Research question: Does a variable damping controller reduce upper-limb muscle activation during upper-limb human robot interaction (pHRI)?

Introduction

Table 1. Attributes of Current Damping Controllers

<table>
<thead>
<tr>
<th>Damping Type</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>Stable and Safe</td>
<td>Slow</td>
</tr>
<tr>
<td>Negative</td>
<td>Agile</td>
<td>Unstable</td>
</tr>
</tbody>
</table>

![Stable + Agile = Variable Damping](image)

We hypothesized that:

1. During movement (MP), the subject would demonstrate less muscle activation using the variable controller than the positive and near equal between variable and negative.
2. While stabilizing (SP), the subject would demonstrate less muscle activation using the variable controller than the negative and near equal between the variable and positive.

![Figure 2: Image of experiment GUI](image)

Figure 2. Image of experiment GUI

![Figure 3: Image of arm configuration and EMG sensor placement during experiment](image)

Figure 3. Image of arm configuration and EMG sensor placement during experiment

Experiment Design

- The subject was tasked to move in four directions (up, down, left, right) while focusing only on reaching the target as fast as possible.
- Six electromyography sensors (EMGs) were attached to the subject on the brachioradialis, bicep, posterior and anterior deltoids, and lateral and longitudinal triceps.

Results

![Figure 4: Group averages from the MP (1a) and SP (1b).](image)

Fig 4. Group averages from the MP (1a) and SP (1b). MP data is the average of agonists in each direction while the SP data is an average of agonists and antagonists. A 95% CI is shown for each condition. Key: FD= Front Deltoid, RD= Rear Deltoid, BR= Brachioradialis, BI= Biceps, T= Lateral Triceps, LT= Longitudinal Triceps.

Movement Phase

- Activation due to the variable condition was less than the positive in all directions.
- There was 9.94% and 5.11% difference in the up and right directions respectively.
- Variable and negative conditions had near equal (<1%) levels of activation.

Stability Phase

- Variable damping produced less activation than the negative condition in the right (0.52%), down (0.93%), and upwards (0.72%), but this was not large enough to prove significance.
- Variable and positive conditions had near equal (<1%) levels of activation.

Discussion

- Significant improvement in results was achieved from emphasizing synergy with robot as opposed to raw speed.
- Results support the hypothesis that the variable damping reduces muscle activation during movement.
- Warrants further investigation of the variable damping controller in upper limb pHRI.
- Further studies must be run to more closely resemble real-world pHRI

Future Works

The Fall 2020 semester will be spent expanding this experiment to be multi-directional, accommodating medial-lateral and anterior-posterior movement in each trial.

Acknowledgements

I would like to thank Fatemeh Zahedi, Dr. Hyunglae Lee, and Tanner Bitz for their guidance and support throughout the semester.