2D Variable Damping Control of the Robotic Ankle Joint to Improve Trade-off between Agility and Stability

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Will assistance from a wearable ankle robot using a variable damping controller result in a faster, more stable kinematic response than other mechanical environments?

Previous research demonstrated the efficacy of a variable damping controller for performing 1D tasks. In this study, seven human subjects wore an ankle robot that provided assistance through different mechanical environments: positive, negative, and variable damping.

Experiment Structure

<table>
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<tr>
<th>Mechanical Environment</th>
<th>Positive</th>
<th>Negative</th>
<th>Tuning/Practice</th>
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</thead>
<tbody>
<tr>
<td>Trials</td>
<td>45</td>
<td>45</td>
<td>90</td>
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Methods

- Predetermined targets appear within ±15° of the sagittal plane (DP) and ±7.5° of the frontal plane (IE).
- For variable damping trials, damping range is [−1, 2] Nms/rad for DP and [−0.5, 1] Nms/rad for IE.
- The DP and IE controllers are applied simultaneously.

Variable damping was calculated using velocity (\(\dot{\theta}\)) and acceleration (\(\ddot{\theta}\)). User intent recognition was based on changes in kinetic energy scaled by the ankle's inertia, \(\dot{\theta}\ddot{\theta}\).

Results

- Data is normalized so that the initial and target positions are represented by a position of 0 and 1, respectively.
- Time data is shifted so that trials are aligned by the point in which the subject has moved 2° in any direction.
- The variable damping profiles have less overshoot than negative damping and have a faster response than positive damping, and the full damping range is used.

Five different performance parameters were selected for group data analysis.

- Overshoot
- Enclosing Ellipses
- Variability Time
- Mean Speed
- Maximum Speed

All five parameters demonstrate the variable damping controller balancing the trade-off between negative damping and positive damping.

Conclusions

- Fixed damping environments demonstrated that there exists trade-off between ankle agility and stability. Fixed: Stability + Agility
- Variable damping environments combined benefits of positive and negative damping. Variable: Stability + Agility
- The 2D variable damping controller appeared to allow subjects to use the full damping range.

Future Work

- Develop a more advanced tuning method for the variable damping controller.
- Collect more subjects' data to perform statistical analysis.
- Collect EMG data to analyze the response of the muscles.

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