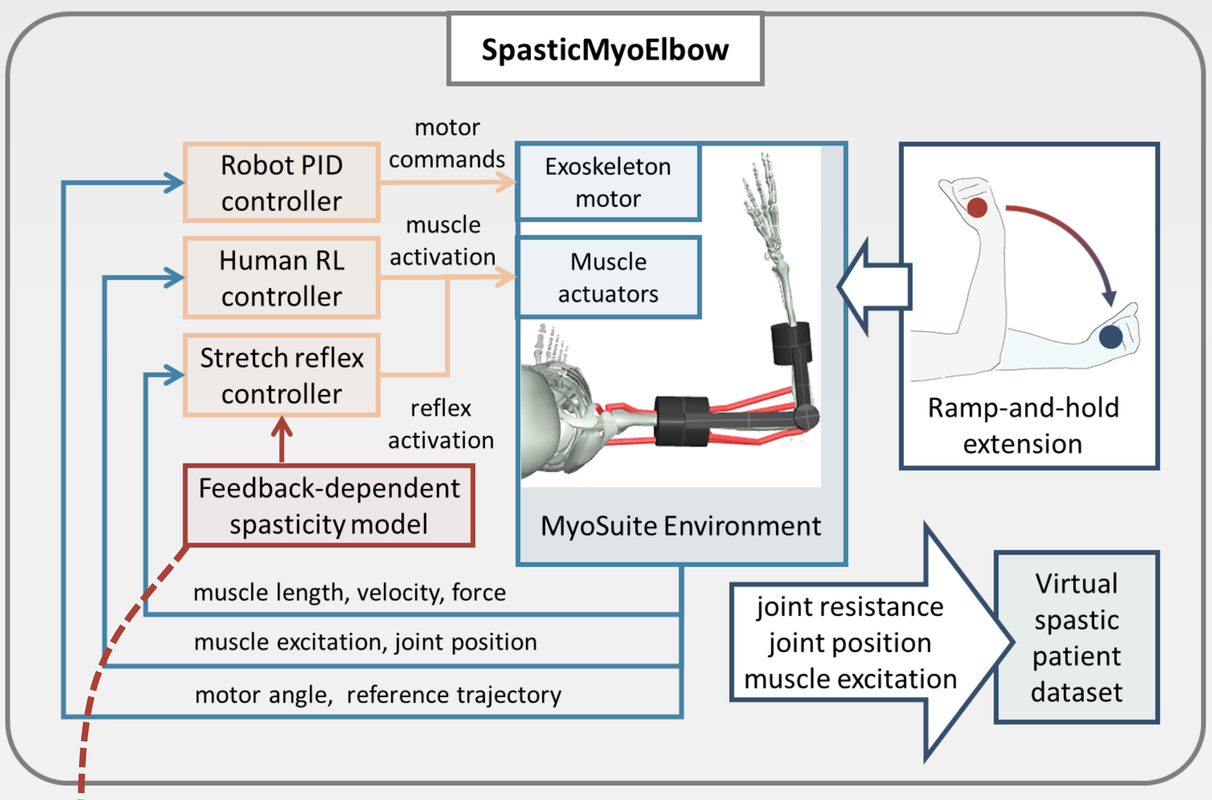
SpasticMyoElbow: Physical Human-Robot Interaction Simulation Framework for Modelling Elbow Spasticity

Spasticity? Abnormal activation of muscles to an externally imposed stretch, which can present as a combination of velocity-dependent, position-dependent, and 'clasp-knife' responses [1]. A complication following neurological disorders, e.g. stroke (17%-38% incidence) [2].

Motivation? The limited experimental data from patients with variable conditions has long posed a major barrier to quantitatively modelling spasticity with robotic measurements and fully validating assessment techniques.



Innovations

- Developing an open and flexible simulation framework, SpasticMyoElbow, for testing spasticity models;
- Comparing the performance of four models of spastic elbows;
- Exploring the application of the tool in the muscle-level spasticity assessment.

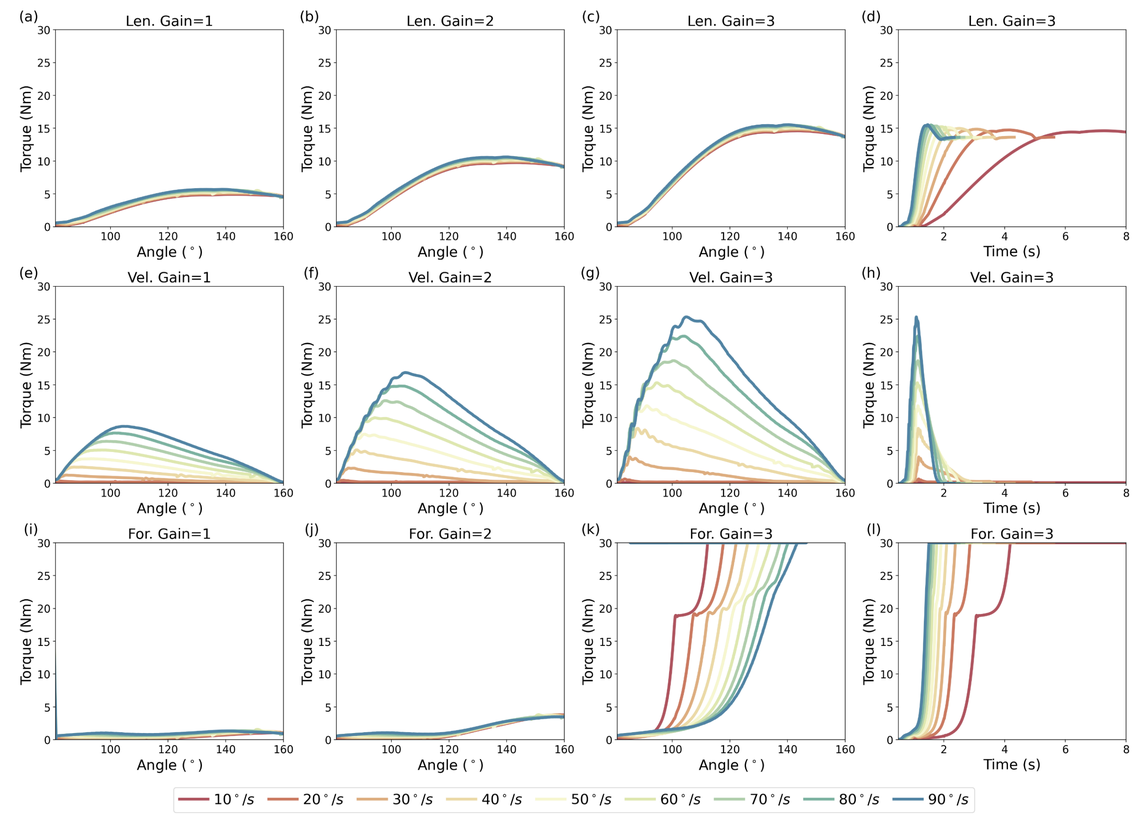


Fig. 2: Reflex torque curves plotted against joint angle and time for the length-, velocity-, and force-dependent spasticity model, with reflex gains ranging from 1 to 3.

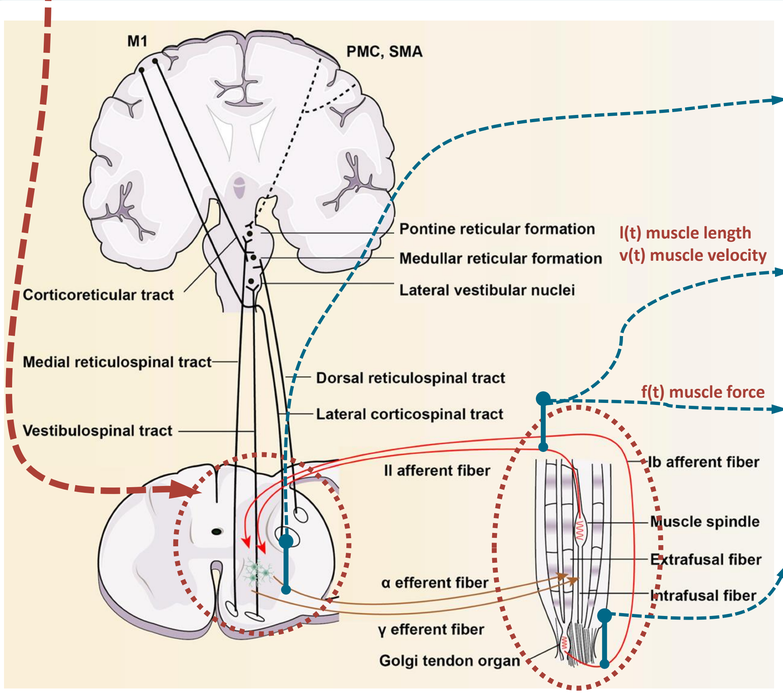


Fig. 1: The descending motor neural pathways and neural reflex circuits related to spasticity [3]

The hybrid activation model of motoneurons:

$$E(t) = C + G_l \cdot R_l(t) + G_v \cdot R_v(t) + G_f \cdot R_f(t)$$

The feedback-dependent reflex models of neural excitation from proprioceptors:

$$R_l(t+\tau) = \begin{cases} (l(t) - l_t)/(l_0 + l_r), & if l(t) \geq l_t \\ 0, & if l(t) < l_t \end{cases}$$

$$l_t = l_0 + \lambda_l \cdot l_r, 0 \leq \lambda_l \leq 1$$

$$R_v(t+\tau) = \begin{cases} A \cdot (v(t) - v_t)/v_{max}, & if v(t) \geq v_t \\ 0, & if v(t) < v_t \end{cases}$$

$$v_t = \lambda_v \cdot v_{max}, 0 \leq \lambda_v \leq 1$$

$$R_f(t+\tau) = \begin{cases} A \cdot (f(t) - f_t)/f_{max}, & if f(t) \geq f_t \\ 0, & if f(t) < f_t \end{cases}$$

$$f_t = \lambda_f \cdot f_{max}, 0 \leq \lambda_f \leq 1$$

$$A = 3 \cdot l_r/(l_0 + l_r)$$

G_l, G_v, G_f: the reflex gains of the spasticity models

λ_l, λ_v, λ_f: the reflex threshold factors

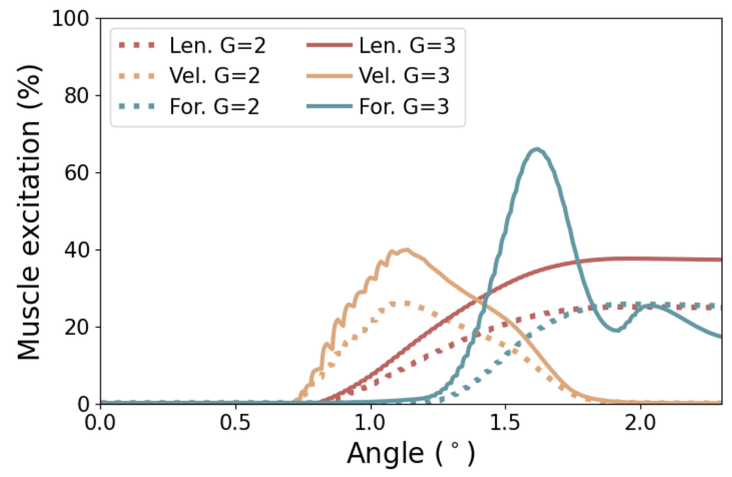


Fig. 3: Muscle excitations of the long head of the biceps brachii modulated by the three spasticity models under a 90 degree/s elbow stretch.

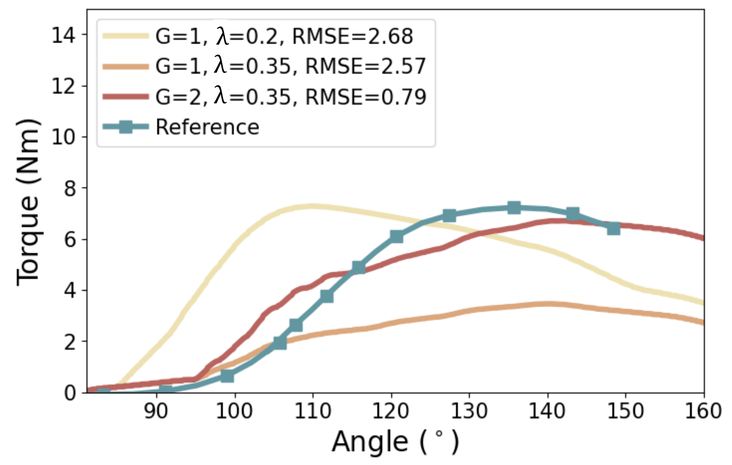
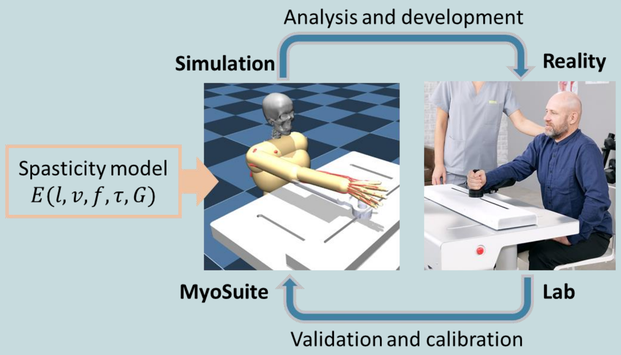


Fig. 4: Reflex torque curves plotted against joint angle for the hybrid spasticity model with different model parameters (G: gains, λ: threshold factor).

Conclusion and future work

- Replicated the constant-velocity stretch experiment in the framework without experimental data input;
- Open source, easy implement and quick simulation speed;
- Will add optimisation algorithms for assessment function;
- Will validate and improve the model with clinical data.





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Ignacio Carlucho, Mustafa Suphi Erden
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