PP-388

Interactive Gait Rehabilitation Through Gamified Real-Time Biofeedback and Adaptive Hip Exoskeleton Assistance: A Preliminary Evaluation

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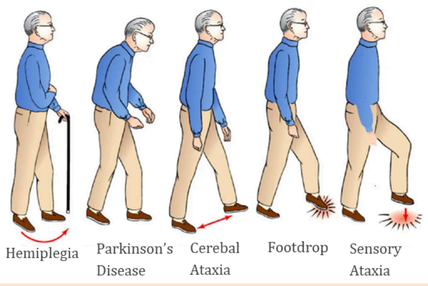
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Bio_Dynamics

Motivation

[1]



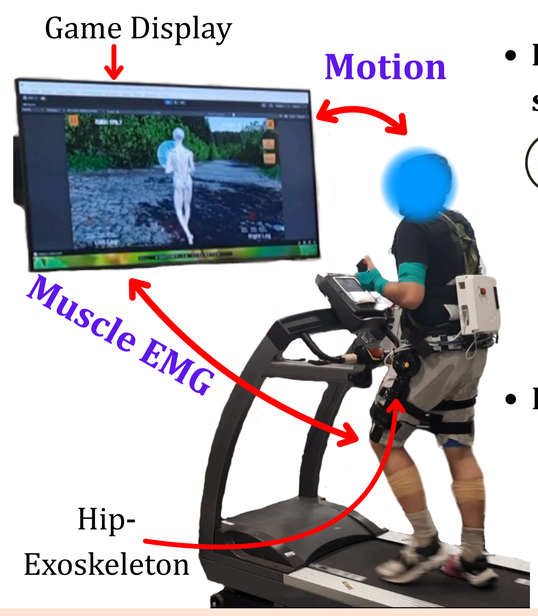
[2]

Reduced quality of life;
Increased caregiver burden and healthcare costs



Rise in gait disorders and mobility impairments

Methods



- **Data was collected from a pilot subject under three conditions:**



No_Torque



Spring Assist Mode

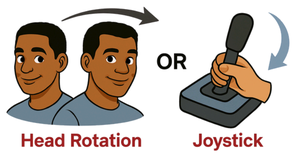


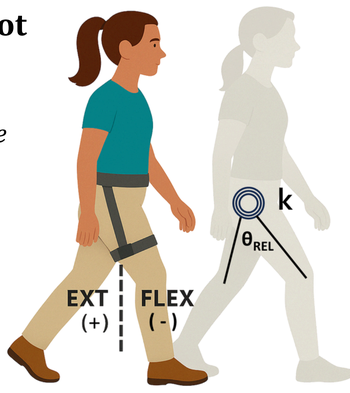
Spring Resist Mode

[3]

$$\tau_R = -\tau_L = k\left(\theta_L - \theta_R\right)$$

- **Direction Control**

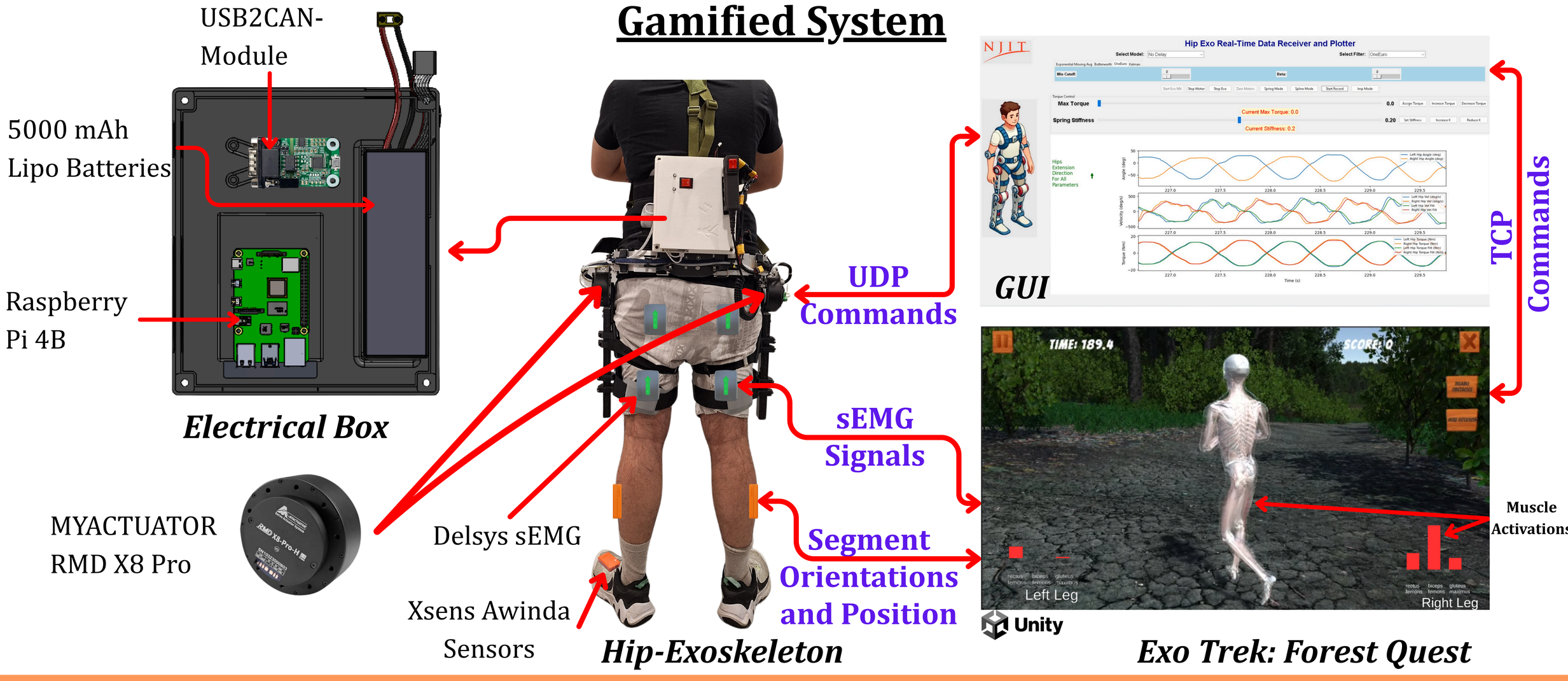




Assistive: In-Phase
Resistive: Out of Phase

$$\theta_{REL} = \theta_L - \theta_R$$

Gamified System



Results

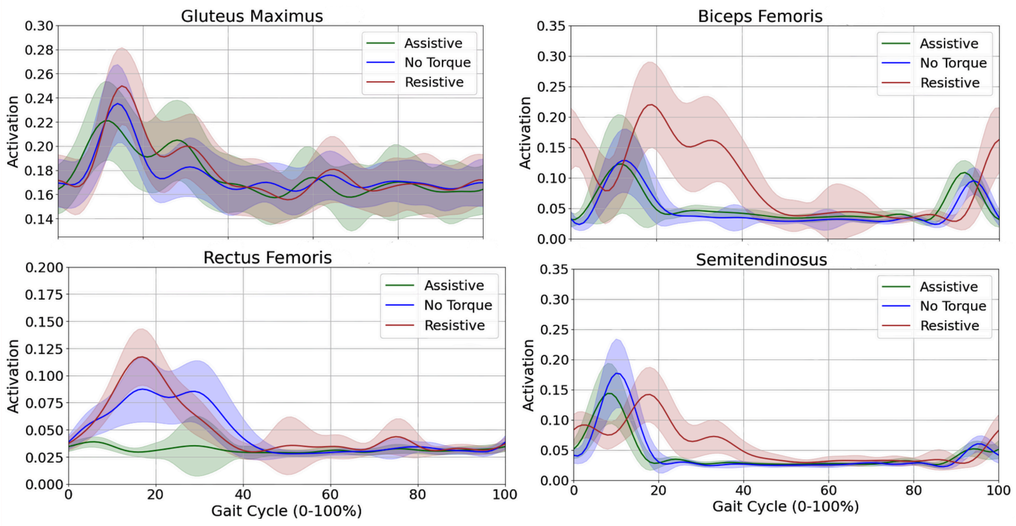
Muscle Activation

- **Gluteus Maximus:** Consistent activation across modes.
- **Rectus Femoris:** Lower activation with assistance.
- **Biceps Femoris:** Highest activation under resistance.
- **Semitendinosus:** Markedly higher activation under resistance; lower in assistive/no-torque.

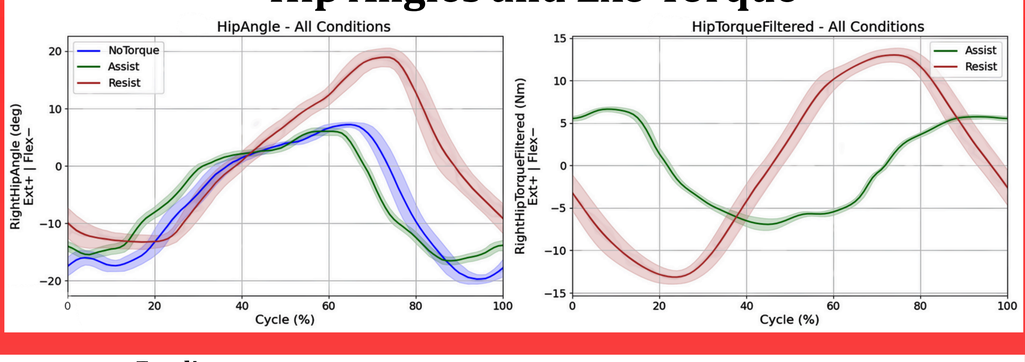
Hip Joint Dynamics

- **Assistive Mode:** Torque aligns with hip angle, aiding flexion and reducing extension effort.
- **Resistive Mode:** Out-of-phase torque opposes motion, promoting higher muscle engagement (especially in extension).

Muscle Activations



Hip Angles and Exo Torque



Key Takeaways

- Developed an interactive gait rehab system with hip exoskeleton and VR biofeedback
- Real-time avatar motion via IMUs; Visualizing muscle contraction with EMG display biofeedback
- Assistive mode → reduced hip muscle activity
- Resistive mode → increased muscle activation
- Highly engaging from subject feedback and questionnaire; potential for personalized therapy
- **Future work:**
  - Expand to larger and gait-impaired populations such as OA, stroke, PD, SCI, CP, and other clinical groups.
  - Transition to a head-mounted display for enhanced engagement, improve game realism, and use pressure insoles for vGRF/COP feedback.
  - Collect data on cost of transportation and heart rate variability under exoskeleton control.

Funding

This work was supported by NIH grants R01NS085122 and R01HD058301, and by NIDILRR grants 90RE5021 and 90REGE0025 through the Rehabilitation Engineering Research Center.

Acknowledgement

The authors would like to thank Erick Nunez for their contributions to the prototype implementation and system setup.

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[2] M. H. Swartz, Textbook of Physical Diagnosis, Elsevier Health Sciences, 2009.

[3] J. Lee, M. E. Huber, and N. Hogan, "Applying Hip Stiffness with an Exoskeleton to Compensate Gait Kinematics," IEEE Transactions on Neural Systems and Rehabilitation Engineering, pp. 1-1, 2021, doi: 10.1109/TNSRE.2021.3132621.