THE AMERICAN UNIVERSITY IN CAIRO

Fall 2024

# CSCE 363/3611 - Digital Signal Processing

# *Electromyography (EMG) Analysis*

Seif Eldawlatly

# Human-Computer Interaction Technology Evolution

- Human-Computer Interaction (HCI) technology has evolved over the years since the invention of computers

***Now***

***Touchscreens***

***Speech Recognition***

***The Future***

***Augmented Reality***

?

# Electromyogram (EMG)

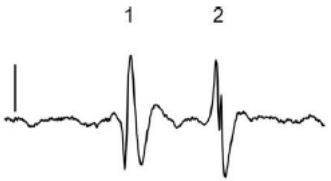
- Movement and position of limbs are controlled by electrical signals traveling back and forth between the muscles and the peripheral and central nervous system

- Electromyogram (EMG) is a record of electrical muscle activity

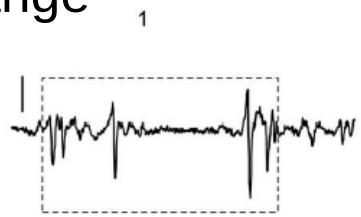
**Needle Electrode**

**Surface Electrode**

- When a disease arises in the motor system, the characteristics of the electrical signals in the muscle change




**Normal EMG**




**Diseased EMG**

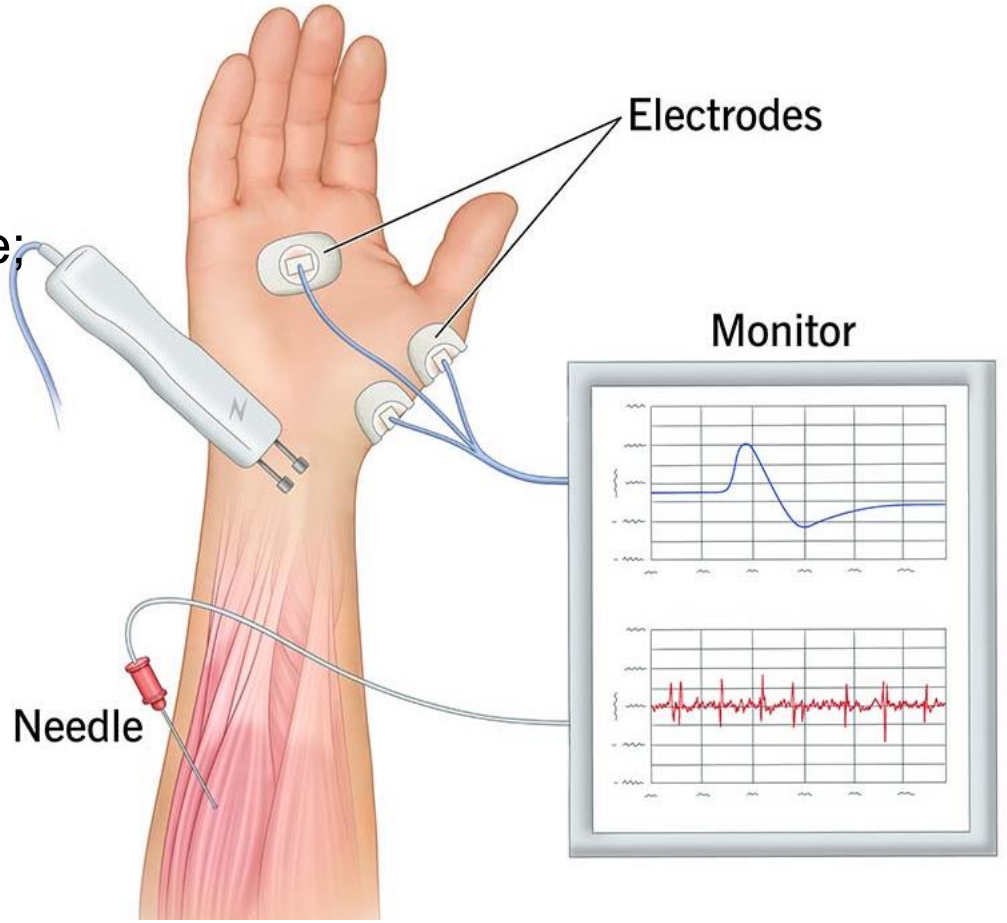
# Meta Wristband

- Meta currently has an EMG wristband to be used to control augmented reality systems

https://www.youtube.com/watch?v=Kx_nVrEKwTE

# EMG Types

- Intramuscular EMG: Uses needle electrodes inserted into muscle tissues.
- Surface EMG (sEMG): Uses electrodes on the skin's surface; non-invasive and more comfortable.

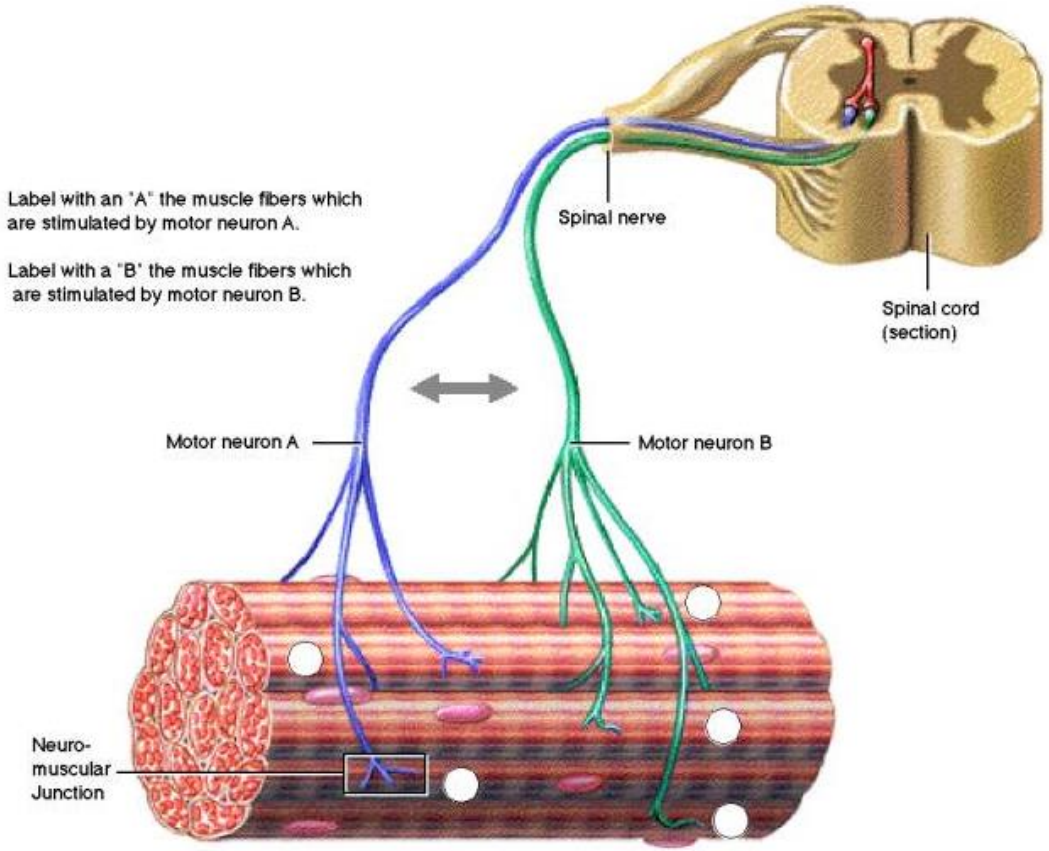



https://my.clevelandclinic.org/-/scassets/images/org/health/articles/4825-electromyography

# Motor Unit

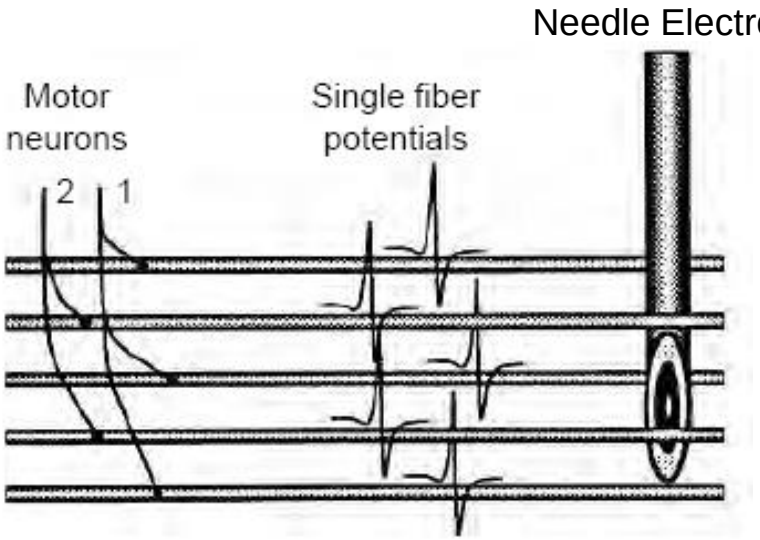
- A **motor unit** (MU) is made up of a motor neuron and the muscle fibers controlled by that neuron

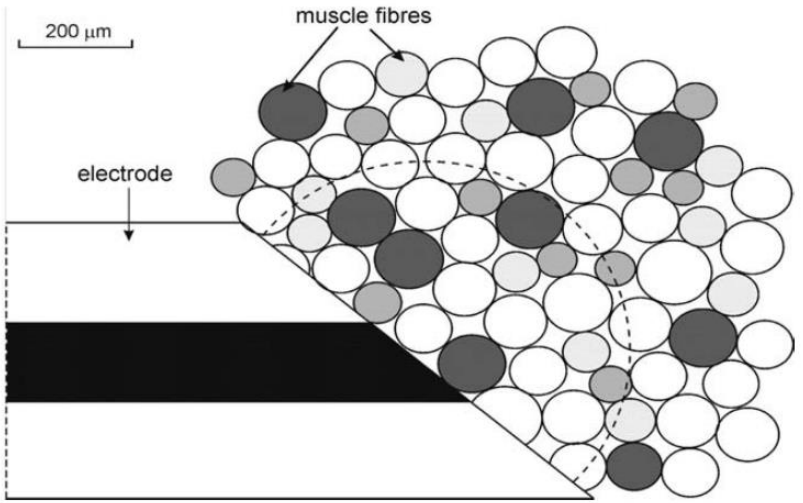
- Groups of motor units often work together to coordinate the contractions of a single muscle



# Motor Unit

- Every motor neuron discharge evokes contraction of all its muscle fibers which is detected as a waveform called motor unit action potential (MUAP)



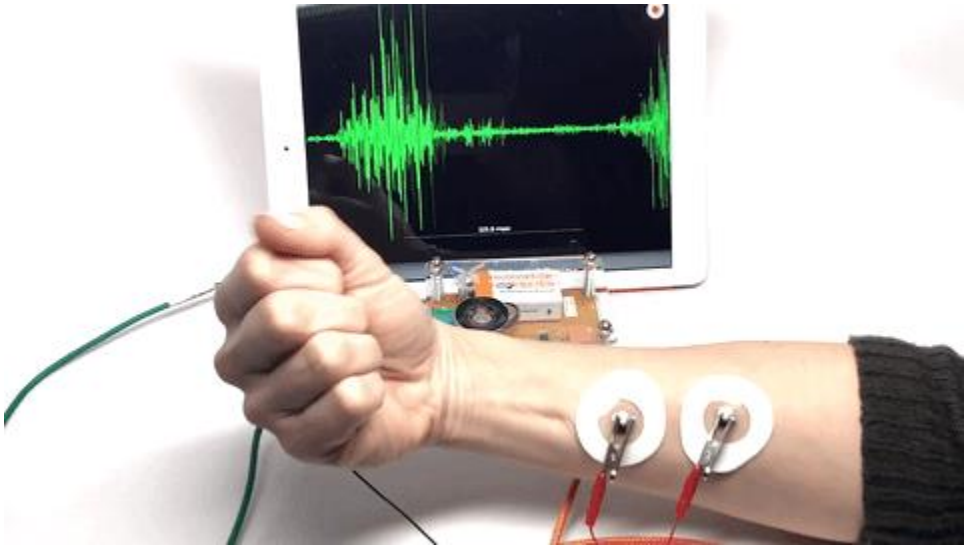




**Fibers belonging to the same MU are marked by the same shade**

- A needle electrode typically detects the activity of several muscle fibers within its pick-up area, which belong to a few different MUs

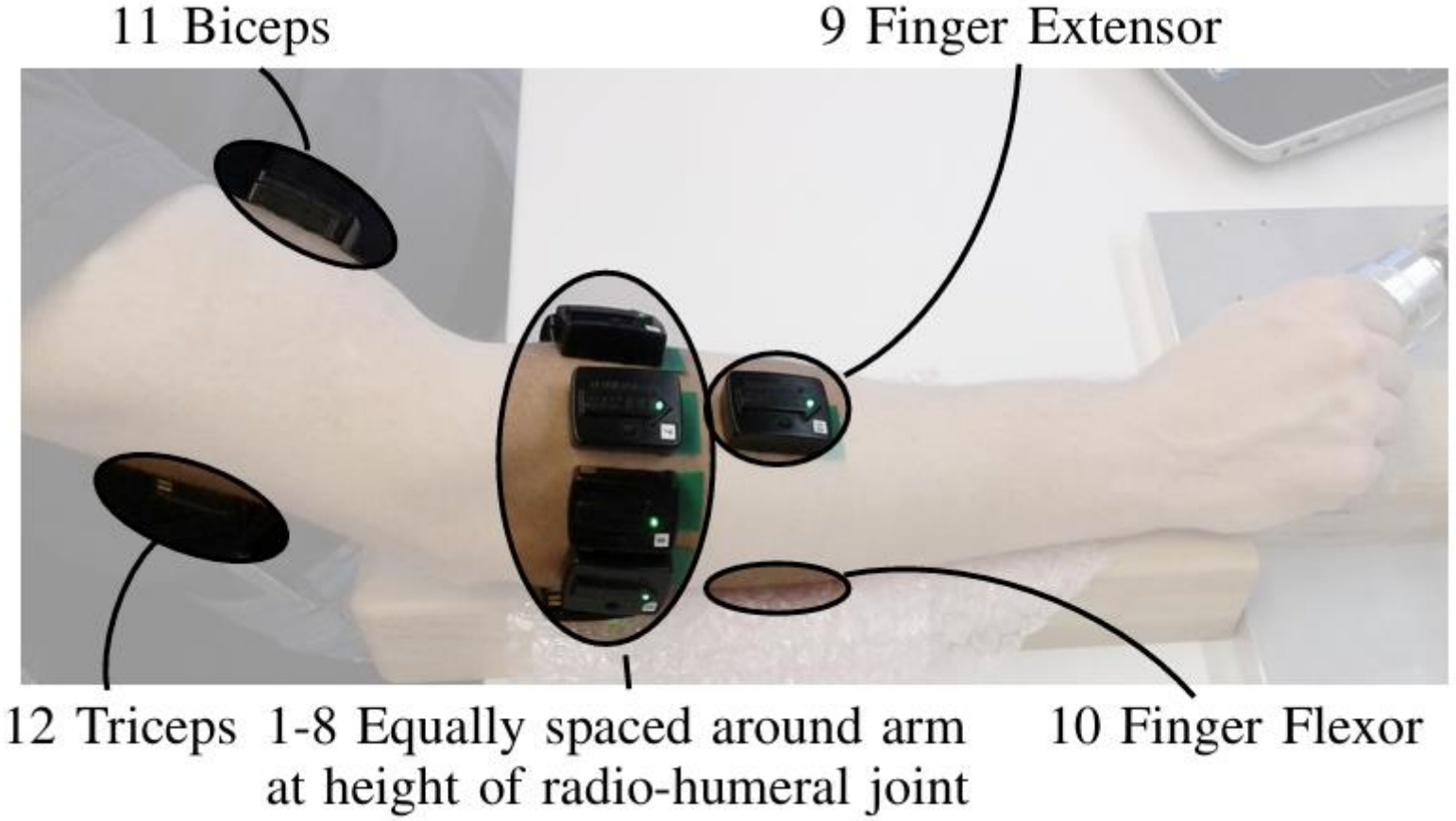
# sEMG

- sEMG detects the electric potential generated by muscle fibers during contraction
- Electrodes placed on the skin pick up these signals, which are amplified and processed
- Signal processing includes filtering to isolate relevant data



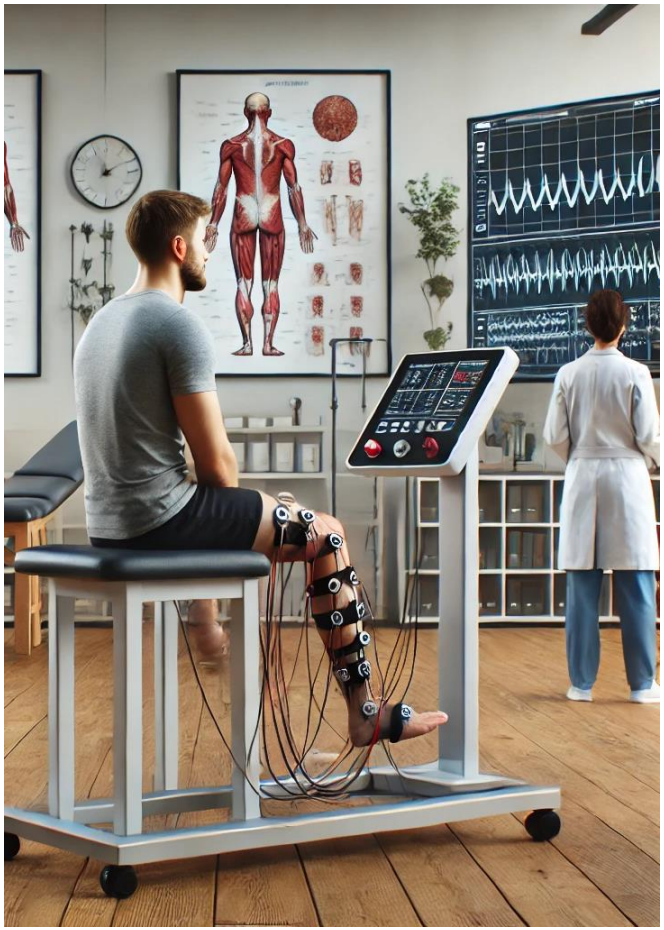
https://backyardbrains.com/products/img/muscleSpikerBoxInMotion.gif

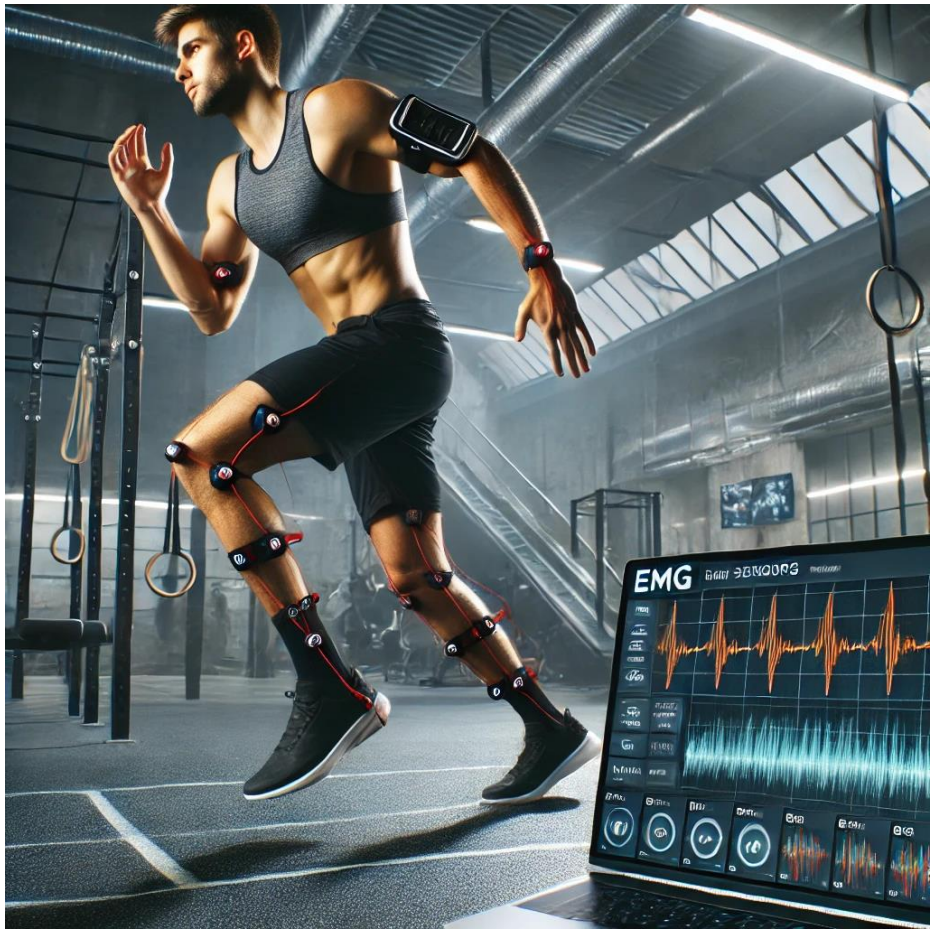
# sEMG Electrodes and Placement




https://doi.org/10.1109/tnsre.2014.2303394

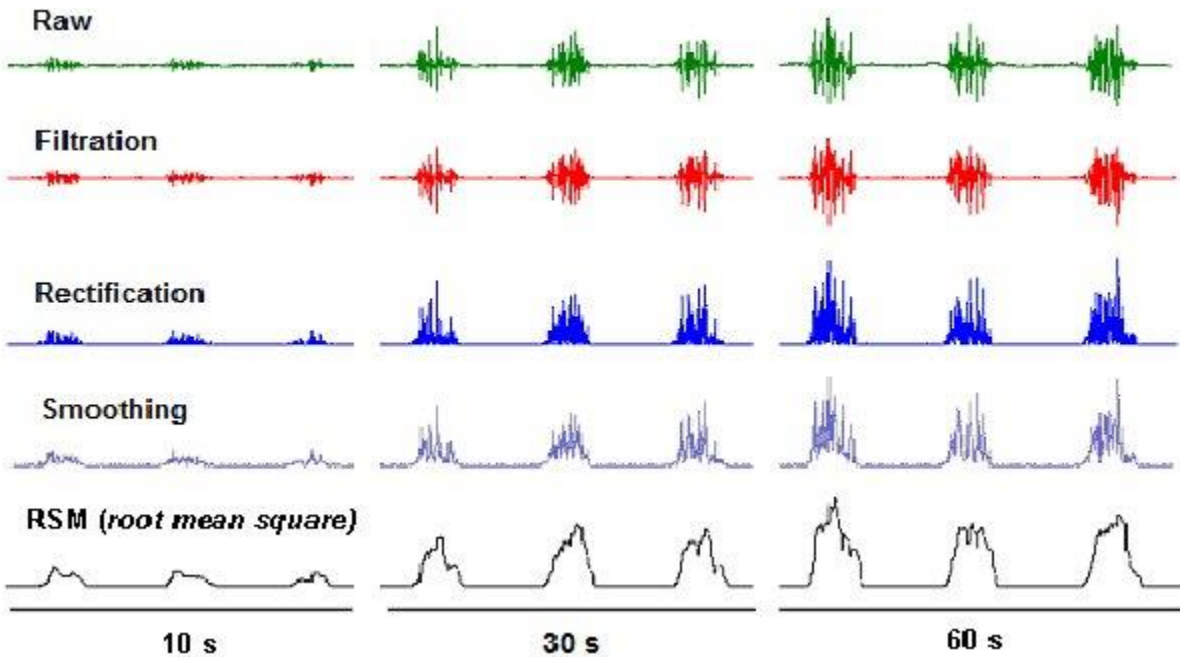
# Applications of sEMG





# Challenges of sEMG

- Skin impedance and electrode placement sensitivity.
- Susceptibility to noise and signal artifacts.
- Data processing requirements




https://doi.org/10.5772/50599

# Dataset

- The dataset represents the data of three subjects: S1, S2, and S3

- All subjects were instructed to perform two hand movement while resting between them
  - Stimulus 0: hand at rest.
  - Stimulus 1: Abduction of all fingers
  - Stimulus 2: Fingers flexed together in fist

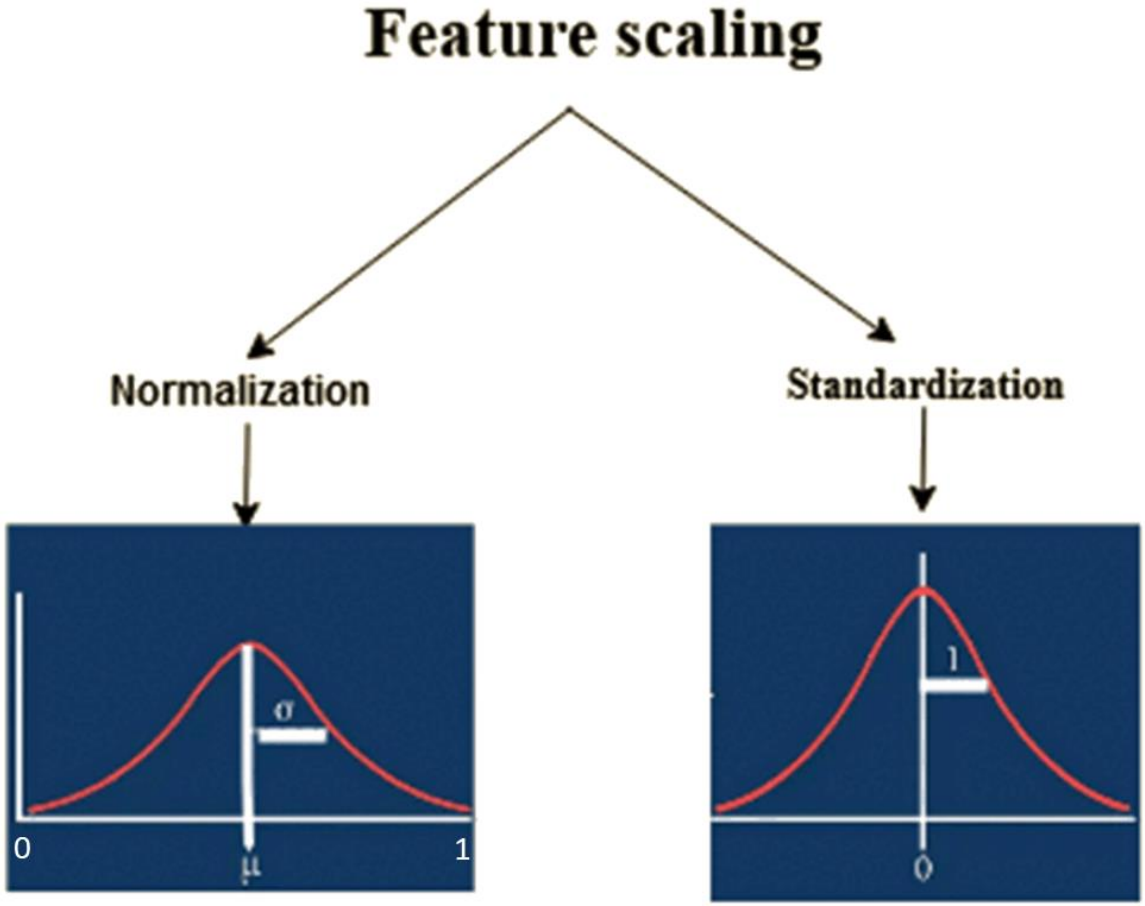
- Each subject performed each movement 10 times where the duration of each stimulus is about 5 seconds with a 3 seconds break between each two successive stimuli.

# Project Objective

- Identify the hand movement done by the subject by analyzing the recorded sEMG signals on all electrodes.

  Three methods are required:
  - Method 1: Use **time domain** data from each electrode individually.
  - Method 2: Use **frequency domain** data from each electrode individually.
  - Method 3: Combining features from all electrodes for each of methods 1 and 2.
- As a pre-processing, you will need to apply a high-pass filter with a cutoff frequency of 10Hz
- Examine the impact of feature scaling on the results
- A leave-one-trial-out approach should be used for evaluation
- The accuracy of all methods will be assessed by computing the accuracy which is measured as the number of trials that are predicted correctly divided by the total number of trials
- Use K-nearest neighbor (KNN) classifier, you need to identify the value of K that results in the best accuracy for each subject.

# Feature Scaling




$$x' = \frac{x - \min(x)}{\max(x) \quad \min(x)}$$

$$x_{transformed} = \frac{x - mean\ (x)}{stander\ devation\ (x)}$$

# *K*-nearest Neighbor (KNN) Classifier

- Most basic instance-based method

- Uses Euclidean distance to determine how dissimilar a pair of points are

$$d(\mathbf{x}_i, \mathbf{x}_j) = \sqrt{\sum_{r=1}^{n} (x_{ir} - x_{jr})^2}$$

- For any new input vector, the nearest $K$ points are considered

- A majority voting scheme is used to classify the new input vector

# *K*-nearest Neighbor (KNN) Classifier