Experimental protocol

1 Setup

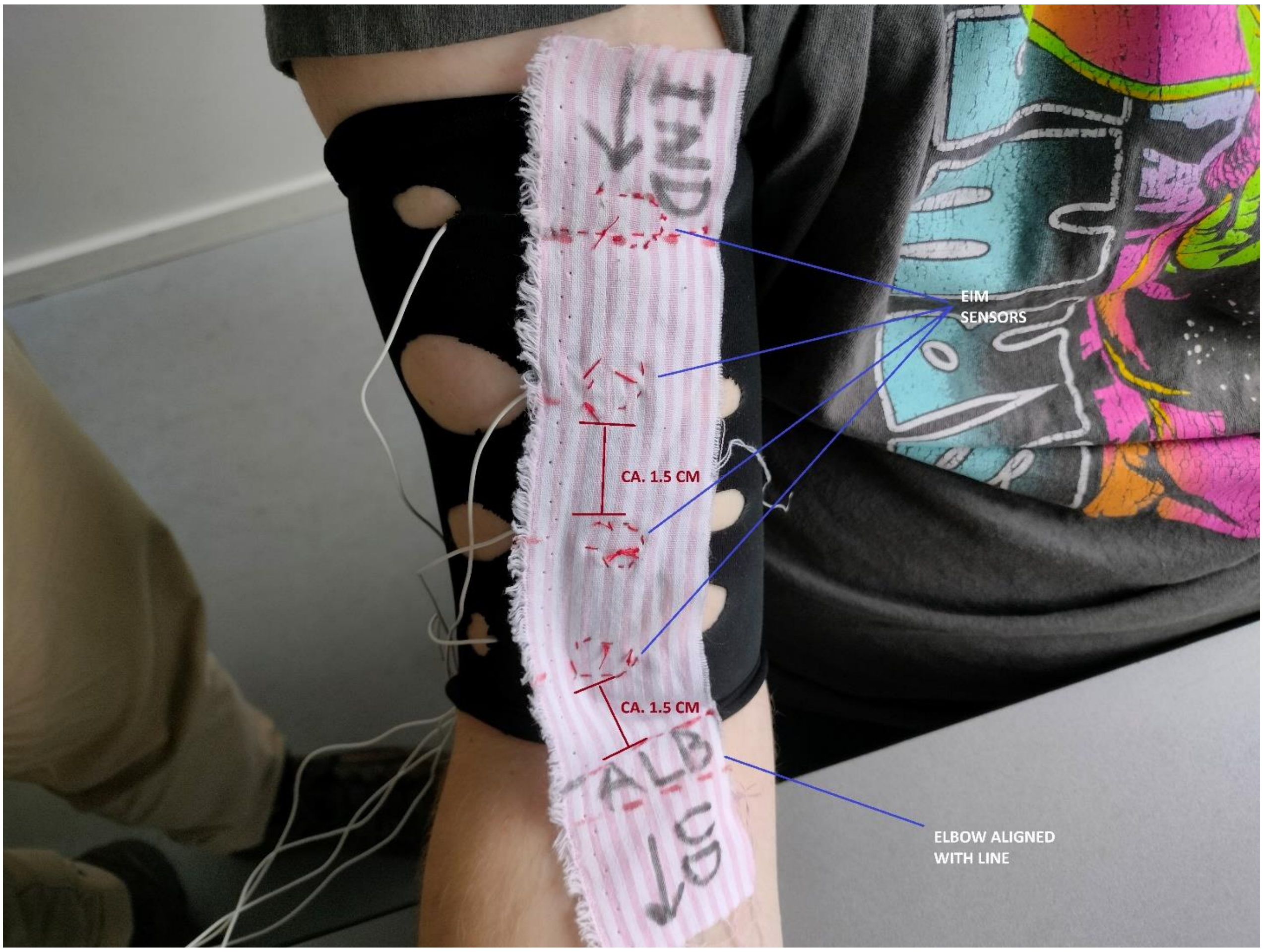


Figure 1

The EIM electrodes are sewn to a sleeve made from the fabric you have available. This is done to ensure proper contact between the electrode surface area and the bicep, and to reduce the variability of placement of the sensors.

The sensors are placed along the biceps 1.5 cm apart, with the lowest sensor towards the forearm being 1.5 cm away from the elbow joint. The elbow joint should be aligned with the stippled lines, as shown on the picture above. It is important that the space between the two middle sensors are placed directly above the middle of the bicep.

2 PURPOSE

The purpose of this experiment is to gather data for the GRU neural network, train the network, process the data output, and finally interface between network and control system.

The purpose of the neural network is to be able to predict the assumed payload weight that the user is lifting and the desired angle of the elbow joint. This is to be able to calculate the feedback and feedforward torque for the control system. The following equations estimates the feedback and the feedforward torque along with their associated functions:

$$\tau_{ff} = \tau_g \cdot a \qquad \tau_g = m \cdot g \cdot l$$

$$\tau_{fb} = k(\theta_d - \theta) + B(\dot{\theta_d} - \dot{\theta}) \qquad \dot{\theta_d} = \frac{d\theta}{dt} = \frac{\theta_d - \theta}{t_{i+1} - t_i}$$

Where τ_{ff} is the feedforward torque control signal, τ_g is the torque generated from the gravitational pull and a is a scalar that the user puts in ranging from 0 to 1. m is the mass of the payload, g is the gravitational acceleration (≈ 9.82), and l is the length of the arm link.

τ_{fb} is the feedback torque control signal, k and B are tuning variables that the control loop is self-tuning. θ and θ_d are the actual and the desired angle, and $\dot{\theta}$ and $\dot{\theta_d}$ are their derivitives. t_i is the discrete time at the datapoint i.

Training is then done on the impedance input, having the elbow angle and payload weight as ground truths. Impedance and elbow angle is logged for each time step. Payload remains constant throughout the sample, only to be changed between samples.

2.1 TRAINING DATA

- Electrical Bioimpedance Ω (From Eliko device)
- Elbow angle θ (0 – 180 deg, aka. full extension → full flexion, gathered from elbow angle tracker)
- Payload weight m (Weight in hand of e.g., 0, 4, 6 kg)

Input

- Electrical Bioimpedance Ω

Output

- Predicted desired angle θ_d
- Predicted payload weight m

When this is achieved, you will have one chain from input to exo skeleton control signal as seen in Figure 2.

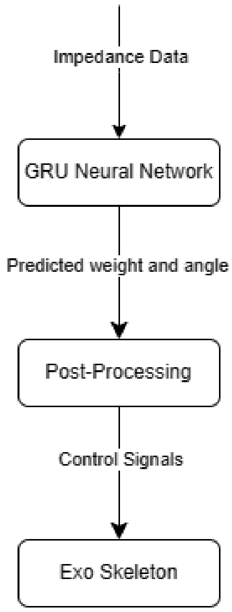


Figure 2

3 MATERIALS

- Eliko device with sensor sleeve and 4 EIM electrodes.
- A computer with the following three programs:
  - Eliko interface data collection program with the drivers installed
  - Elbow angle tracker program
  - Macro to start / stop recording samples

4 SAMPLE GENERATION PROCESS

1. **Weights:** Choose weights (e.g., 0kg, 4kg, 6kg in our case).
2. **Grips:** Consider three grips: palm up (i.e., regular bicep curls), palm inwards (i.e., bicep hammer curls), palm down (i.e., forearm curls).
3. **Samples:**
   - Static: No movement.
   - Dynamic: Predetermined motions.

4.1 PROCEDURE:

- For each participant, weight, grip, and arm:
  - Execute static samples.
  - Execute dynamic predetermined samples.
  - Include any additional useful samples.

4.1.1 Static samples:

- **SampleIndex_X**participant_**Y**kg_180deg_**Z**grip
- **SampleIndex_X**participant_**Y**kg_135deg_**Z**grip
- **SampleIndex_X**participant_**Y**kg_90deg_**Z**grip
- **SampleIndex_X**participant_**Y**kg_45deg_**Z**grip
- **SampleIndex_X**participant_**Y**kg_0deg_**Z**grip

Examples:

- 2_ththe_4kg_135deg_hammer
- 4_sivin_0kg_45deg_palm-down

4.1.2 **Dynamic samples:**

- **SampleIndex_X**participant_**Y**kg_FullRangeOfMotion_**Z**grip
  - Start out with a relaxed arm, fully bend your arm slowly and make sure to squeeze the bicep at the top and wait there for 5 seconds, then slowly relax your arm again.

- **SampleIndex_X**participant_**Y**kg_LowerHalfRangeOfMotion_**Z**grip
  - Start out with a relaxed arm, bend your arm slowly close to 90 degrees and wait there for 5 seconds, then slowly relax your arm again.

- **SampleIndex_X**participant_**Y**kg_UpperHalfRangeOfMotion_**Z**grip
  - Start out at 90 degrees, fully bend your arm slowly and make sure to squeeze the bicep at the top and wait there for 5 seconds, then slowly relax your arm again.

- **SampleIndex_X**participant_**Y**kg_FullRangeOfMotionWithStop_**Z**grip
  - Start out with a relaxed arm, bend your arm slowly close to 90 degrees and wait there for 5 seconds, then fully bend your arm slowly and make sure to squeeze the bicep at the top and wait there for 5 seconds, bend your arm slowly close to 90 degrees and wait there for 5 seconds, then slowly relax your arm again.

- **SampleIndex_X**participant_**Y**kg_FullRangeOfMotionWithJitters_**Z**grip
  - Start out with a relaxed arm, while jittering (as if you had parkinsons disease), fully bend your arm slowly and make sure to squeeze the bicep at the top and wait there for 5 seconds, then slowly relax your arm again while still jittering.

- **SampleIndex_X**participant_**Y**kg_FullRangeOfMotionWithPulsing_**Z**grip
  - Start out with a relaxed arm, while pulsing (a little bit more aggressively than jittering), fully bend your arm slowly and make sure to squeeze the bicep at the top and wait there for 5 seconds, then slowly relax your arm again while still pulsing.

Examples:

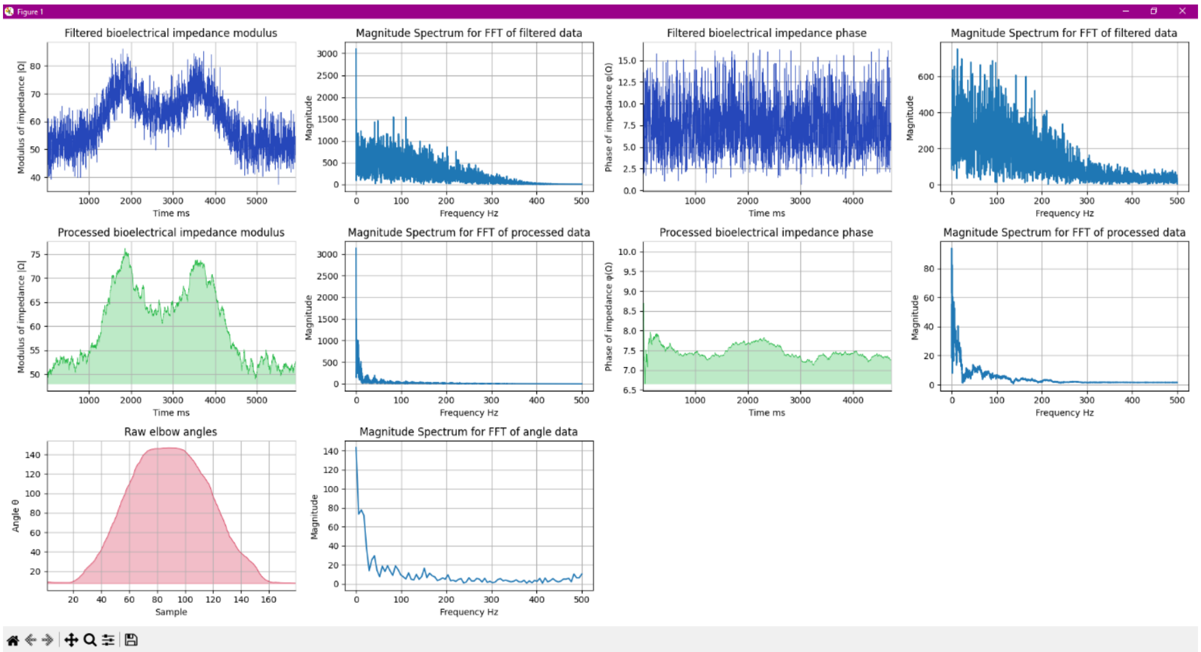
- 46_ththe_6kg_FullRangeOfMotion_hammer
- 55_sivin_4kg_FullRangeOfMotionWithJitters_palm-down

This systematic approach creates a diverse dataset for training the GRU network, covering various weights, grips, and movements to enhance predictive accuracy from EIM data. We recommend creating a folder for each sample, to contain the data.

5 Sample Collection Process

1. Wear the sensor sleeve on your upper arm, ensuring the electrodes are all on your bicep, and the middle of the sleeve being in the middle of your bicep surface area.
2. Connect to the computer with the *MUSE* Eliko data interface.
3. Start the *angle_calculator.py* elbow angle tracker program and *MacroRecorder* program.
4. For each generated sample:
    a. Using the *start_recording.mrf* macro, start sampling of each program simultaneously.
        i. A guide for how to set up and use the Eliko interface data collection program is found here: [MUSE: Muscular Signal Processing for Exoskeleton Control]
    b. Perform your sample.
    c. Use the *stop_recording.mrf* macro to stop sampling.

To ensure that the data is being logged properly, you can use the provided *visualizer.py*. A full range of motion sample should look as follows in the visualizer:



It is generally recommended to train the network with as many samples as possible; you may even include samples that you believe may aid the network in discovering a relationship between EIM, weight, and elbow angle.