An Individual-specific, Affordable, Robotic Gait Trainer for People with Neurological Injury

rehabilitation with insight from robotics and engineering

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Background

For people with neurological impairments after spinal cord injury or stroke, electromechanical, or robotic, gait trainers have shown significant functional benefit [1]. **While beneficial, robotic gait trainers are prohibitively expensive**. For instance, the most commercially successful robotic trainers cost approximately 20% of a large hospital's annual capital expenditures, making unaffordable for most healthcare facilities.[2]. The high cost comes from the use of multiple actuators that require sophisticated control algorithm.

Figure 1. Lokomat by Hocoma uses four motors to control the movement of four joints and is the most commercially successful gait trainer [3] (left). ALEX exoskeleton is a research device used to examine gait [4] (right).

A single actuator can inexpensively drive a single motion

Objectives

- Design and develop an **affordable** robotic gait trainer using **a single motor**
- Produce **individual-specific** gait patterns with adjustable linkage mechanism

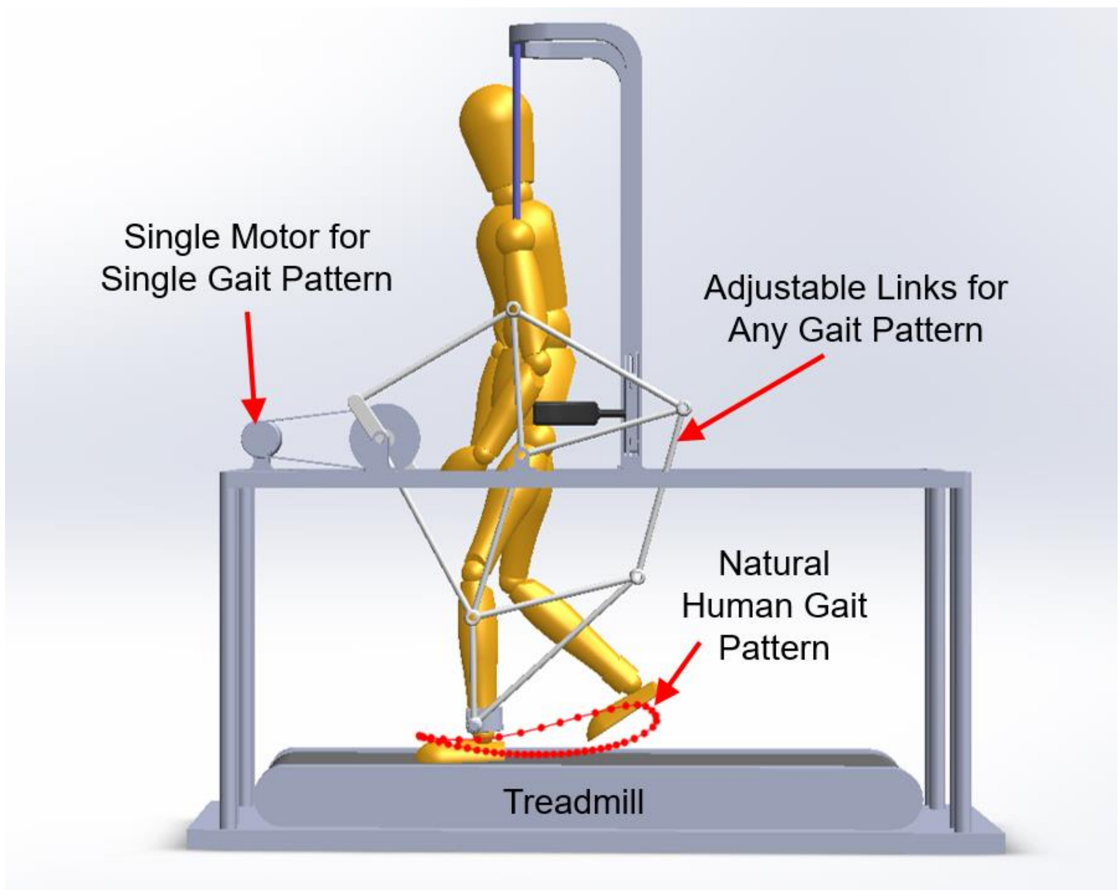

Figure 2. Rendering of robotic gait trainer utilizing a single motor to produce a natural gait trajectory. The device can produce individual-specific gait patterns by adjusting link lengths.

Methods

Reference Gait Data Post-Processing

To create reference gait patterns that cover the variations in gait database from 113 heathy subjects

- **Mean of total 113 healthy subjects' gait patterns**
- **Nine canonical gait patterns with different step lengths**

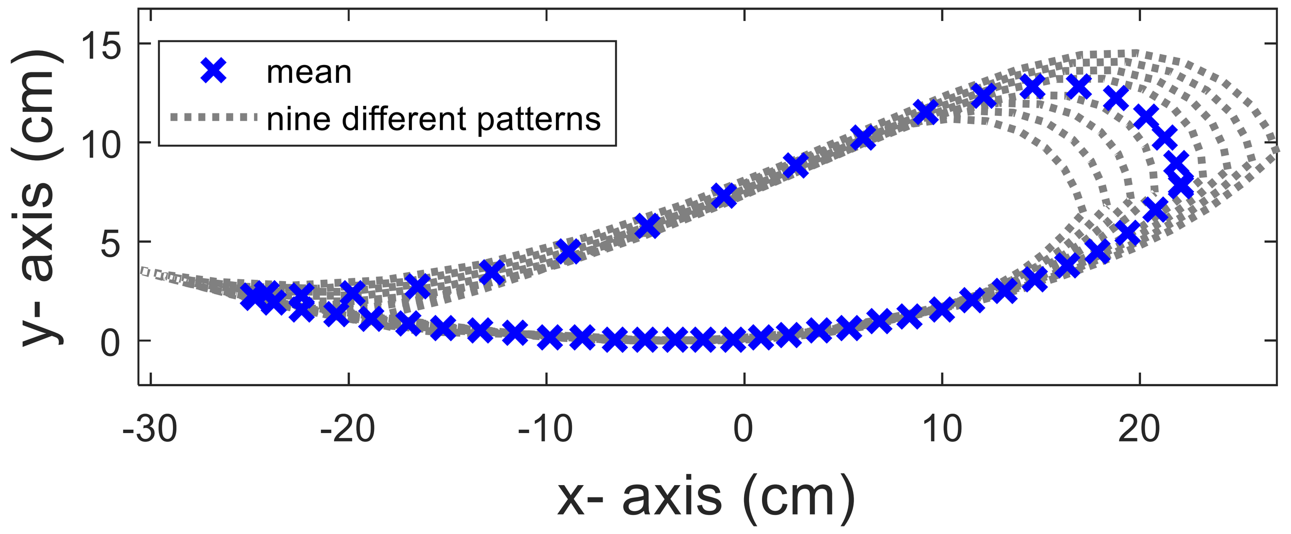

Figure 3. Mean of total 113 healthy subjects' gait pattern and total 9 gait patterns with different step lengths in x-y plane (average of 10 subjects for large, medium and small step lengths and their intermediates).

Optimization

- To find the optimal link lengths that match the mean of 113 healthy subjects' gait patterns

Optimization Formulation

$$\min_{L} \quad J(L) = \frac{1}{2}\sum_{k=1}^{f}\{p_H(t_k) - p_E(\tau_k, L)\}^2$$

such that $L_{Lower} \leq L \leq L_{upper}$

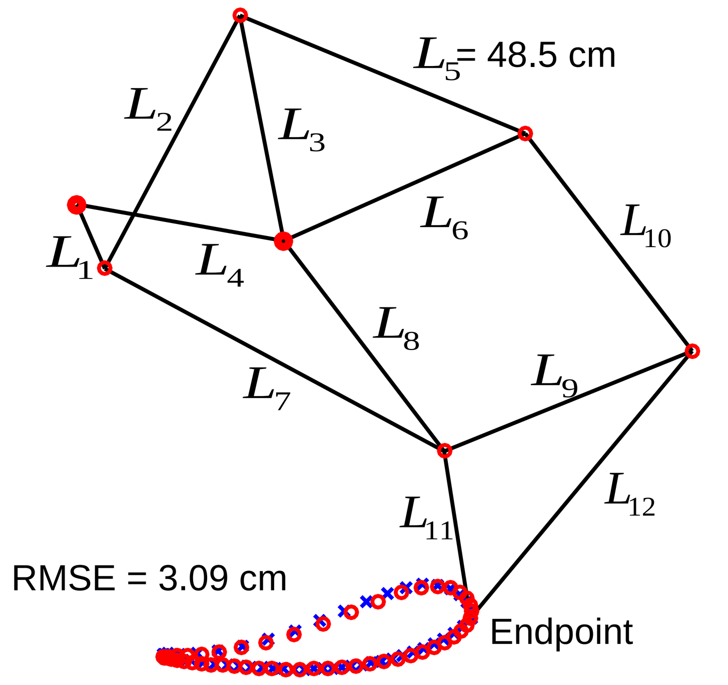

Figure 4. Structure of kinematic mechanism and it's end-point path (red circle) tracking mean gait pattern of 113 healthy subjects

Optimization for Different Gait Pattern

- Minimize link adjustment to fit different gait patterns
- For each number of adjustable links :

Error = min(mean(||RMSE||))

Number of Adjustable links: 2 (L4 and L8)

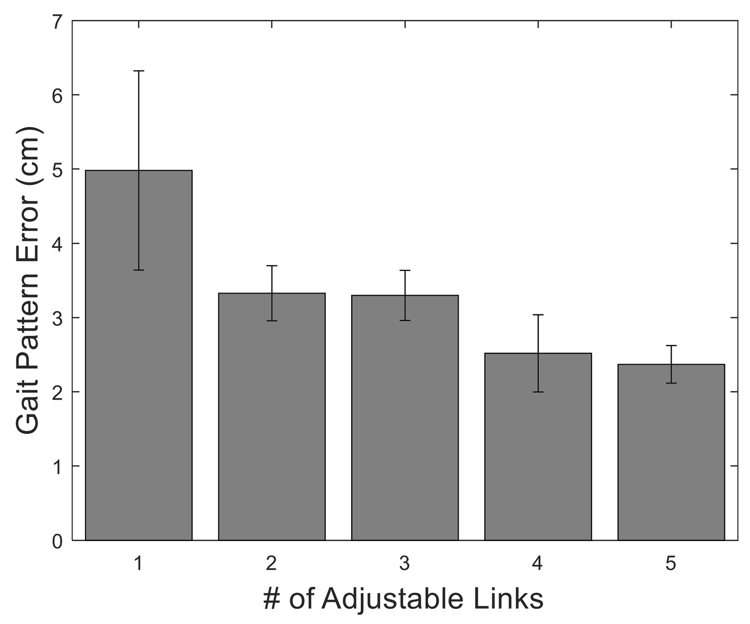

Figure 5. Error curve for number of adjustable links. Adjusting just two links (*L4* and *L8*) accounts for 80% of the maximum reduction in trajectory error.

Results

Simulation Results

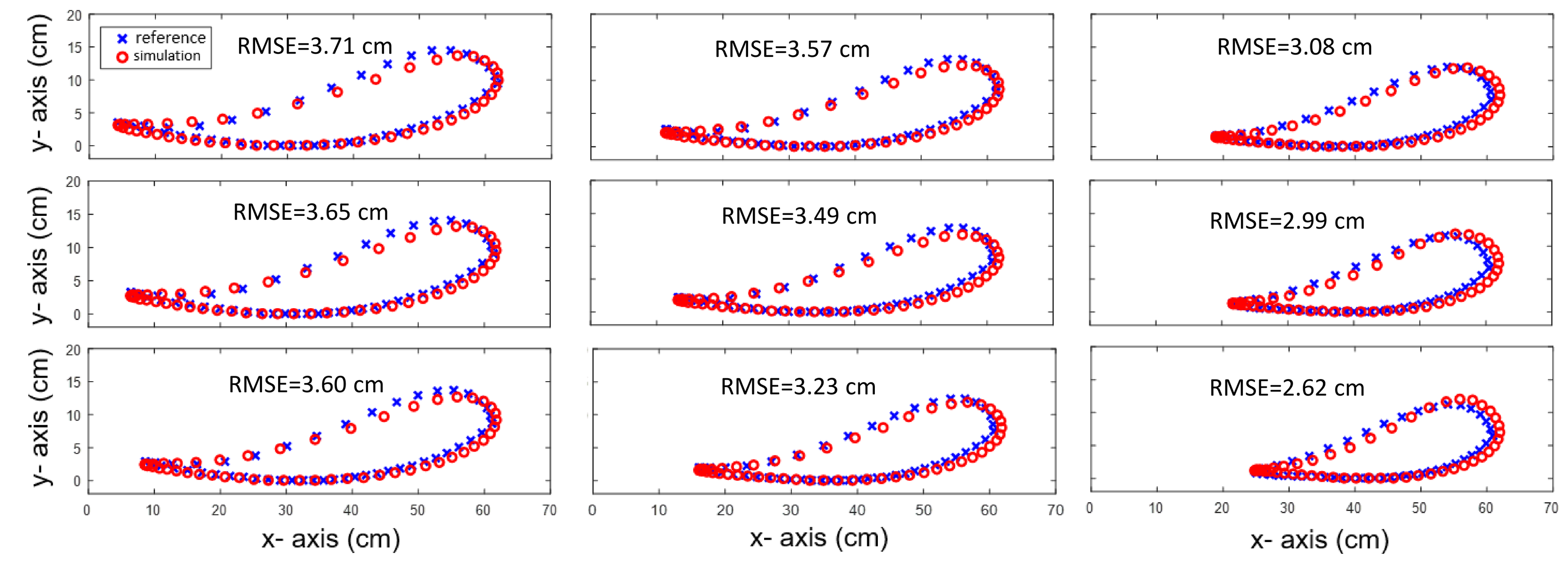

Figure 6. Simulation results of optimization. The reference gait patterns of 9 different step lengths (blue x) and end-point path of the mechanism by adjusting 2 selected links (L4 and L8 in Fig. 4).

Experimental Results

- Physically validated motorized wooden model using optical motion capture system
- Evaluated three gait patterns of different step lengths

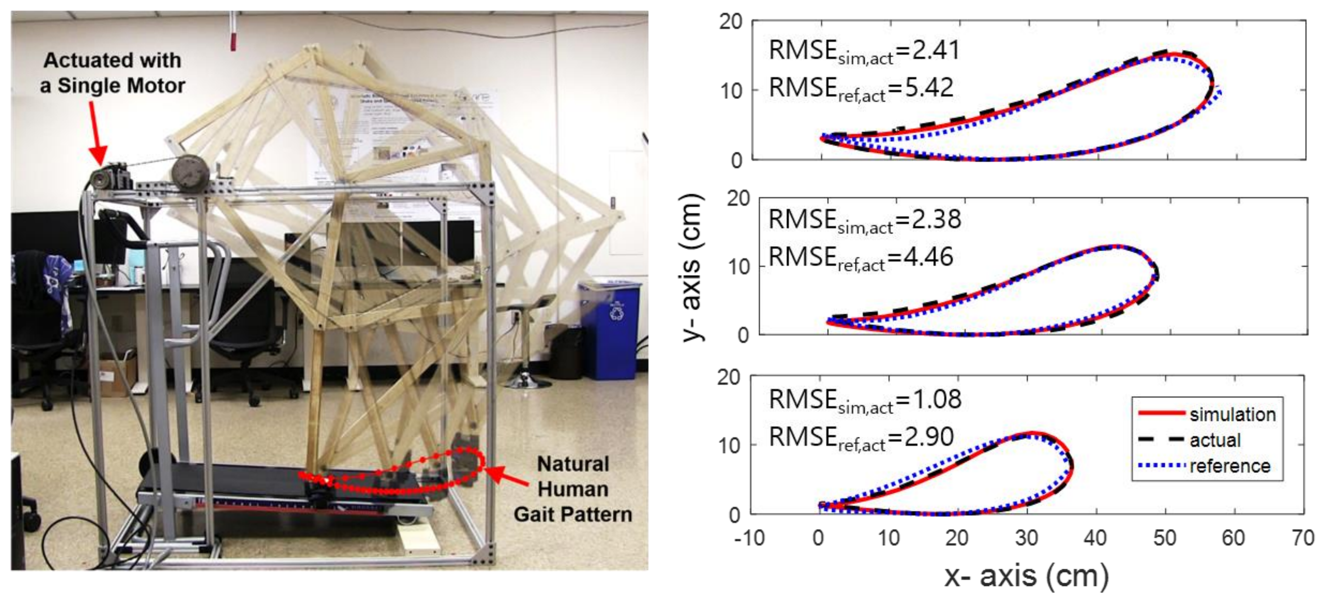

Figure 7. Motorized wooden model of the gait trainer (left) and experimental results using optical motion capture system by adjusting link lengths to match with three different step lengths (large-top, medium-middle and small-bottom, right).

Conclusion and Future work

- Adjusting two links can fit a wide range of step lengths.
- Construct a bilateral alpha-prototype and evaluate the importance of individual-specific gait patterns.

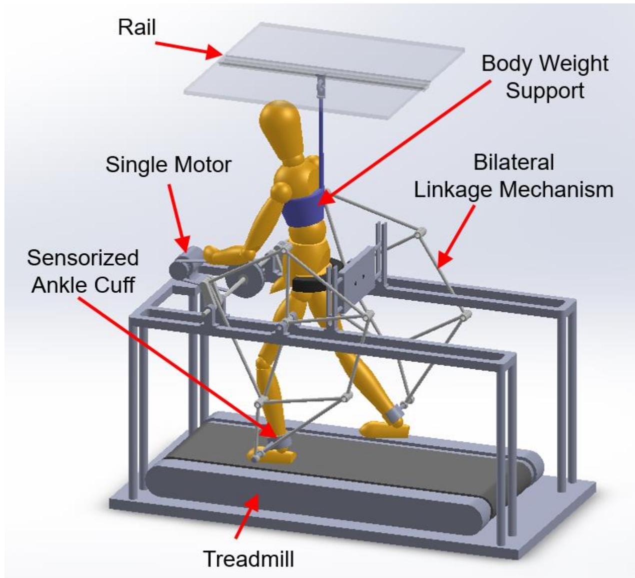

Figure 8. The design of a bilateral alpha-prototype gait trainer.

References and Acknowledgement

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