GaitSole: Closed-Loop Foot Drop Correction for Stroke

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Background

Foot drop is a condition characterized by the inability to dorsiflex the foot while walking due to weakness or paralysis of dorsiflexion muscles controlled by the peroneal nerve.

- Nearly **20-30%** of the **94 million** global stroke survivors living with long-term disability are impaired by foot drop.[1, 2]
- Latest **Functional Electrical Stimulation (FES)** technologies facilitate foot clearance but fail to suppress **maladaptive compensations** like hip-hiking and circumduction.[3] This leads to chronic joint pain and long-term orthopedic complications.[4]
- Our design utilizes **adaptive closed-loop feedback** to reinforce the relevant neural pathways essential for restoring a balanced and symmetric gait.

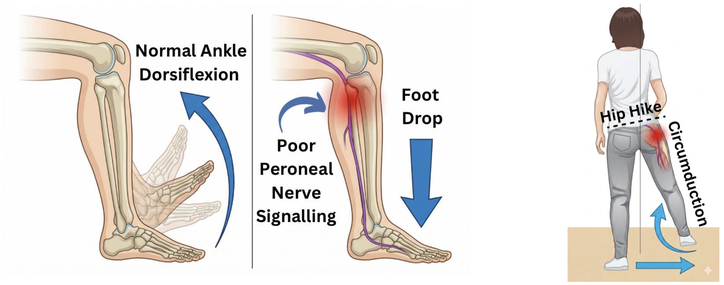

Fig 1. Biomechanics of Foot Drop and Compensatory Gait

Objectives

- **Real-Time Detection:** Identify gait phases and detect compensatory movements using sensor-embedded insoles.
- **Active Correction:** Deliver synchronized FES to the peroneal nerve for controlled dorsiflexion and plantar flexion.
- **Feedback & Adaptation:** Monitor post-stimulation plantar pressure to verify successful foot-drop correction and dynamically adjust stimulation parameters for the next gait cycle.

Methodology

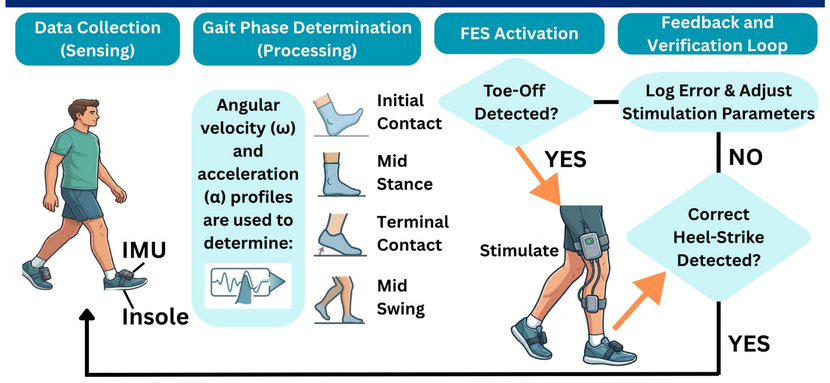

Fig 2. Closed-Loop Logic: Pressure feedback adjusts stimulation for synchronized gait

Results & Discussion

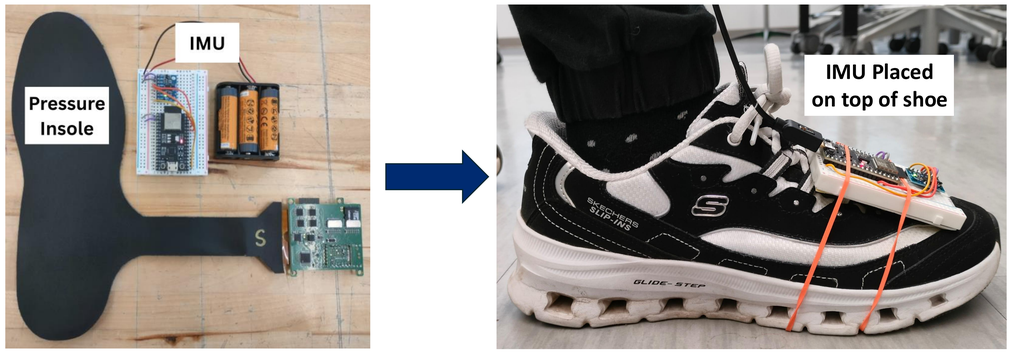

Fig 3. GaitSole Prototype: (Left) Piezoresistive insole with 6-DOF IMU. (Right) Shoe-mounted configuration for data capture.

- Collected walking data across three distinct gait modalities.
- Data Processing Pipeline[5]:
  - **Filtering:** 4th-order Butterworth Low-Pass (6 Hz) to remove high-frequency motion artifacts.
  - **Normalization:** DC offset removal for signal centering.
  - **Event Detection:** Multi-sensor fusion logic identifying MSW, IC, and TC.
  - **Drift Correction:** Zero-Velocity Update (ZUPT) integration at the MS anchor.

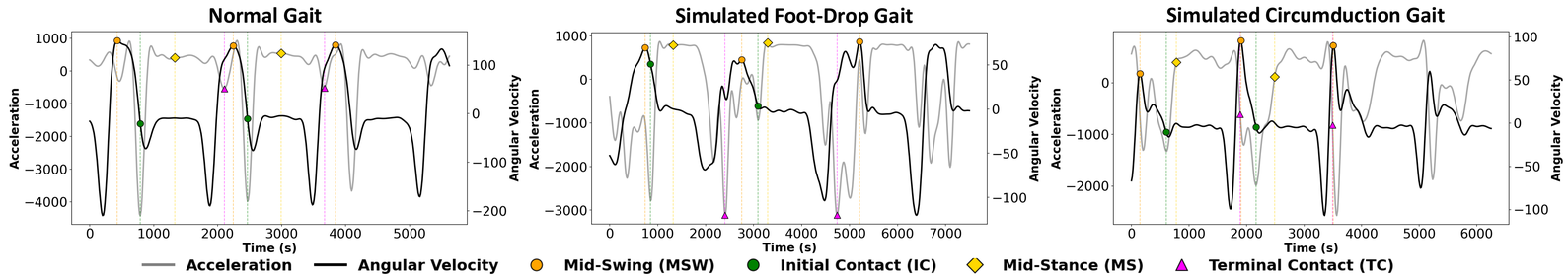

Fig 4. Algorithmic Gait Segmentation: Automated event marking (MSW, IC, MS, TC) across normal and simulated pathological walking modalities.

Impact of Our Solution

Minimizes subjective observations by providing clinicians with objective gait assessments

Evaluates recovery progress by quantifying changes in gait symmetry

Restores natural dorsiflexion and muscle function

Future Work

- **Miniaturization:** Integrate all sensors within a slim ankle sleeve for improved patient comfort and daily use.
- **Adaptive FES Testing:** Conduct clinical trials to refine the closed-loop logic, ensuring the stimulation levels adapt dynamically to varying walking speeds and terrains.
- **Long-term Neuroplasticity Study:** Assess recovery of neural function by quantifying improvements in gait symmetry and post-FES performance.
- **Mobile App Development**: For monitoring progress and clinician-led remote adjustment of stimulation parameters.

Acknowledgement

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References

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