Quantification of Shoulder Joint Impedance Based on Various Arm Postures

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Research question

Can we quantify shoulder stiffness based on different arm postures utilizing of a 4-bar spherical parallel manipulator ?

Motivation

- The human shoulder plays an integral role in upper limb motor function. As the basis of arm motion, its performance is vital to the accomplishment of daily tasks.
- Impaired motor control, as a result of stroke or other disease, can cause errors in shoulder position to accumulate and propagate to the entire arm.
- In order to better quantify shoulder stiffness and damping, we make use of a novel low-inertia shoulder exoskeleton.
- This research focuses on providing low frequency gaussian random yaw perturbations on shoulders of healthy subjects and observe their torque response which is essential in the system identification to calculate inverse response function and measure shoulder stiffness (Fig 1).

Fig. 1

Methodology

- 5 young, healthy participants were chosen to participate in this study to collect their force response based on the filtered gaussian random perturbations.
- The gaussian perturbations with Root mean Square (RMS) value 2 degrees in yaw direction was used with a 3 Hz frequency to provide comfortable perturbations.
- We make use of a time domain system identification methodology known as Short Data Segment (SDS).
- The multisegmented correlations can be defined as:

$$\phi_{yu}(i,k) = \frac{1}{NR}\sum_{r=1}^{R}\sum_{i=t-N/2}^{t+N/2} u(i-k,r)y(i,r)$$

- Where the system dynamics is assumed across each realisation r of the total set (R). N is the number of points in each segment and t is the time at the middle of each realisation.

Conclusions and future work

- As expected, the shoulder stiffness values at the extreme range of motion postures.
- As the amount of variance is still quite high, we need to conduct more trials with additional human subjects to reduce this variance for a reliable stiffness estimate.
- Conducting muscle studies based on the gathered EMG signals.

Results

Shoulder Stiffness Quantification

- Preliminary results show that the shoulder stiffness quantification follows a similar trend across the different human subjects with stiffness values increase in the values towards the extremities (Fig 3).

Percentage Variance Accounted For (VAF)

- In the experimental study, the variance-accounted-for (VAF) metric was utilized to quantify how well the time-varying model of joint impedance explains the output torque data.
- During our quantification studies, we were able to gather the results with a VAF>95% for all the 15 postures.

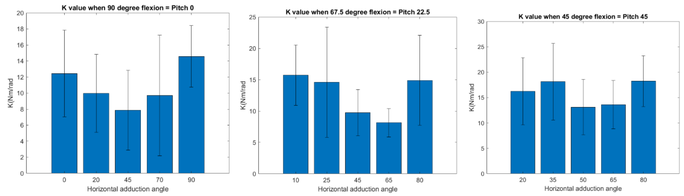

Fig 3

References:
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2. J. Hunt and H. Lee, "Development of a Low Inertia Parallel Actuated Shoulder Exoskeleton Robot for the Characterization of Neuromuscular Property during Static Posture and Dynamic Movement," 2019 International Conference on Robotics and Automation (ICRA), 2019.

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