstract

We apply independent component analysis as well as source imaging to surface electromyographic (EMG) data collected from a whole arm electrode array.

Three theoretical benefits over classical bipolar recordings:

- ***Source signals are separated to a greater degree***
  - i.e. less cross-talk
- ***Signals are cleaner due to source separating effects of the spatial filter***
- ***No expert knowledge required for electrode placement***

These could potentially combine to increase recording quality for deep muscles especially without invasive needle electrodes.

I. Introduction

Electroencephalographic (EEG) research employs many sophisticated processing and analysis techniques such as:

- ***Independent component analysis (ICA)***
- ***High-resolution source imaging***
- ***Connectivity analysis***

EEG source imaging also has the following benefits:

- ***Non-invasive***
- ***No expert knowledge for electrode placement***

EMG research typically uses a small set of methods. Ordinarily, surface EMG recording uses a bipolar electrode pair placed above each muscle of interest, requiring domain knowledge for adequate placement. The resulting signal suffers, particularly when placement is suboptimal.

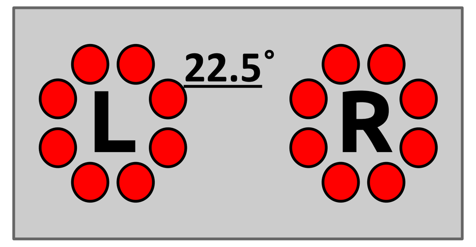
In an attempt to increase the quality of non-invasive, combined EEG/EMG analysis, we do the following:

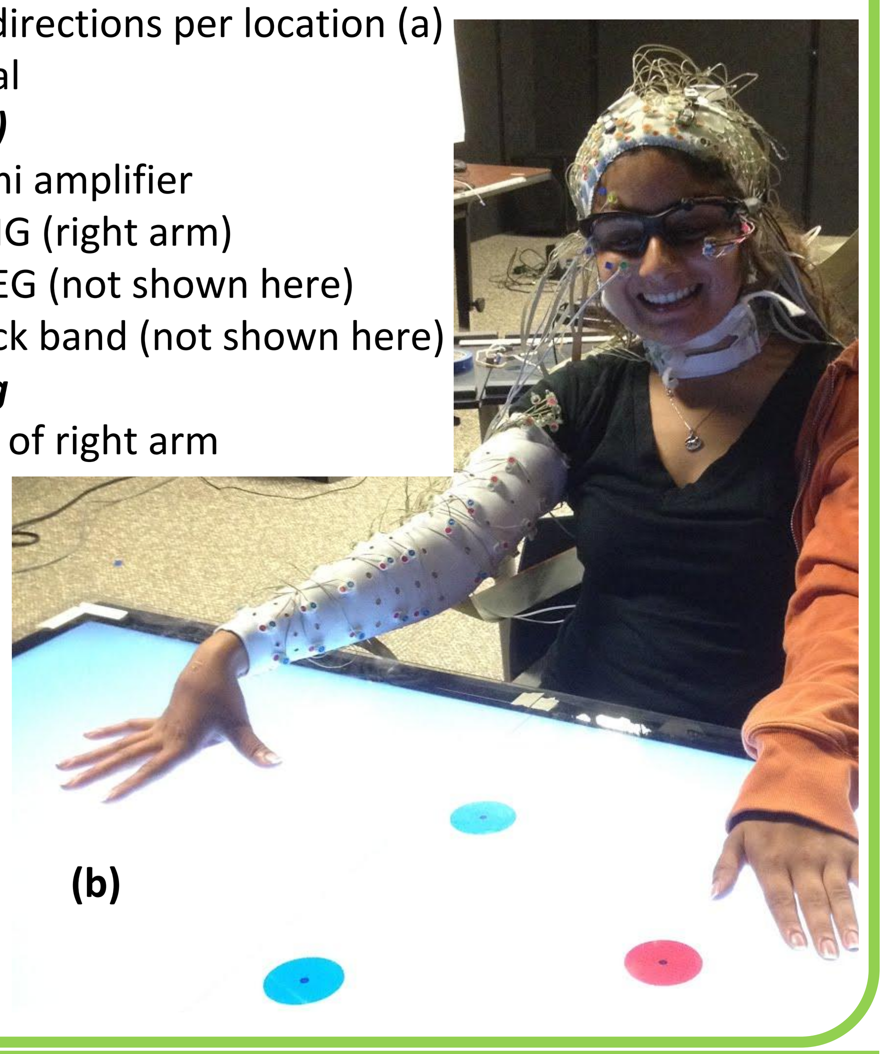
- ***Collect EMG using a whole-arm electrode array***
- ***Apply ICA decomposition***
- ***Localize independent component (IC) EMG sources to determine source origins***

II. Materials

- **Pilot experiment**
  - ***Subject Task***
    - Center-out reaching task
    - 2 locations, 8 directions per location (a)
    - 1200 trials total
  - ***Data recording (b)***
    - 512 Hz, Biosemi amplifier
    - 54 channel EMG (right arm)
    - 128 channel EEG (not shown here)
    - 32 channel neck band (not shown here)
  - ***Anatomic imaging***
    - Structural MRI of right arm

(a)

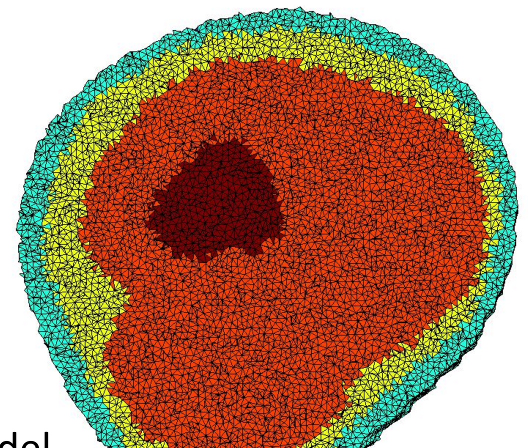




(b)

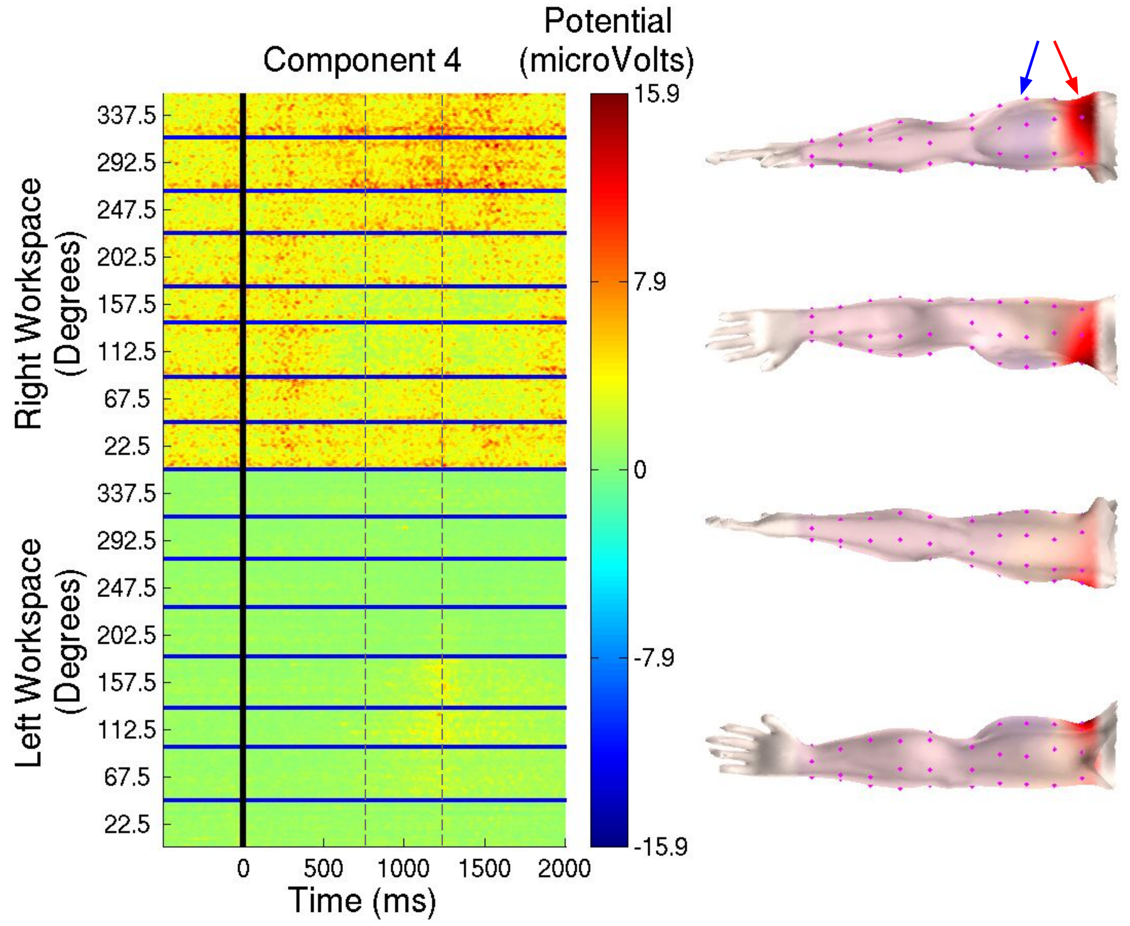
III. Methods

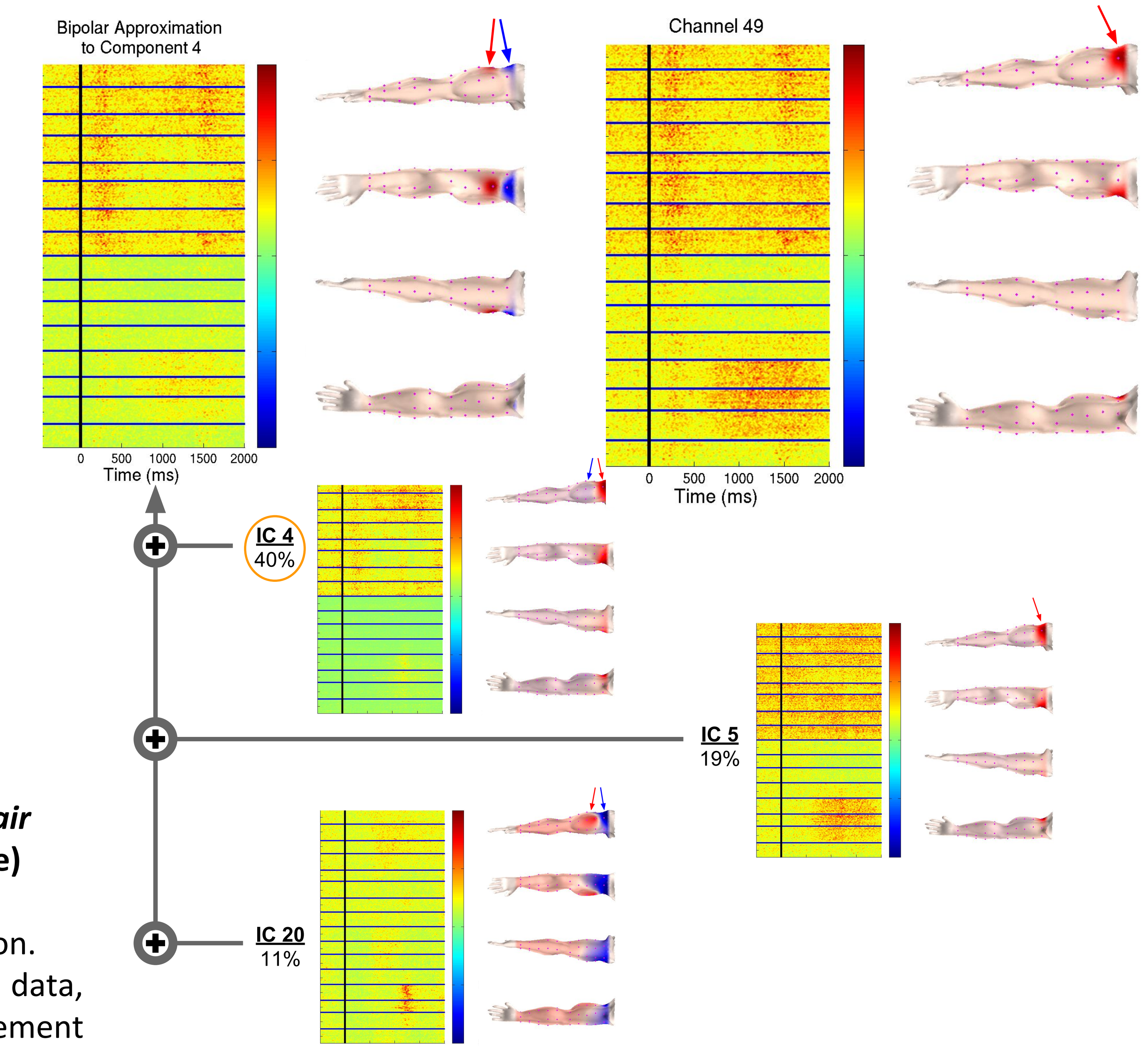
- **Preprocessing**
  - Bandpass filter 20 Hz to 58 Hz
  - Common average reference
- **Source Separation**
  - Adaptive Mixture ICA (AMICA)
- **Source Imaging**
  - Hand segment MRI
  - Generate electrical forward model
    - Finite element method (FEM) model
    - Four tissue types (skin, fat, muscle, bone)
  - Estimate equivalent current dipole (ECD) locations in arm



IV. Results

1. Independent Component Analysis





- **Left: IC 4**
- **Middle: Bipolar pair with signal closest to IC 4**
  - ***Below: 3 largest contributing ICs to the closest bipolar pair***
- **Right: Closest single channel to IC 4 (after average reference)**

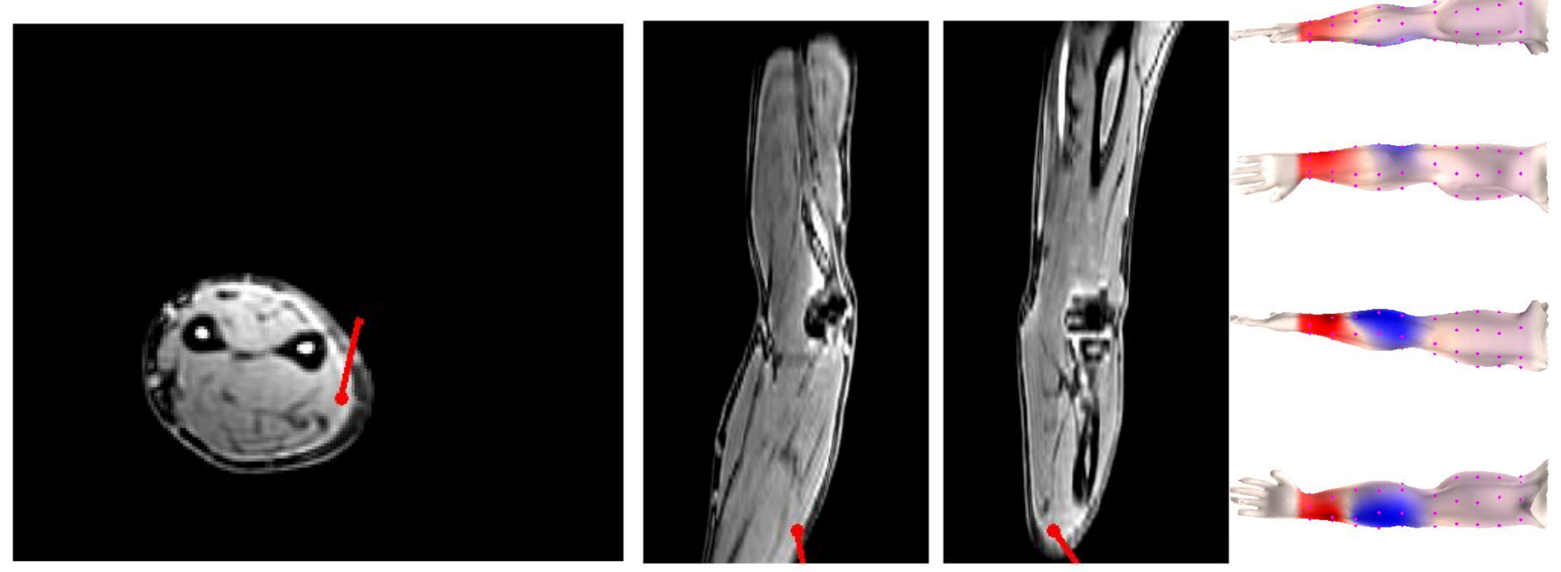
Note activity features of ICs 4, 5, 20 into the bipolar pair derivation. Plots to the left of the arm models show the rectified EMG trial data, time locked to trial start (black line) and sorted by movement direction. Gesture departure and arrival cues marked by dashed lines.

2. Source Imaging

- **Left: IC 22**
- **Right: IC 26**

The left three plots in each figure show the estimated ECD source position and moment for that IC overlaid on the appropriate MRI slices. The arm models to the right of MRI slices show the IC topography for comparison. These model dipoles are not incompatible with a model of net surface EMG signals as arising at the muscle termination into the tendon.

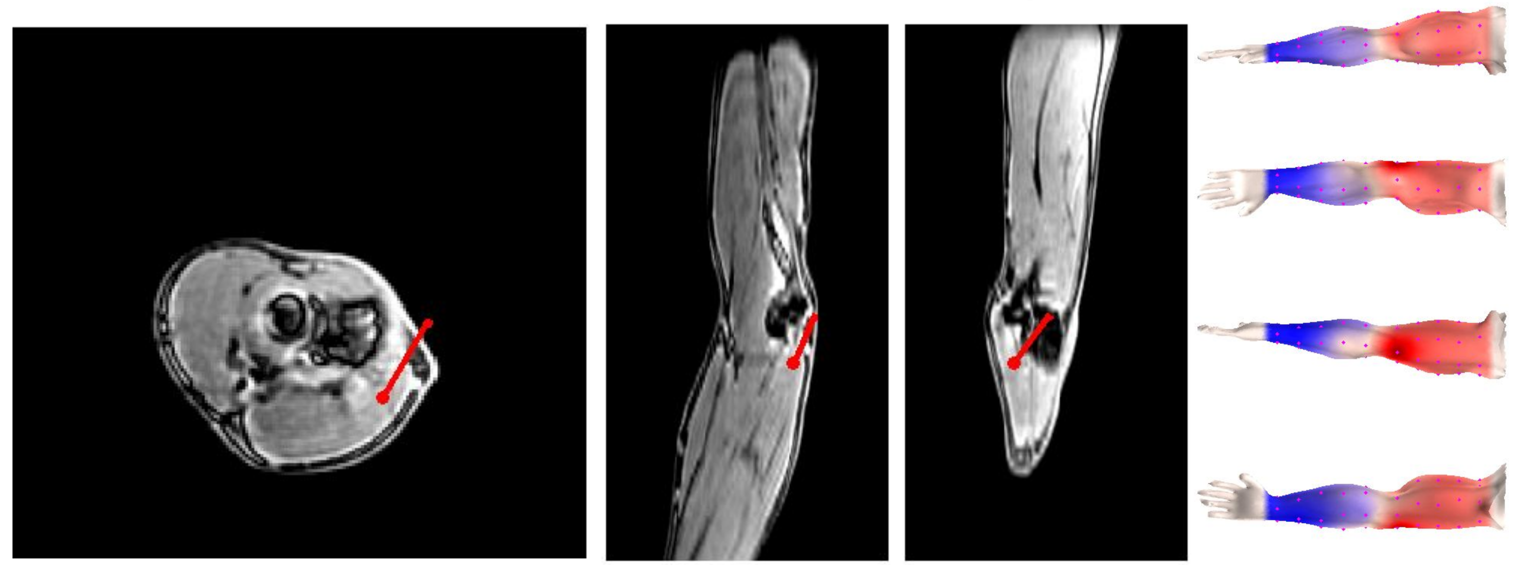
IC 22



Possibly:

- Flexor carpi ulnaris
- Palmaris longus

IC 26



Possibly:

- Flexor carpi radialis
- Pronator radii teres

V. Future Plans

- **Improved data acquisition**
  - ***Collect at 2000 Hz***
- **Refine Localization**
  - ***Use higher-resolution MRI***
  - ***Detailed segmentation to separate:***
    - Individual muscles
    - Tendons
  - ***Implement electrical anisotropy of muscles***
- **Experimental validation**
  - ***Compare two tasks***
    - Thumb flexion vs. wrist flexion
      - Deep muscle activation
      - Superficial muscle activation
  - ***Record array sEMG and concurrent intramuscular iEMG from needle electrodes***
  - ***Compare sEMG Independent Components to iEMG single muscle signals***

VI. Acknowledgments

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