Myoelectrical Torque Estimation of the Ankle in Real-Time

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Background

Myoelectrical → electrical signal in muscle

Torque Estimation → muscle contraction force

of the Ankle → simple system

in Real-Time → biologically relevant

Background – Rationale

F(neural signal) = Force

we are trying to find this

Background – Rationale

F(neural signal) = Force

we are trying to find this

- ➔ Rehabilitation
- ➔ Wearable Robotics & Robotic assistance
- ➔ Correct for neural signalling errors in patients with neurological injury

Background

Haggie et al. [1]

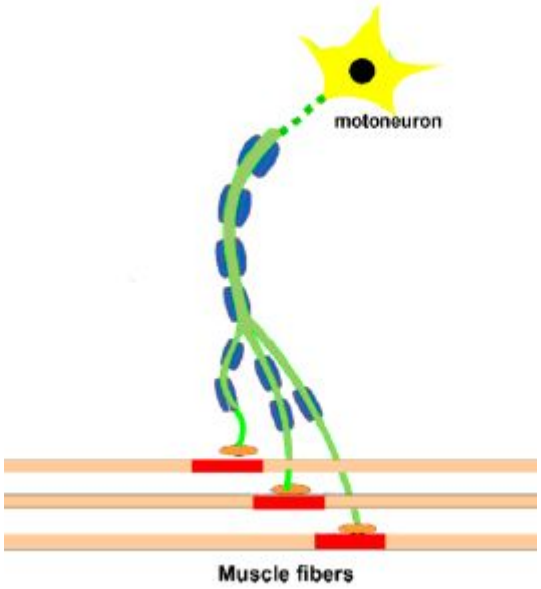
Background

Solution:
Measure Motor Neuron Signal exactly to reconstruct subject's desired muscle force

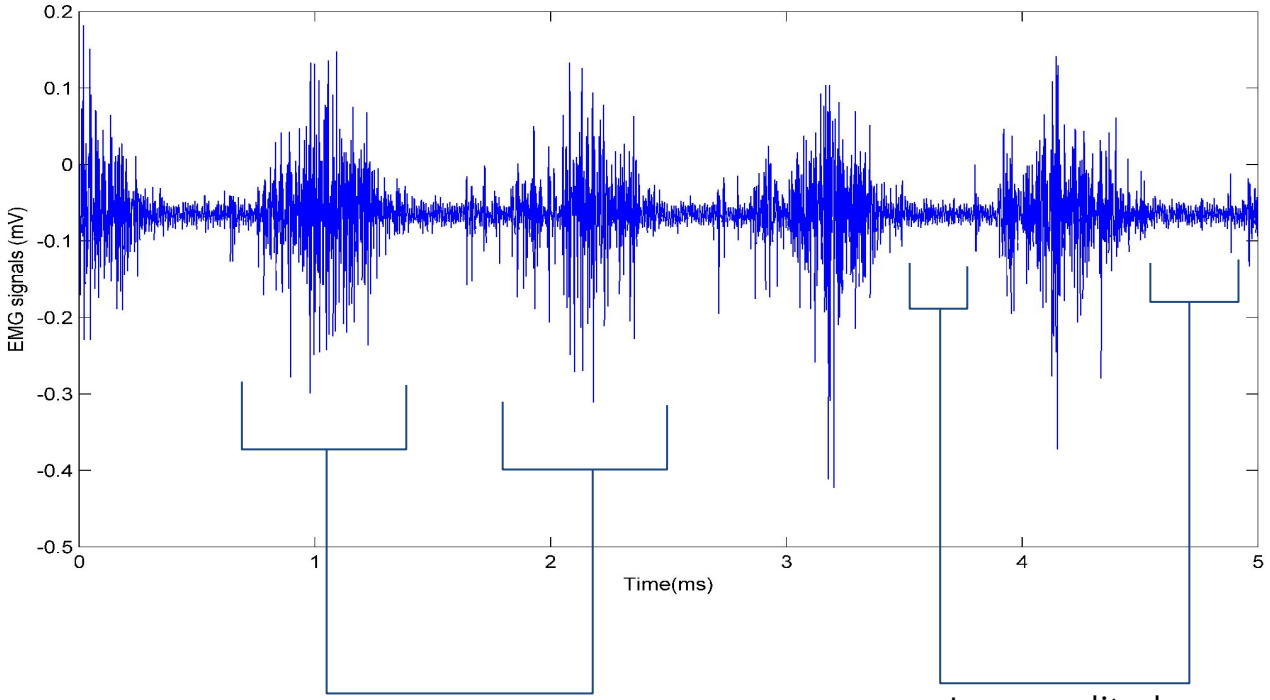
What exactly is this signal?

Background

Motor Neuron



Voltage Signal



High amplitude

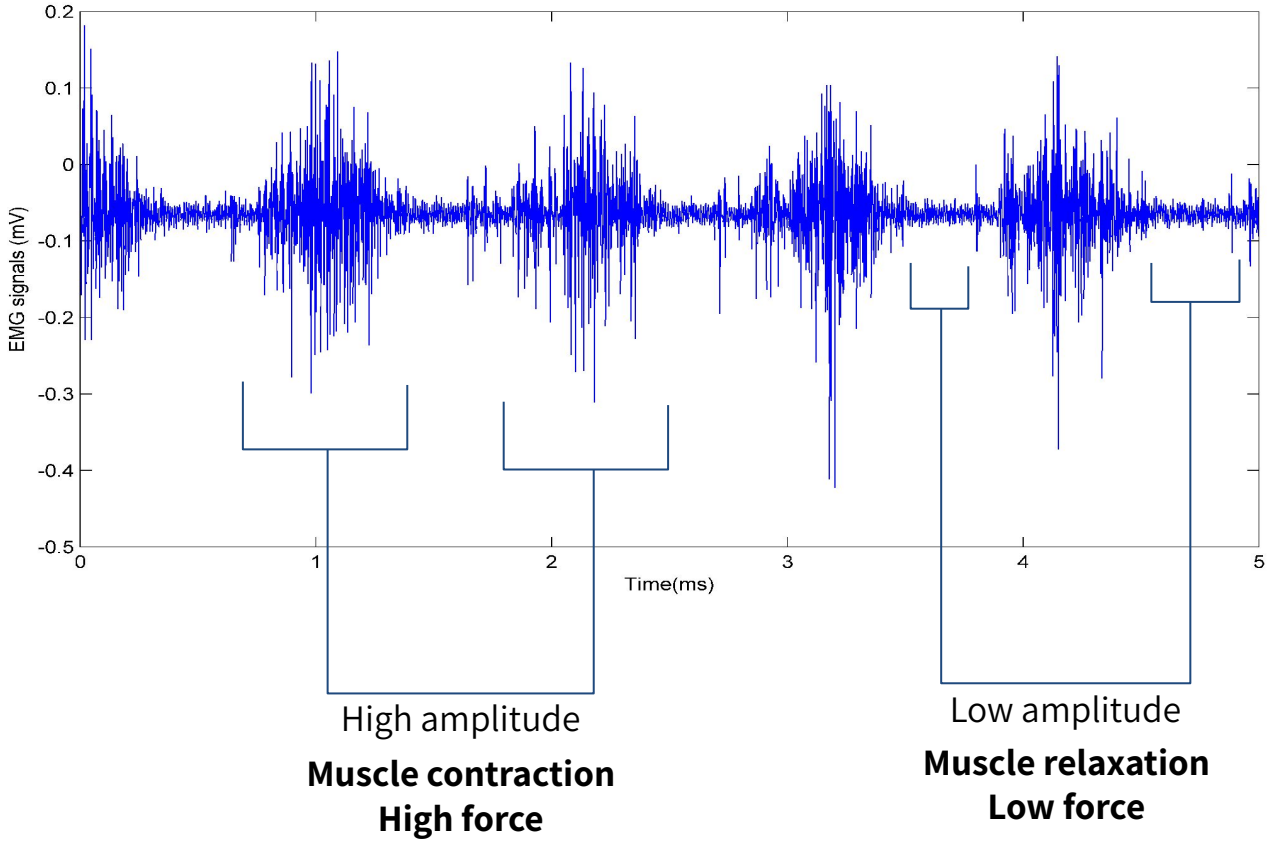
Muscle contraction
High force

Low amplitude

Muscle relaxation
Low force

Background

Baseline Method - RMS EMG



High amplitude

Muscle contraction
High force

Low amplitude

Muscle relaxation
Low force

Proposal

Solution:
Measure Motor Neuron Signal exactly to reconstruct exactly what the muscle is doing

Can we measure when a motor neuron fires as a discrete event, instead of a noisy summation of voltage changes?

Yes, we can!

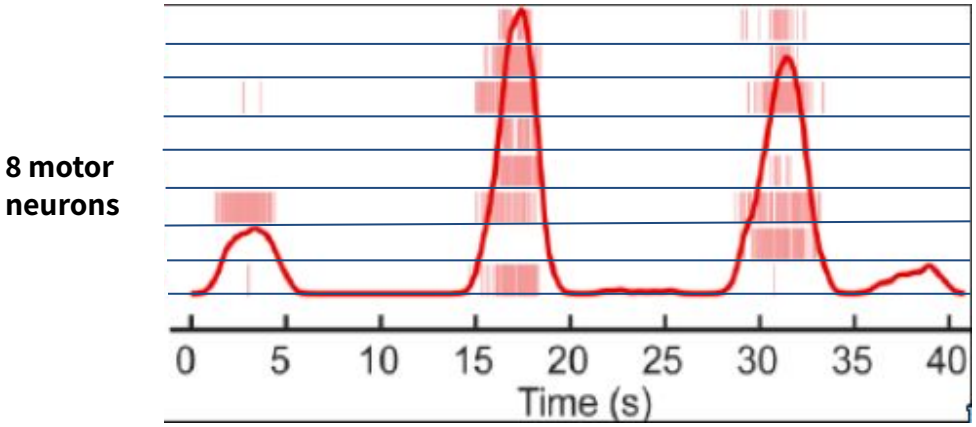
Proposal - Methods

Neural Drive

- ➔ Cocktail Party Effect
- ➔ “Listen in” on motor neurons
- ➔ Track their firing
- ➔ Better potential for predicting muscle force

Problem:
This takes 2 hours

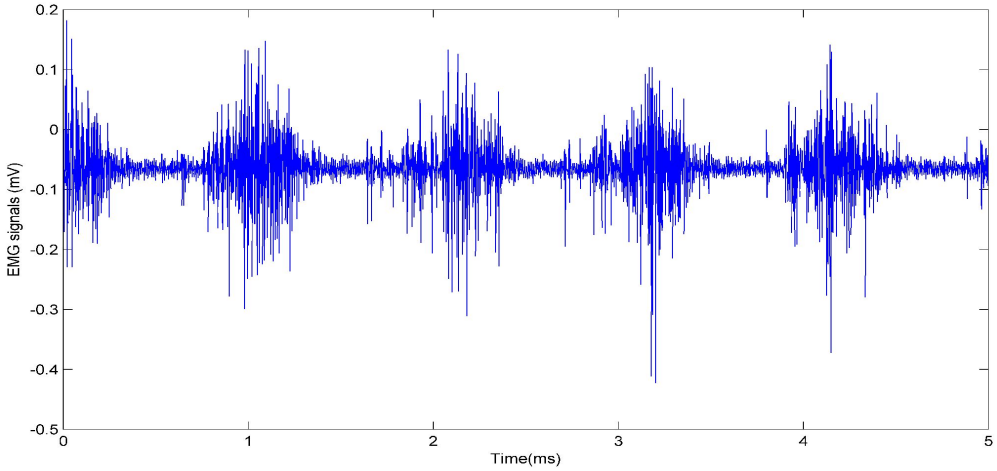
Neural Drive

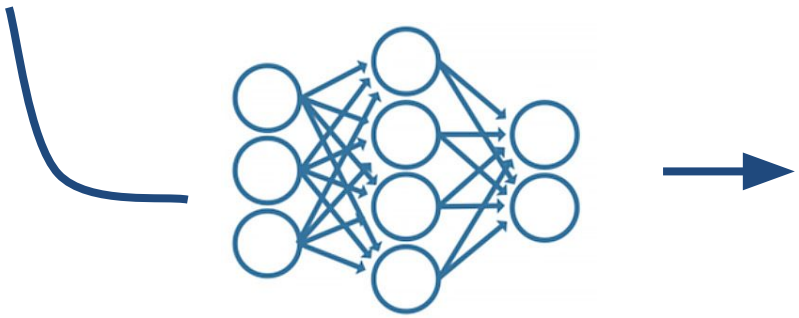


Proposal - Methods

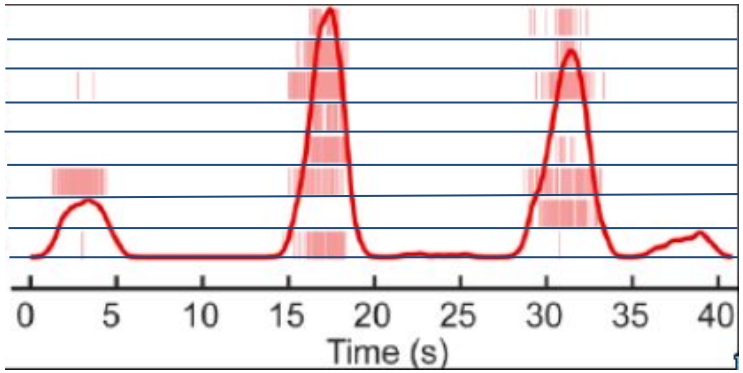
Convolutional **N**eural **N**etwork - **CNN**

➔ Really good at finding patterns in complex sequential data



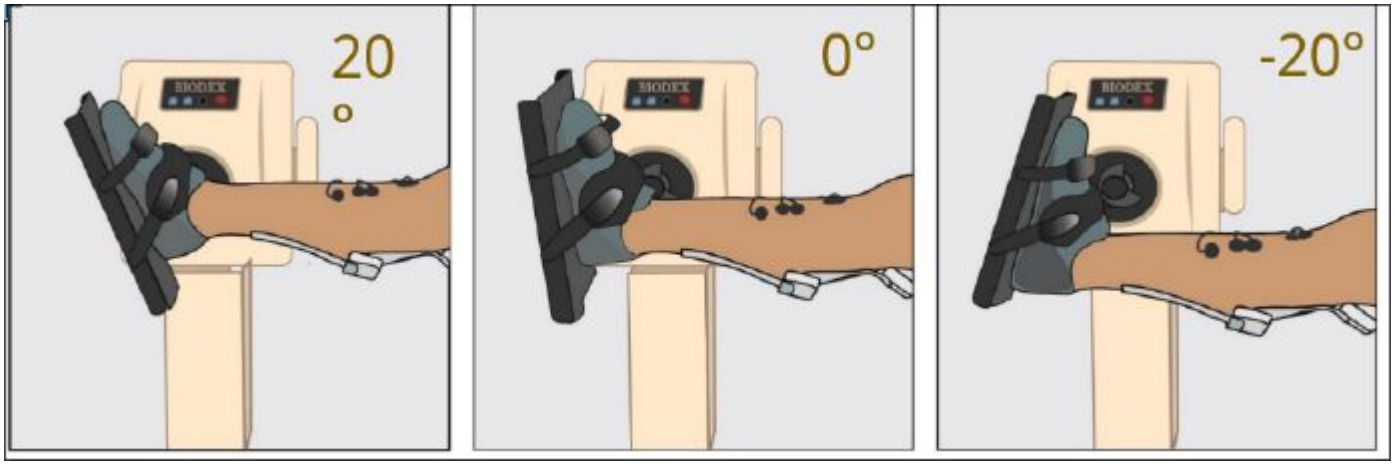


Proposed Method:
Real-time Neural Drive



Methods - Subjects

- ➔ Recruited 8 subjects
- ➔ Pushed and pulled their foot (rotating their ankle joint)
- ➔ Measured electrical activity in calf muscles
- ➔ Measured the force the subjects exerted



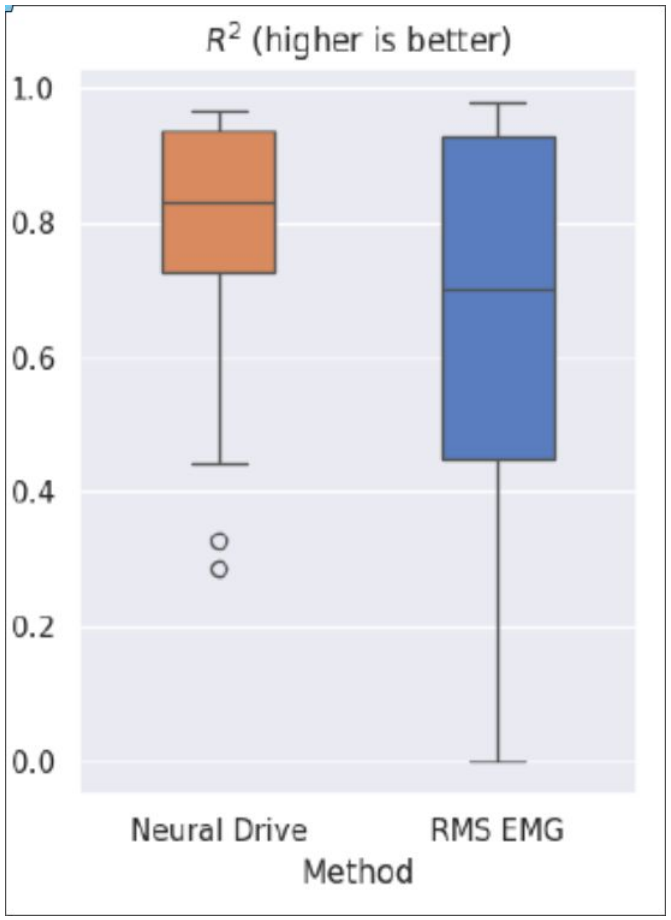
Methods - Analysis

- ➔ Trained the CNN with noisy electrical signal as input and the neural drive as output to calculate **Real-time Neural Drive**
- ➔ Conducted a non-linear fit with either the baseline RMS EMG method or **Real-time Neural Drive** as predictor **X** values and the subject's muscle force as the response **Y** value
- ➔ Utilized linear mixed-effects model to verify superiority of **Real-time Neural Drive**
- ➔ Calculated time-to-predictions

Results

- Green Dotted Line — subject's true force output
- Orange Line — Real-Time Neural Drive's force prediction
- Blue Line — Baseline

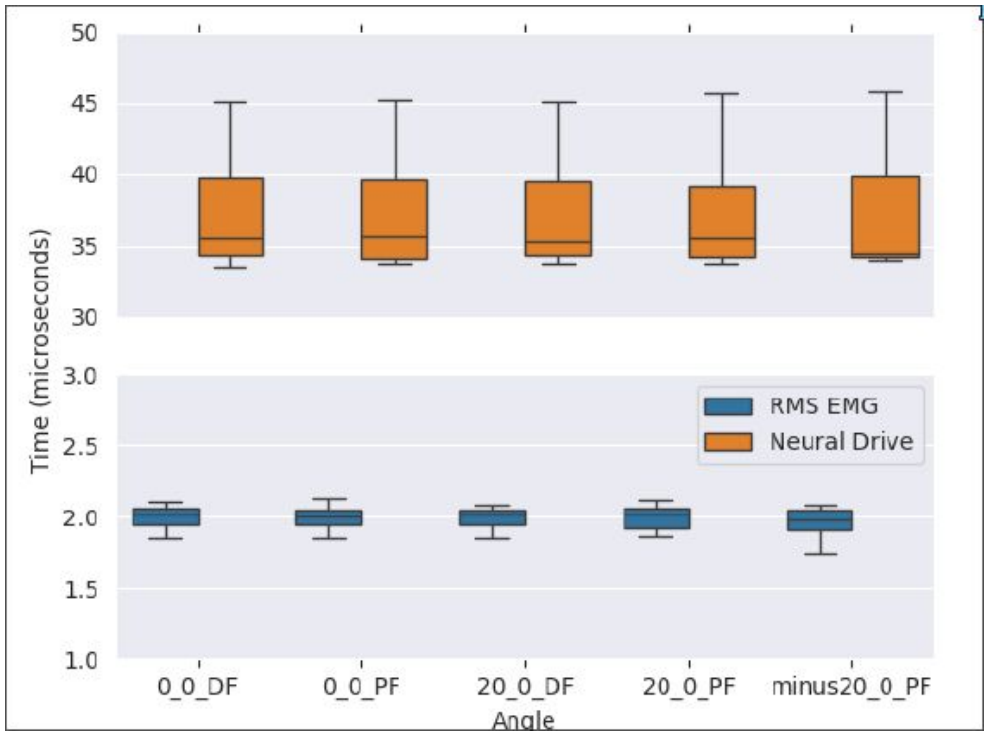
Results



Real-time Neural Drive Prediction:

More consistent and **better on average** at explaining the patient's force

Results



Real-Time Neural Drive:

38.72 microseconds[a] from receiving signal to predicting force.

a) Calculated on ORIN Nano, an embedded platform for machine learning models from NVIDIA.

Conclusions

- ➔ Can measure motor neuron firings accurately
- ➔ Real-Time Neural Drive shows promise in translating neural code of movement into force
- ➔ Has a place in development of wearable robotics
  - ◆ Facilitates intuitive, accurate control

Next Steps

- ➔ Integrate the method into an actual wearable device
- ➔ Replicate study with neurologically injured population (stroke)
- ➔ Develop transfer function between healthy and stroke populations

Image citations

[1] L. Haggie, L. Schmid, O. Röhrle, T. Besier, A. McMorland, and H. Saini, “Linking cortex and contraction—Integrating models along the corticomuscular pathway,” *Front. Physiol.*, vol. 14, May 2023, doi: 10.3389/fphys.2023.1095260.