IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

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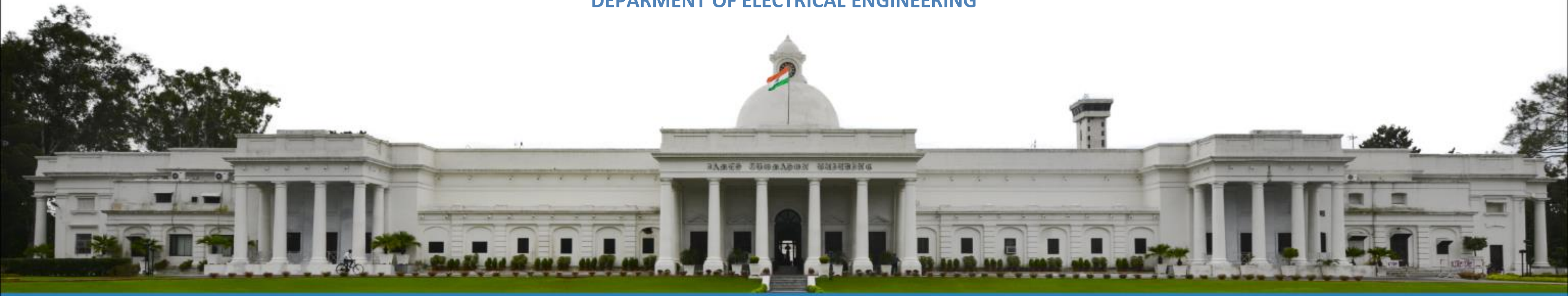
DEPARMENT OF ELECTRICAL ENGINEERING



Neural Control of a Hand Exoskeleton based on Subject Intention

Outline

1. Development of Learning Scheme using surface EMG signal

2. Development of Learning Scheme using surface EEG signal

3. Working Demos

4. Conclusion

Introduction

- To develop a learning scheme based on surface EMG signal and then through EEG signal using BPN Neural Network.

- To actuate the index finger exoskeleton using the learned network.

Electromyogram

- Measure of electrical activity of the muscles.

- Measurements can be done from a single muscle fiber, a single muscle or a group of muscles.

- Invasive and Surface electrode based methodology.

Surface EMG

- Invasive:
  - Painful
  - Medical Expert
  - Time consuming

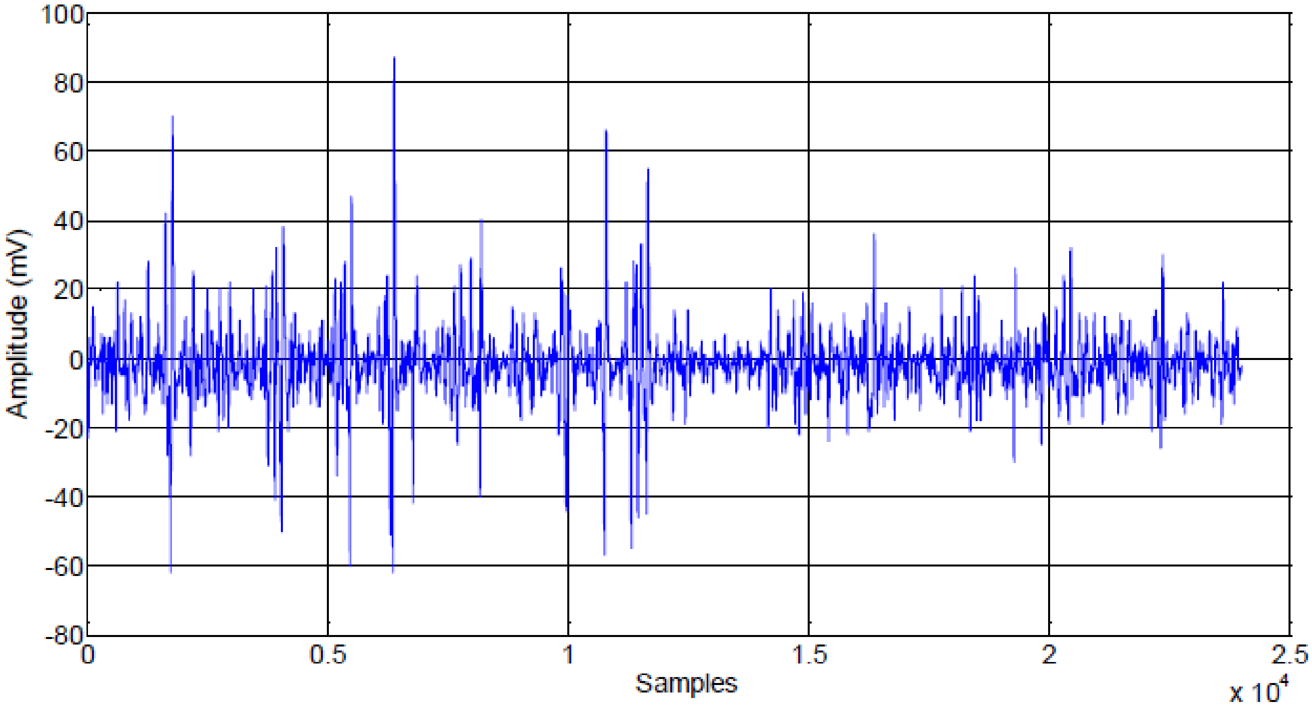
- Surface EMG based method: Preferred in our study

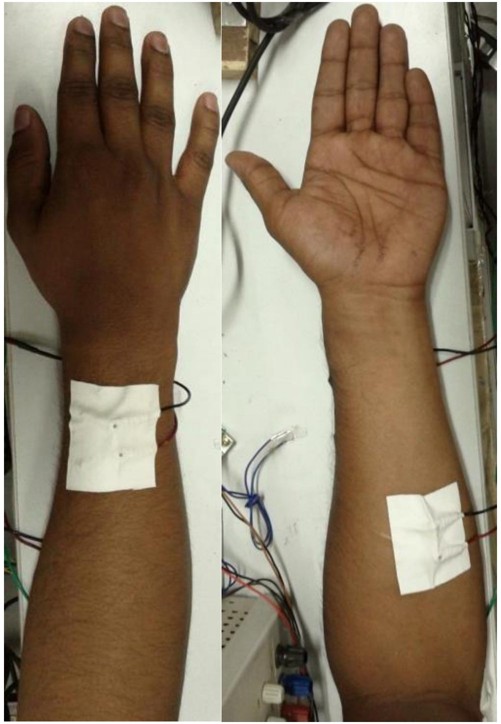
Surface EMG: Electrical Characteristics

- Amplitude:
  - From 0 to around 20 mV
  - Depends on the muscle

- Frequency Range:
  - Upto 1000 Hz
  - Usable range: 30 – 500 Hz

Control of Exoskeleton using Surface EMG signal





Feature Extraction

- The Hjorth parameters extracted are represented in frequency and time domain:

1. Activity:

- measures the variance of the time-varying data.
- represents the surface envelope of the power spectrum in the frequency domain.
- The value of Activity is large/small, if there are many/few high frequency constituents of the signal.

$$m_0 = \int_{-\infty}^{+\infty} S_p(w)dw = \frac{1}{T}\int_{t-T}^{t} g^2(t)dt$$

Feature Extraction

2. *Mobility:*

- It is defined as the square root of variance of the first derivative of the signal divided by variance of the signal.
- represents mean/dominant frequency

$$m_2 = \int_{-\infty}^{+\infty} w^2 S_p(w)dw = \frac{1}{T}\int_{t-T}^{t} (\frac{dg}{dt})^2 dt$$

Feature Extraction

3. *Complexity:*

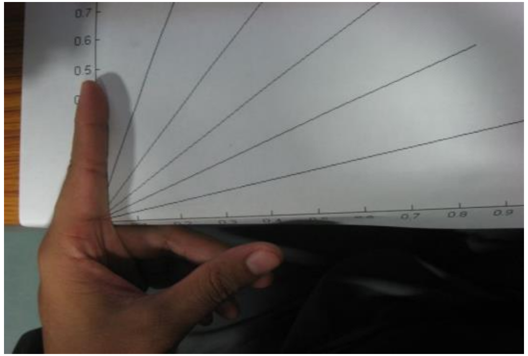
- It is a measure of the similarity of the shape of a signal to a pure sine waveform.

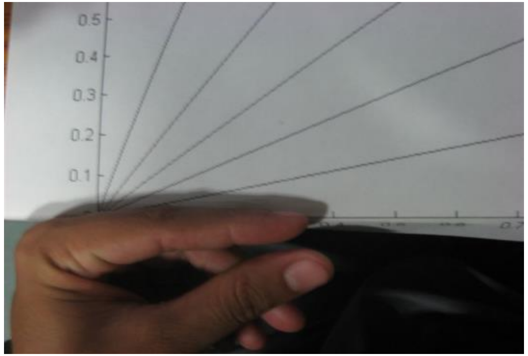
- If the value of the complexity is closer to one , the shape of the signal is more similar to a sine waveform.

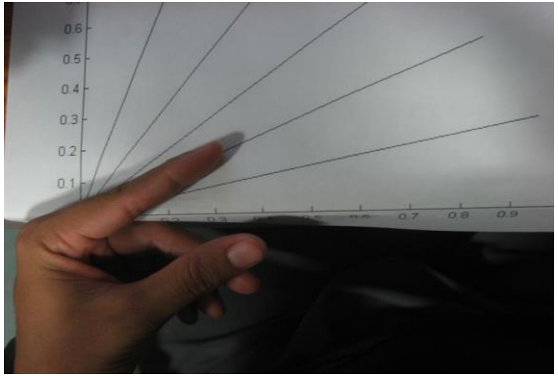
$$m_4 = \int_{-\infty}^{+\infty} w^4 S_p(w)dw = \frac{1}{T}\int_{t-T}^{t} (\frac{d^2 g}{dt^2})^2 dt$$

Control of Exoskeleton using Surface EMG signal

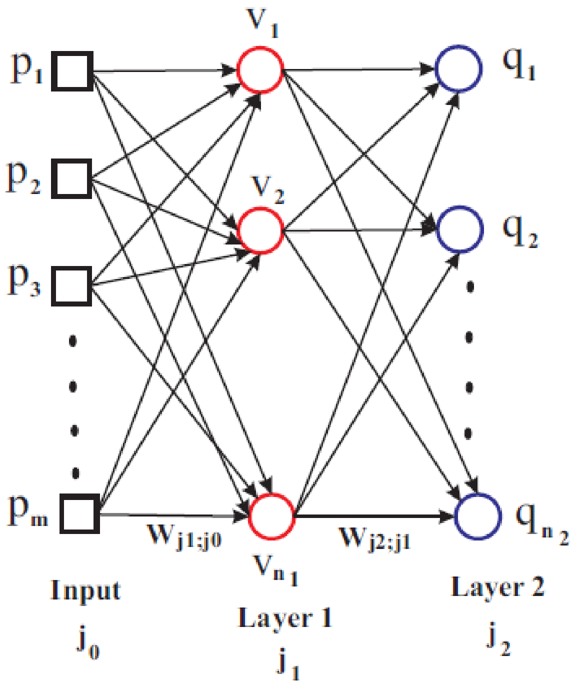
Finger Motion for Training the Network







Back Propagation Algorithm



Back Propagation Algorithm

The update laws for the weights connecting the output and the hidden layers is as follows:

$$\begin{aligned} W_{j_2 j_1}(t+1) &= W_{j_2 j_1}(t) + \alpha(q_{j_2}^d - q_{j_2})q_{j_2}(1 - q_{j_2})v_{j_1} \\ &= W_{j_2 j_1}(t) + \alpha\delta_{j_2} v_{j_1} \end{aligned}$$

where, α is the learning rate and

$$\delta_{j_2} = (q_{j_2}^d - q_{j_2})q_{j_2}(1 - q_{j_2})$$

Back Propagation Algorithm

The update law for the weights connecting the hidden and the input layers is as follows:

$$W_{j_1 j_0}(t+1) = W_{j_1 j_0}(t) + \alpha \delta_{j_1} p_{j_0}$$

where, α is the learning rate and

$$\delta_{j_1} = v_{j_1}(1 - v_{j_1}) \sum_{j_2=1}^{n_2} \delta_{j_2} W_{j_2 j_1}$$

Control of Exoskeleton using Surface EMG signal

Multilayer Neural Network

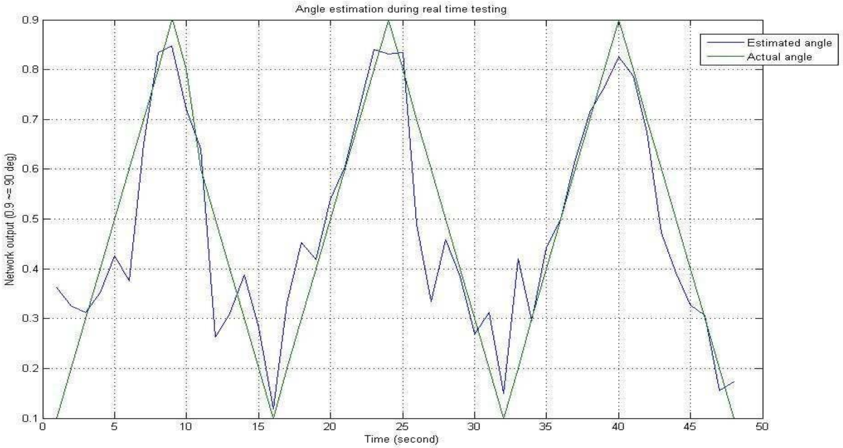
Input: Hjorth Paramters

$$Activity\ (y) = \sum_{i=1}^{N} \frac{(y(i)-\mu)^2}{N}$$

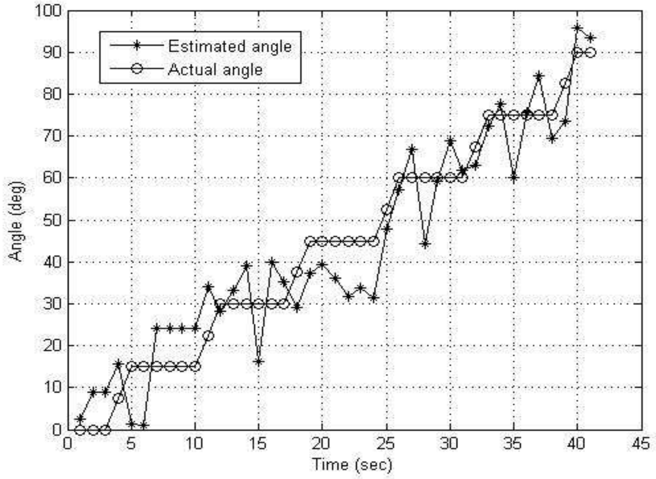
$$Mobility\ (y) = \sqrt{\frac{variance(y')}{variance(y)}}$$

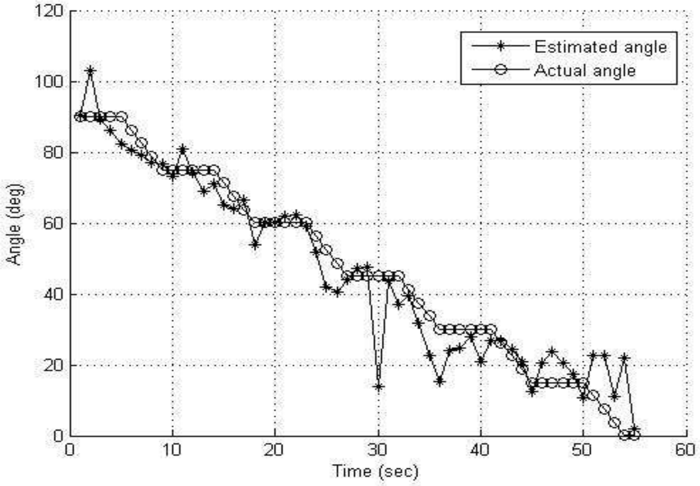
$$Complexity(y) = \frac{Mobility\ (y')}{Mobility\ (y)}$$

Output: Finger MCP joint angle corresponding to Flexion/Extension Motions

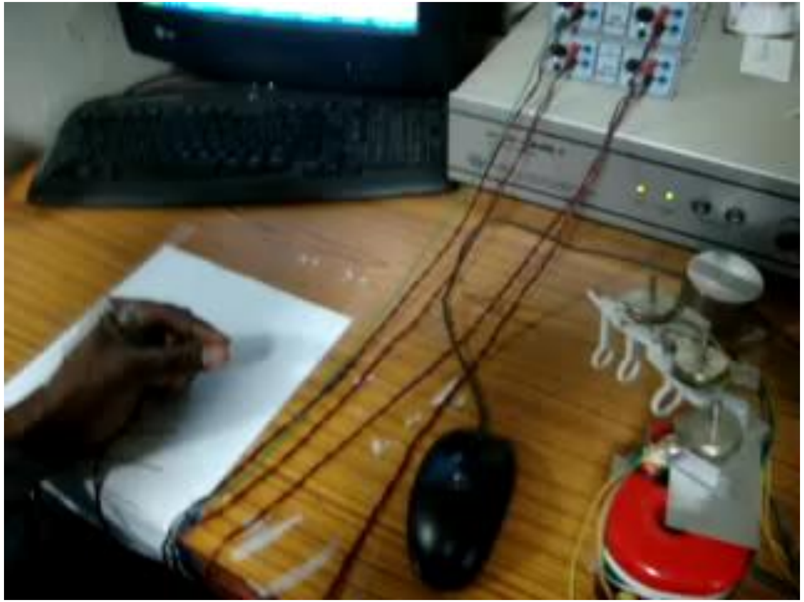


Control of Exoskeleton using Surface EMG signal

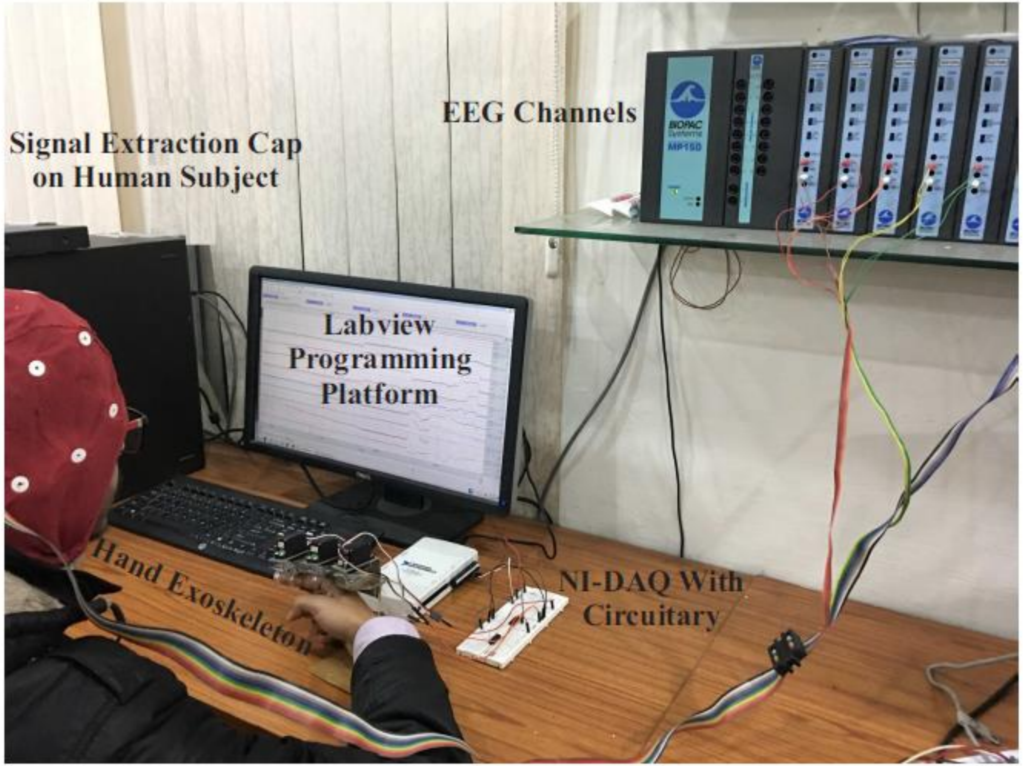




Working Demo



With EEG Signal



Data Acquisition and Processing

- The EEG cap worn by the human subject is connected with BIOPAC MP 150 system via NIDAQ 6212 interfaced with LabVIEW platform.

- The EEG cap contains 21 electrodes , of which 20 of them are connected 10 EEG channels and one common ground electrode.

- It required noise free environment and focused thinking process.

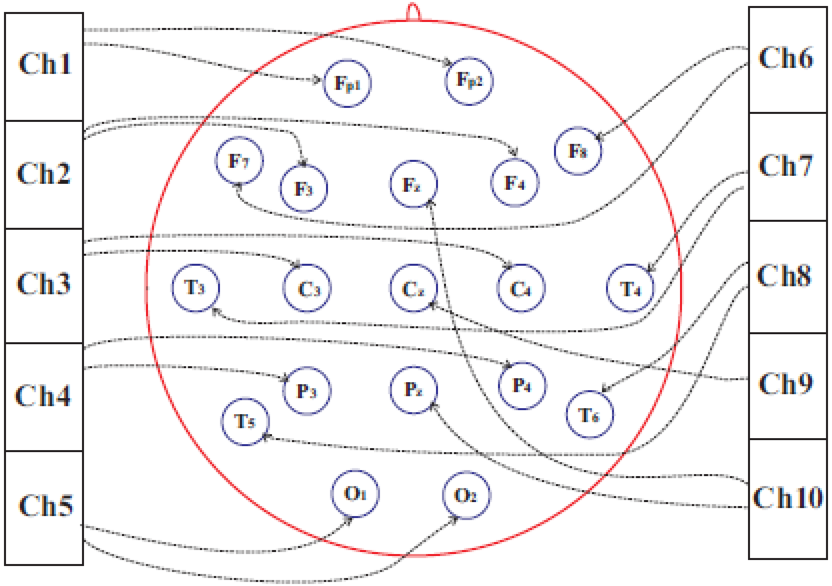
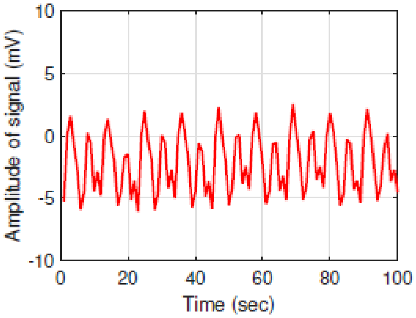
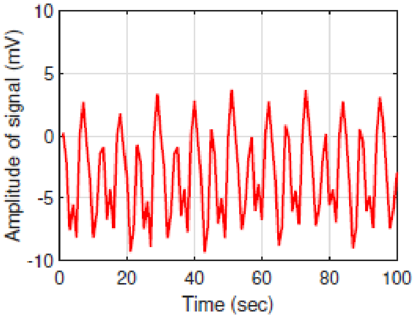


Fig: Electrode position and connection to channel

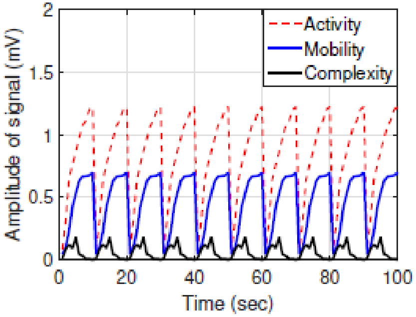
Results



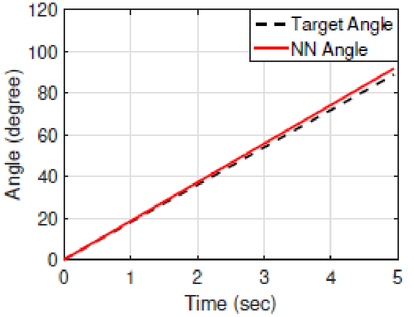
(a) Channel 2 EEG Signal.



(b) Channel 3 EEG Signal.



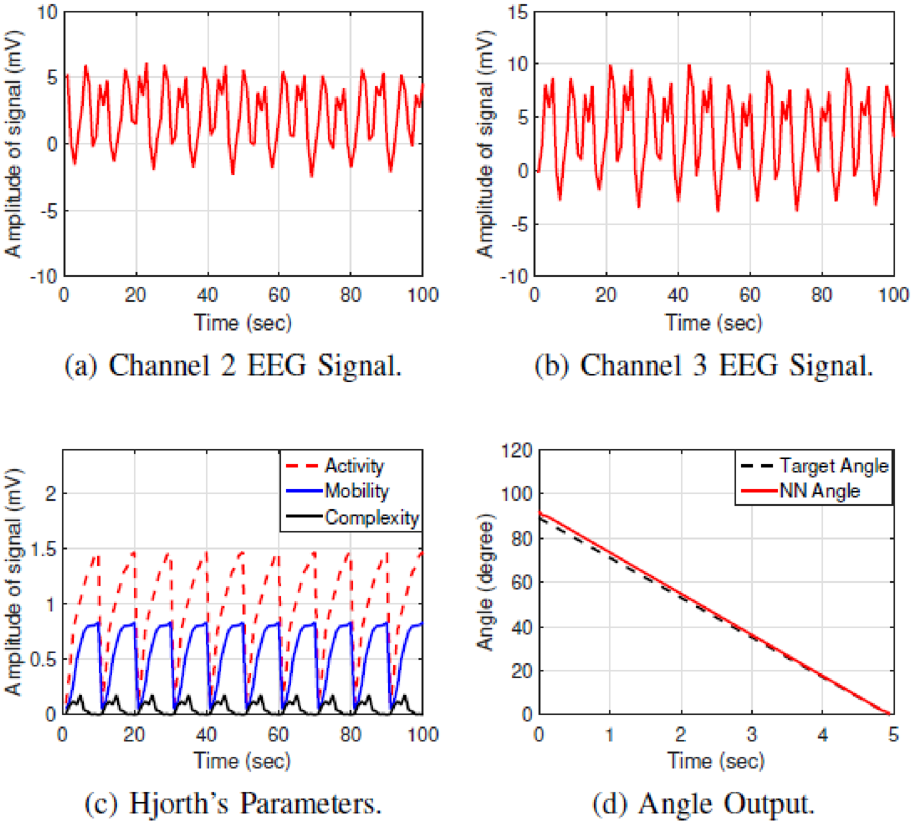
(c) Hjorth's Parameters.



(d) Angle Output.

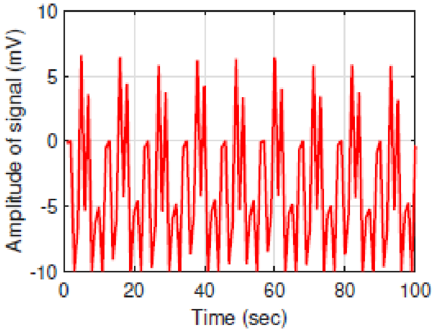
90 degree flexion movement results of index finger exoskeleton.

Results

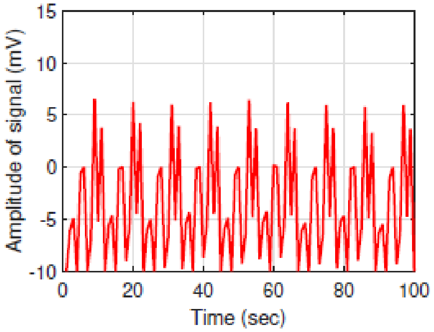


90 degree extension movement results of index finger exoskeleton.

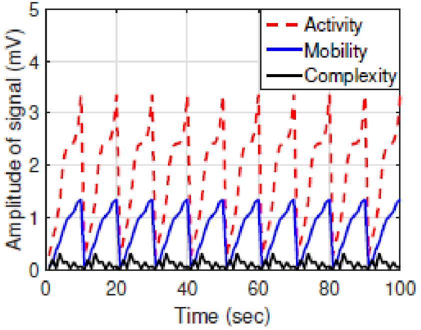
Results



(a) Channel 2 EEG Signal.



(b) Channel 3 EEG Signal.



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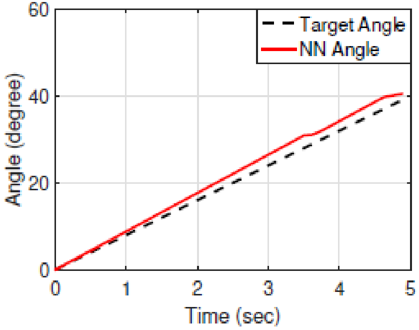
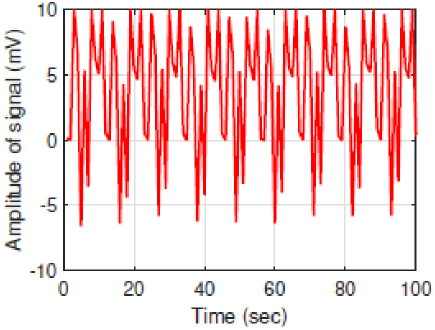


(d) Angle Output.

40 degree flexion movement results of index finger exoskeleton.

Results



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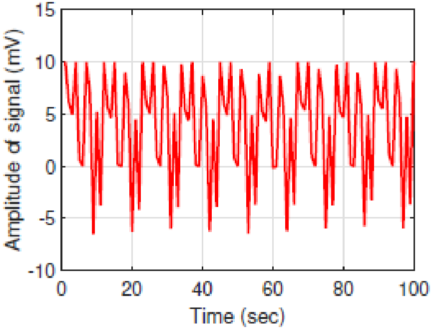
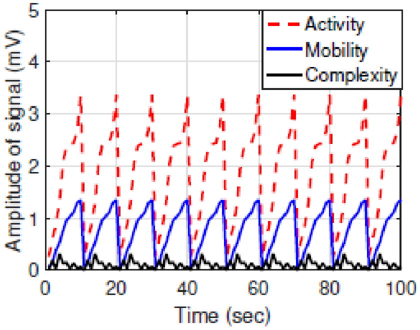


(b) Channel 3 EEG Signal.



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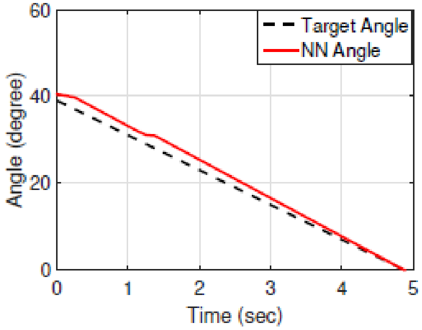
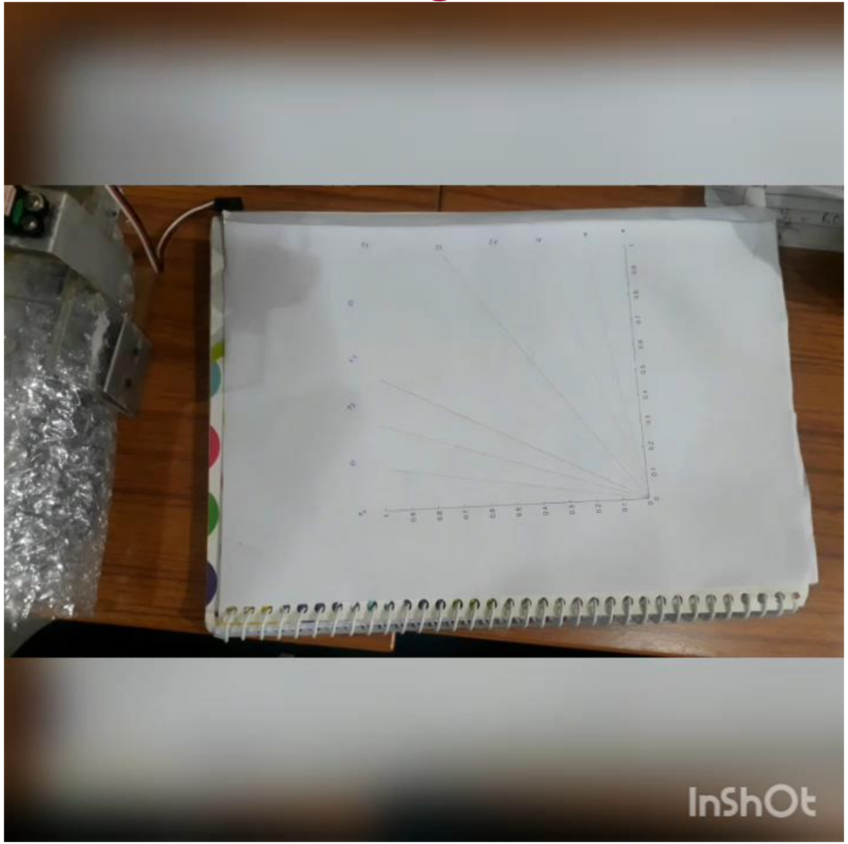


(d) Angle Output.

40 degree extension movement results of index finger exoskeleton.

Working Demo



Conclusion

- Performed control through EEG signal

- EMG signal based control

Thank You!