An interactive Python notebook as an educational tool for neuromuscular control

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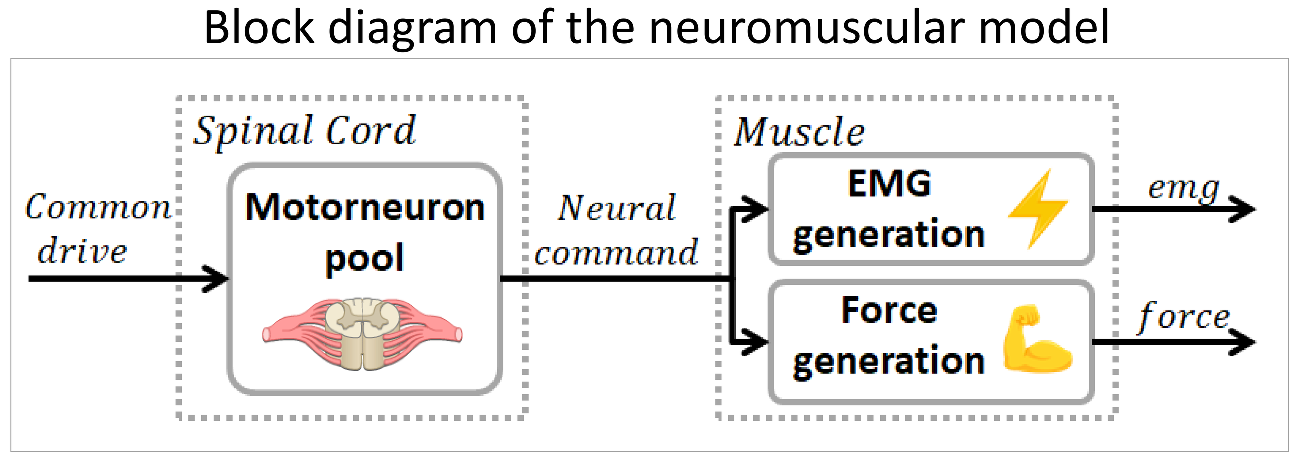
1. Introduction

- We developed an interactive Python notebook for the use as a **learning** and **research** tool of mechanisms underlying **muscle force control**;
- The notebook was designed in **Jupyter** using the **Python** programming language.

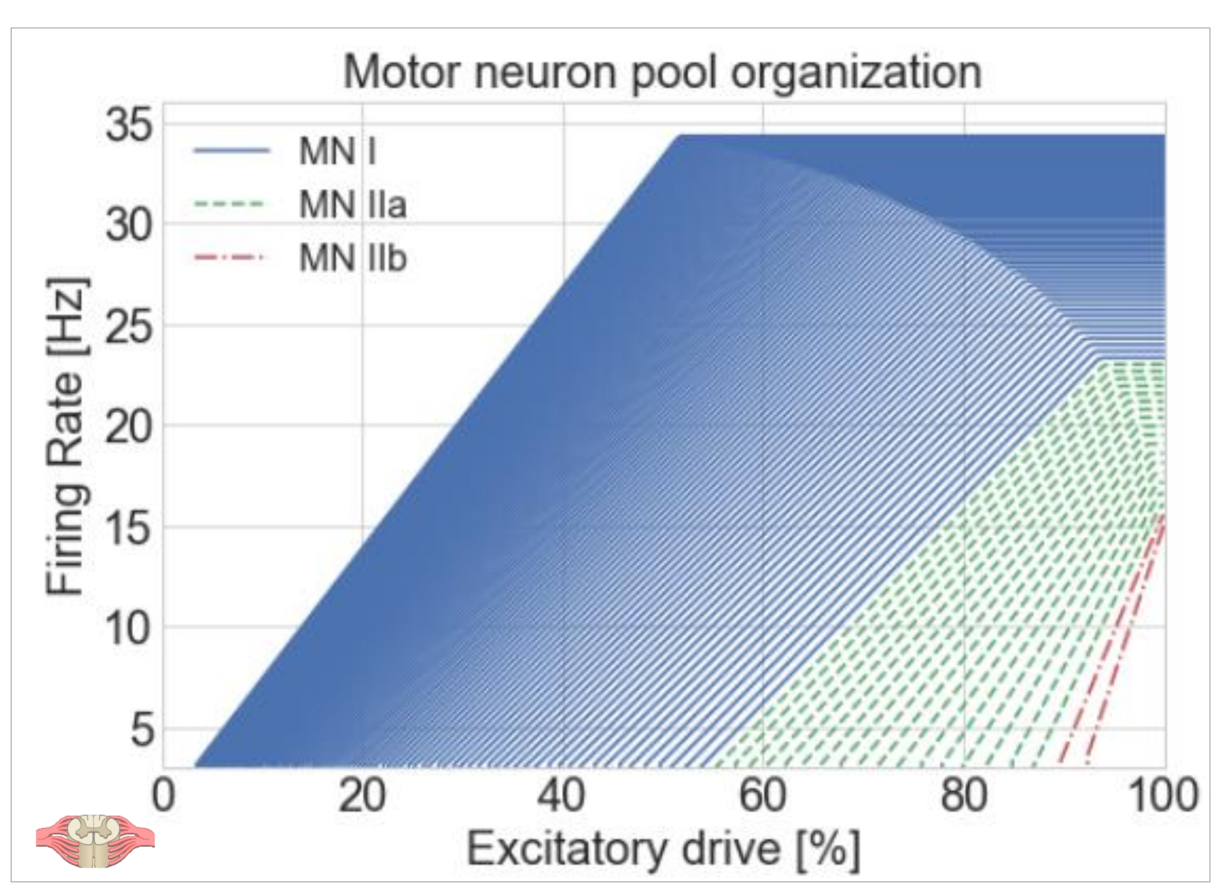
2. Methods

- Two basic neuromuscular structures were included: the **spinal cord** and the **muscle**;
- The spinal cord structure is composed by a **motorneuron pool** model, which is excited by the **common drive** and generates the **neural command**;
- The muscle structure includes two models: **electromyogram** (EMG) and **force** generation.

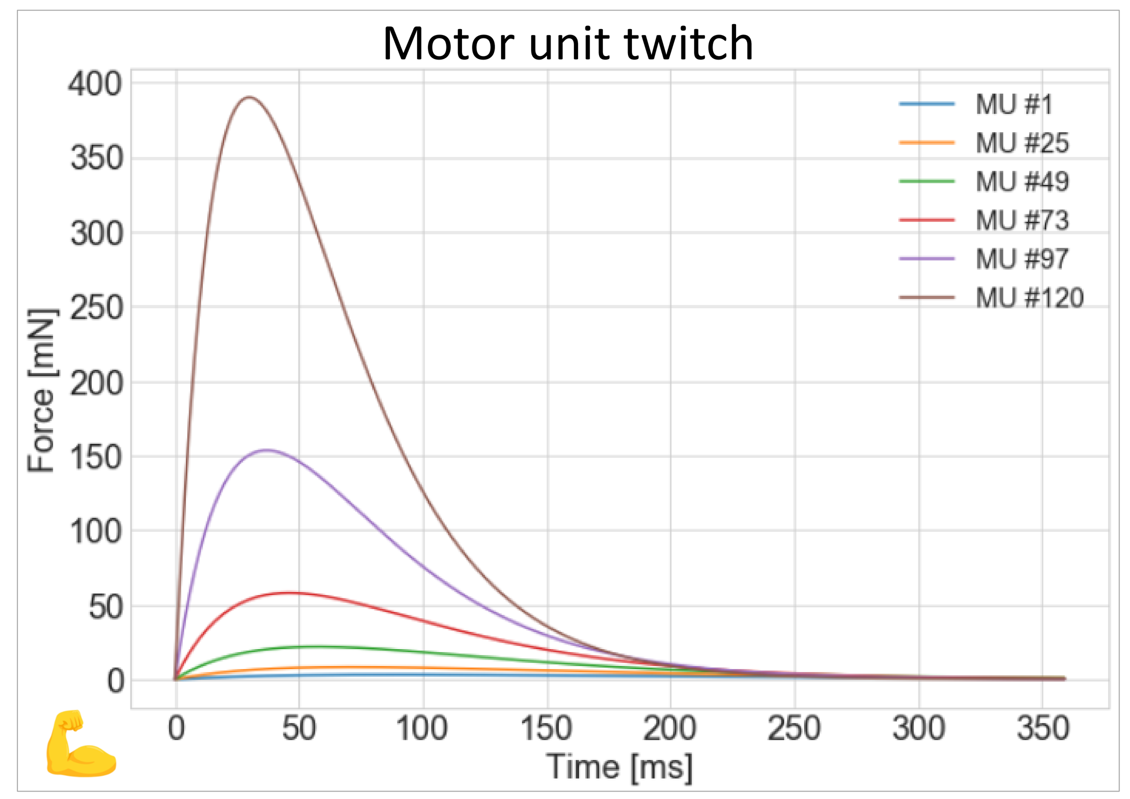
Block diagram of the neuromuscular model



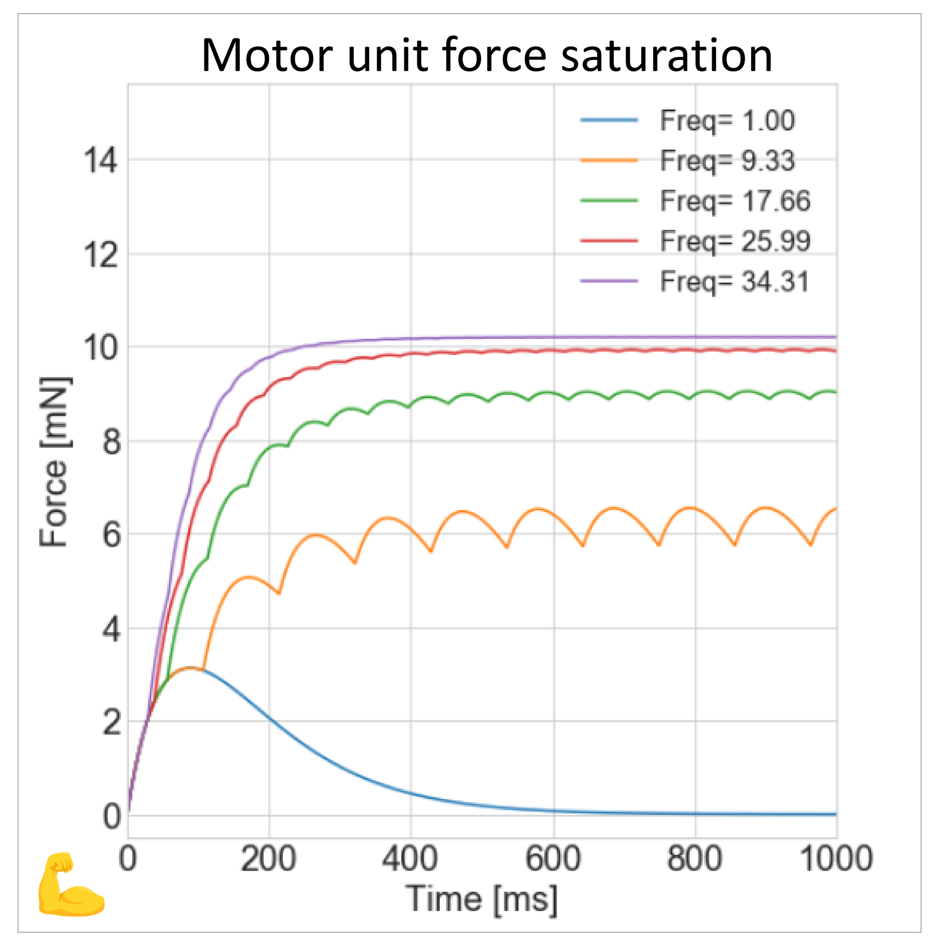
- The **neural command** was based on a phenomenological model, proposed by Fuglevand et al. (1993);
- **Recruitment** and **rate coding** were adopted to represent the activity of a population of spinal motor neurons;



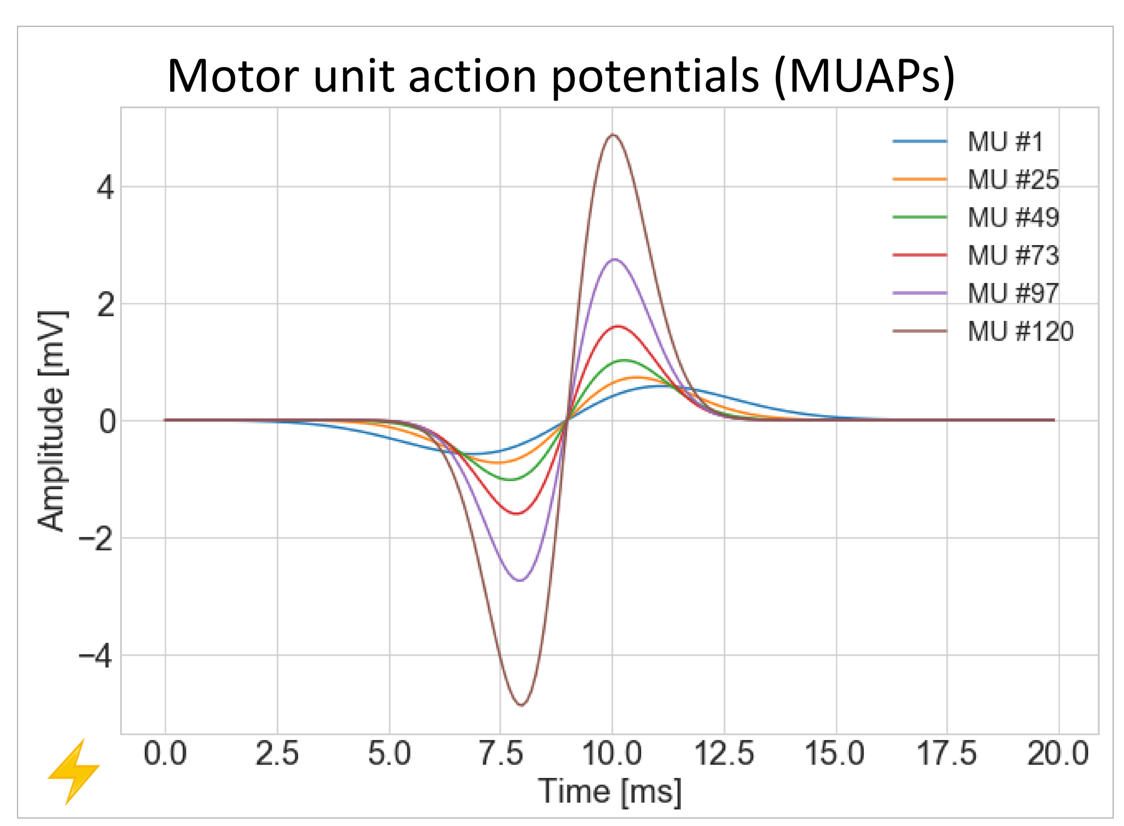
- Discharge rate **variability** and **synchronization** (Yao et al., 2000) between motor neuron discharges was also represented in the model.
- Muscle **force** generated by each motor unit was represented as the impulse response of a second-order critically-damped system (Milner-Brown et al., 1973);



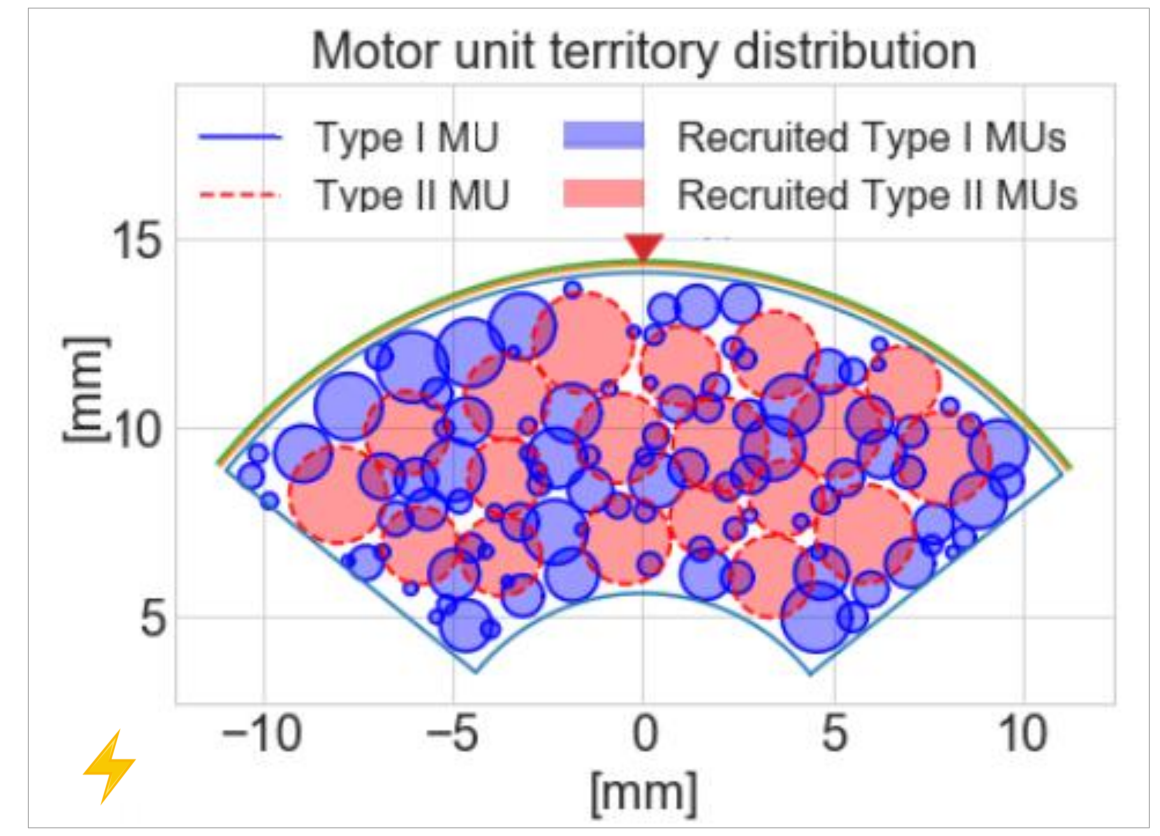
- Muscle force **saturates** (non-linear function) depending on motor unit firing rate.



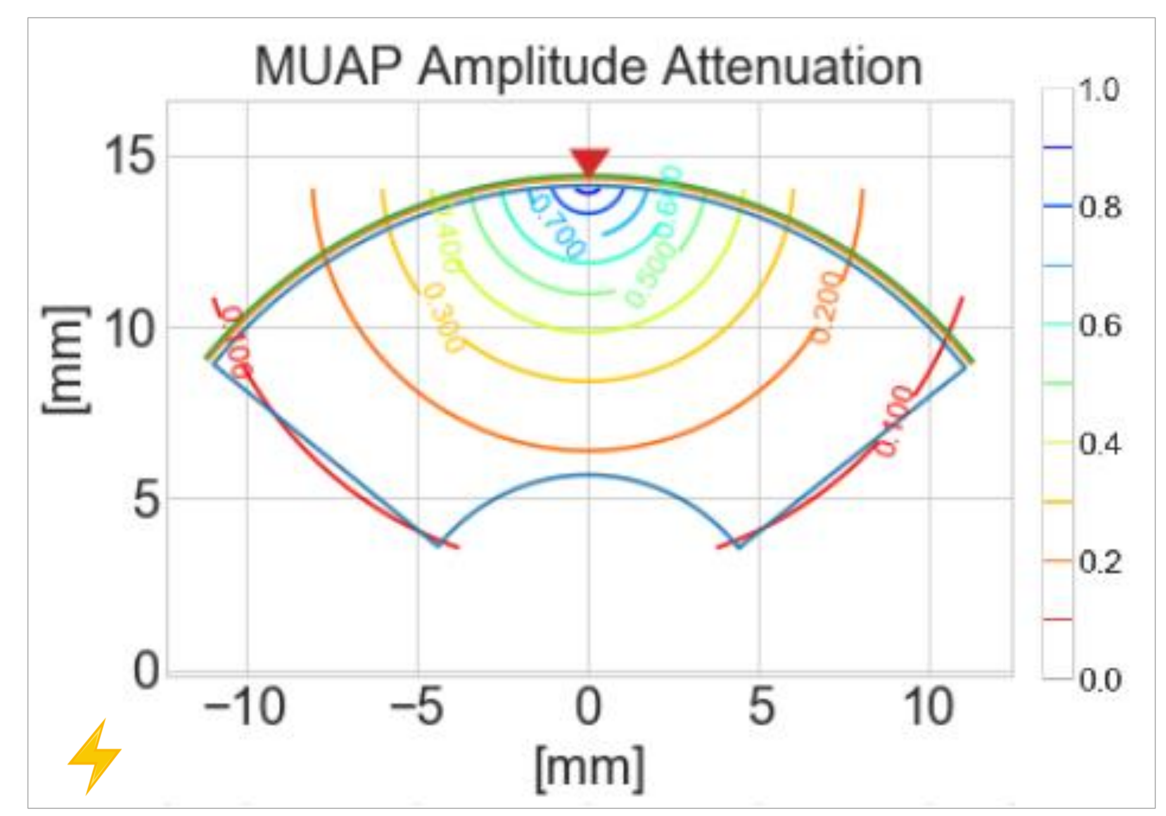
- Motor unit action potentials (**MUAPs**) were represented as **Hermite-Rodriguez** functions (Lo Conte et al., 1994);



- **Morphology** of muscle cross-sectional area and the **distribution** of motor units within the cross section can be altered to represent specific muscle features;

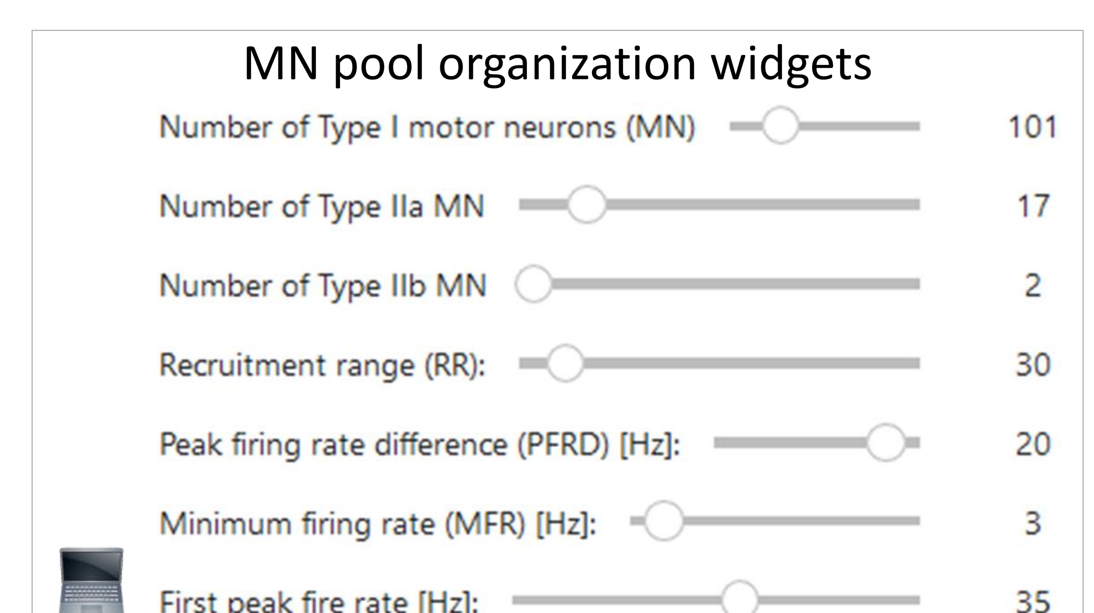


- **Amplitude** and **duration** of **MUAPs** depend on the relative **distance** between surface electrode and motor units position.

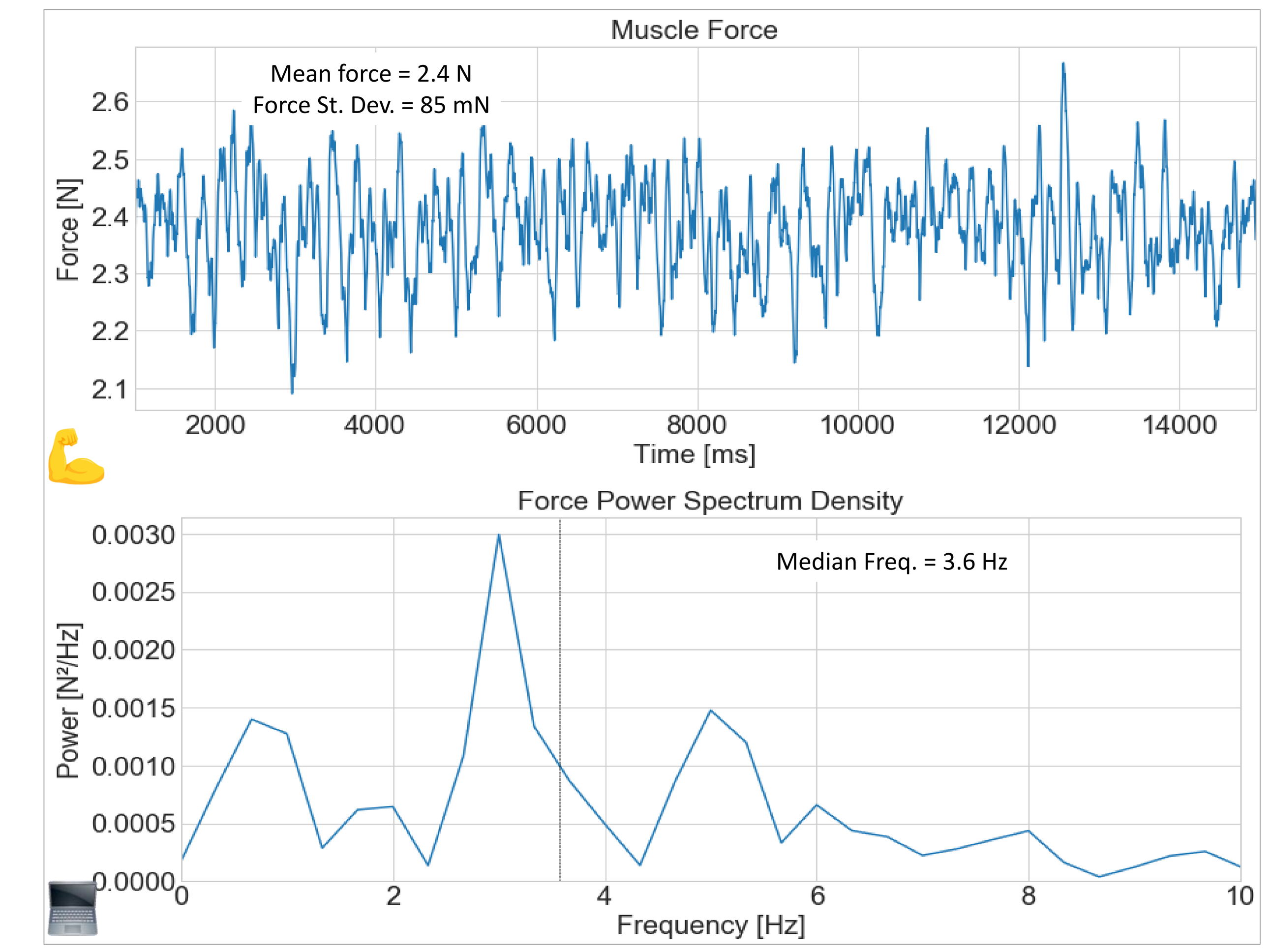


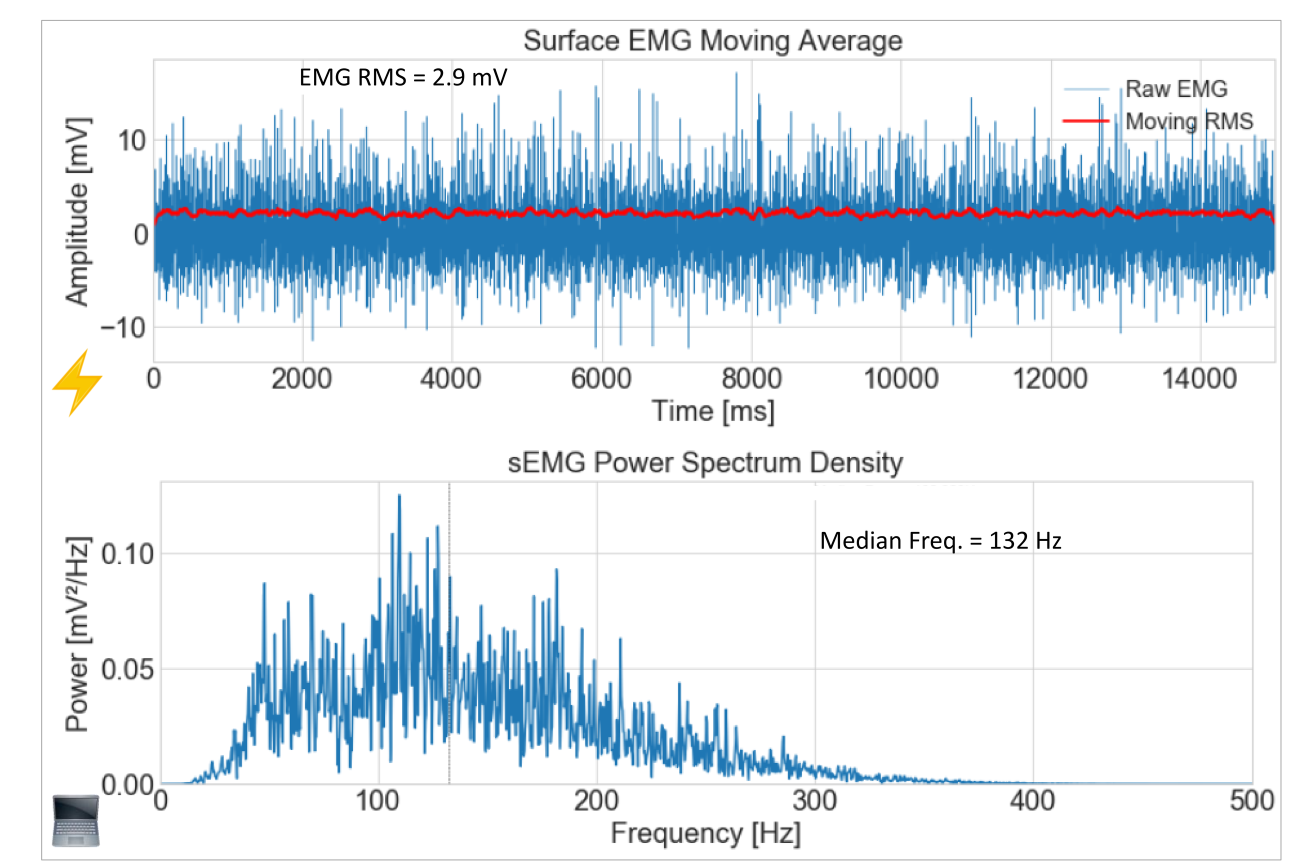
3. Results

- All **properties** of the system can be easily modified to study how each element of the neuromuscular system influences **force** and **EMG** generation;



- Both **time-** and **frequency-domain** analyses of **force** and **EMG** were included in the notebook.





4. Conclusion

- Simulations performed with the notebook shows that **force-EMG** relation, **force variability**, and **EMG power spectrum** produced by the model match experimental outcomes from humans.
- The interactive notebook is freely available at www.github.com/molinaris.

5. Acknowledgements

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