Human-in-the-loop wearable robot optimization for squat

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Introduction

- Human-in-the-loop optimization (HIL) methods have been used to optimally assist and maximize users’ performance [1, 3].
- Metabolic cost is used to evaluate the performance of the assistance, but has disadvantages of slow sampling rate and delay.
- Metabolic estimate using EMG signals can be utilized to overcome these shortcomings [2].
- Lift-related studies have mainly focused on hip and knee assistance. However, it is revealed that Ankle joint also engages in squat tasks [4].
- In this paper, we suggest optimal squat assistance method with AFO using physiological signals, such as muscle synergies and metabolic estimate.

Methodology

- The research can be split into 2 main steps.
- In “parameter Identification” step, subjects were instructed to do a few squat tasks, and then parameters of synergies and metabolic estimate are searched.
- In “Human-in-the-loop” step, on the basis of the searched parameters, control parameter, torque gain $\Theta$, is searched by minimizing metabolic estimate.

Parameter Identification - Synergy

- 8 muscles are measured: Rectus femoris (RECT), Tibialis anterior (TA), Soleus (SOL), lateral Gastrocnemius (GAS), Vastus medialis oblique (VMO), Vastus lateralis oblique (VLO), Biceps femoris (BICE), and Semitendinosus (SEMI).
- Given signals from either muscles or torque, synergies are identified using Non-negative matrix factorization,
  $$M = WC$$
  where $M$ is either EMG signals or desired torque trajectory, $W$ is synergy weight matrix, and $C$ is the signal of the synergies.

Parameter Identification - Metabolic Estimate

- Metabolic estimate transfer function is the following [2]:
  $$\frac{d}{dt}(P(t)) + \frac{1}{\tau_d} (P(t) + \frac{1}{\beta} EMG(t - \tau_{delay})) \hat{P}(t) = \frac{1}{\tau} EMG(t - \tau_{delay})$$
  where $\tau, \beta, \tau_{delay}$ are rise time constant, rise/decay ratio, and time delay of emg signals.
- Instead EMG signals, muscle synergies are adopted as input.
- Pattern search function in Matlab toolbox is used.

Future Work

- Still design and adjust details in the HIL optimization step.
- Plan to conduct all the step in near future.

Reference