Automated Obstacle-Crossing Events Detection and Joint Kinematics for Fall-Risk Analysis in Post-Stroke Discharge

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The Development of a Wearable Sensor-Derived Algorithm to Predict Falls in Post-Subacute-Stroke Discharge

Background

- Stroke survivors face a high risk of falls.[1-4] Our Cognitive-Motor Behavior Lab team found that those who failed a customized obstacle-crossing test at hospital discharge had a 10-fold increase in fall risk (83% specificity and 67% sensitivity).[5]
- We added wearable IMU sensors to detect gait biomarkers that differentiate fallers from non-fallers. However, this sensors lacks customizability and provides limited kinematic outputs that are readily extractable.

Objective

- To develop a customized automated algorithm that: (1) identifies the precise obstacle-crossing time point, and (2) extracts comprehensive joint kinematics of obstacle-crossing beyond what commercial systems provide, enabling targeted fall-risk biomarker analysis.

Participants

- Ambulatory stroke survivors (n=23) being discharged home from inpatient rehab, mean age 66.2 years (SD 13.1), 28.3 days (SD 16.3) post-stroke.

Sensor-Derived Obstacle-Crossing

- 2 trials of obstacle crossing at a 10% leg-length height positioned in the center of a 10m walking while wearing 8 IMU sensors (Figure 1 & 2).

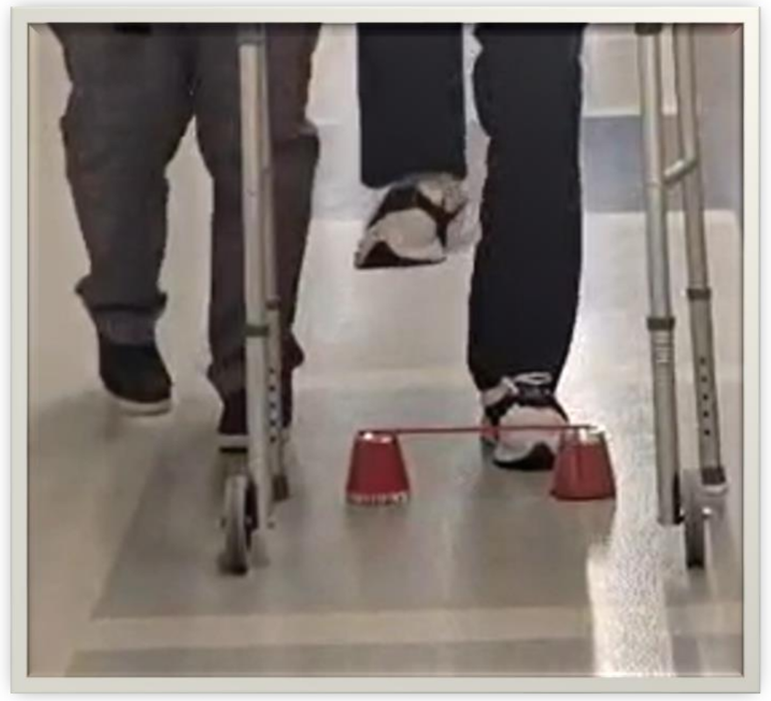

Figure 1.

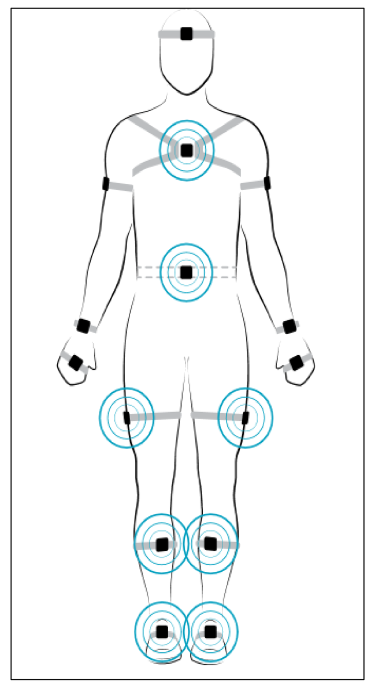

Figure 2.

Methods

1. **Event Detection:** Foot-mounted IMU gyroscopes identified gait events using threshold-based peak detection (Figures 3 & 4).
2. **Trajectory Reconstruction:** Madgwick AHRS and ZUPT algorithms computed 3D foot trajectories and spatial gait metrics (Figure 5).
3. **Precision:** High temporal accuracy (20±10 ms error, ~2% gait cycle) enabled reliable stride-level kinematics.

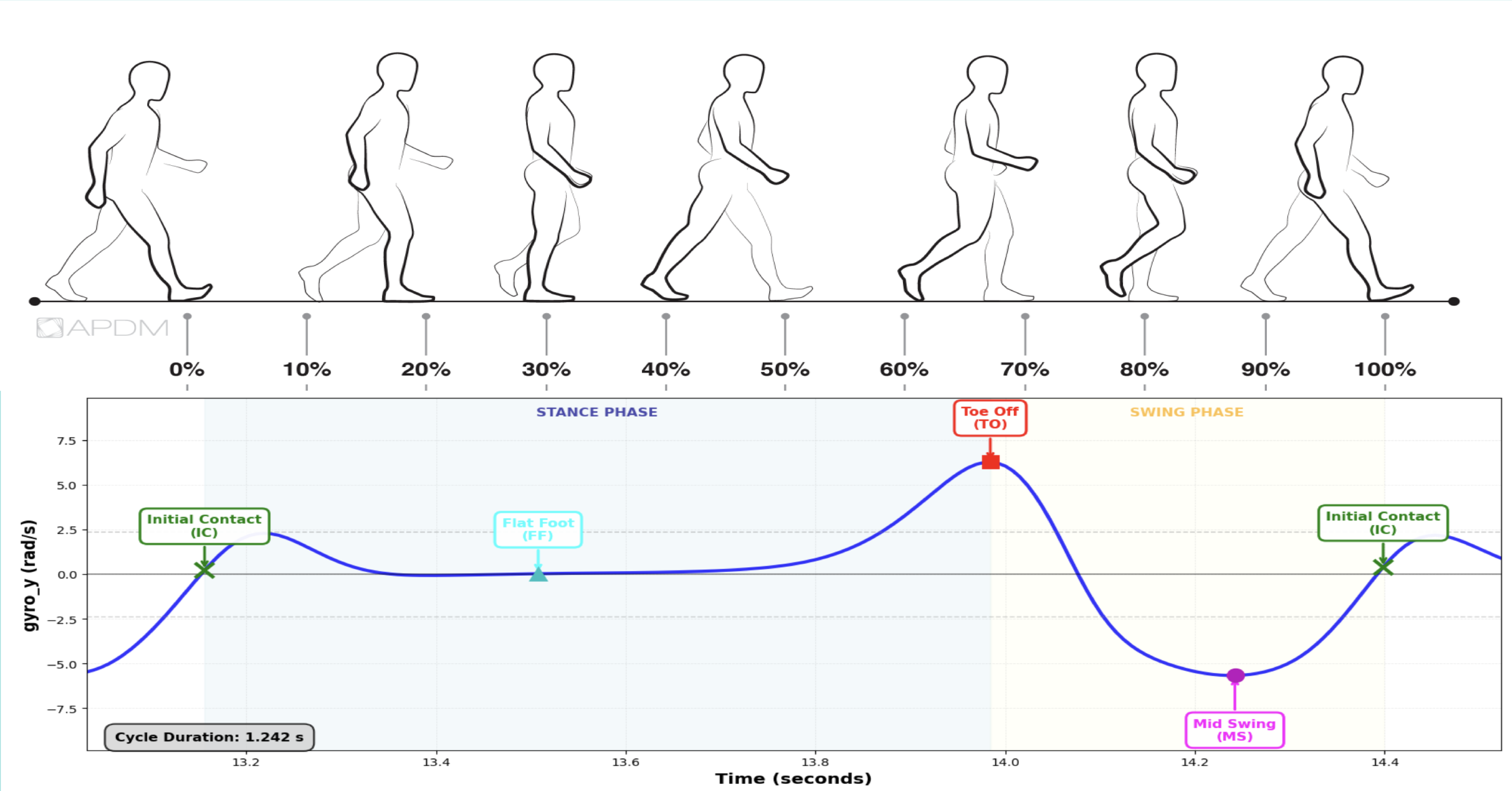

Figure 3. Gait Cycle Analysis (gait events): **IC** (Initial Contact): Heel strike, stance phase begins, **FF** (Foot Flat): Full foot contact, weight stabilization, **TO** (Toe Off): Foot lifts off the ground, swing phase begins, **MS** (Mid Swing): Peak elevation of swing phase, foot clears ground.

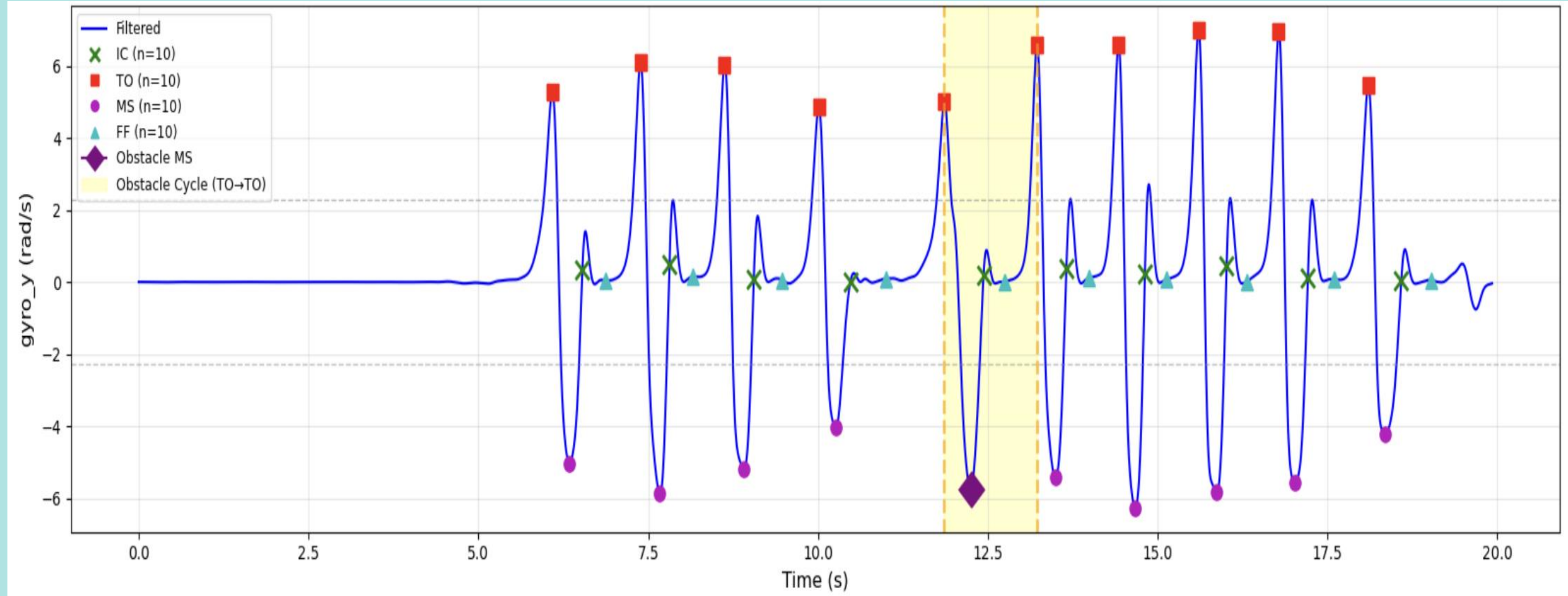

Figure 4. Gait event detection and obstacle-crossing time point during 10m walking.

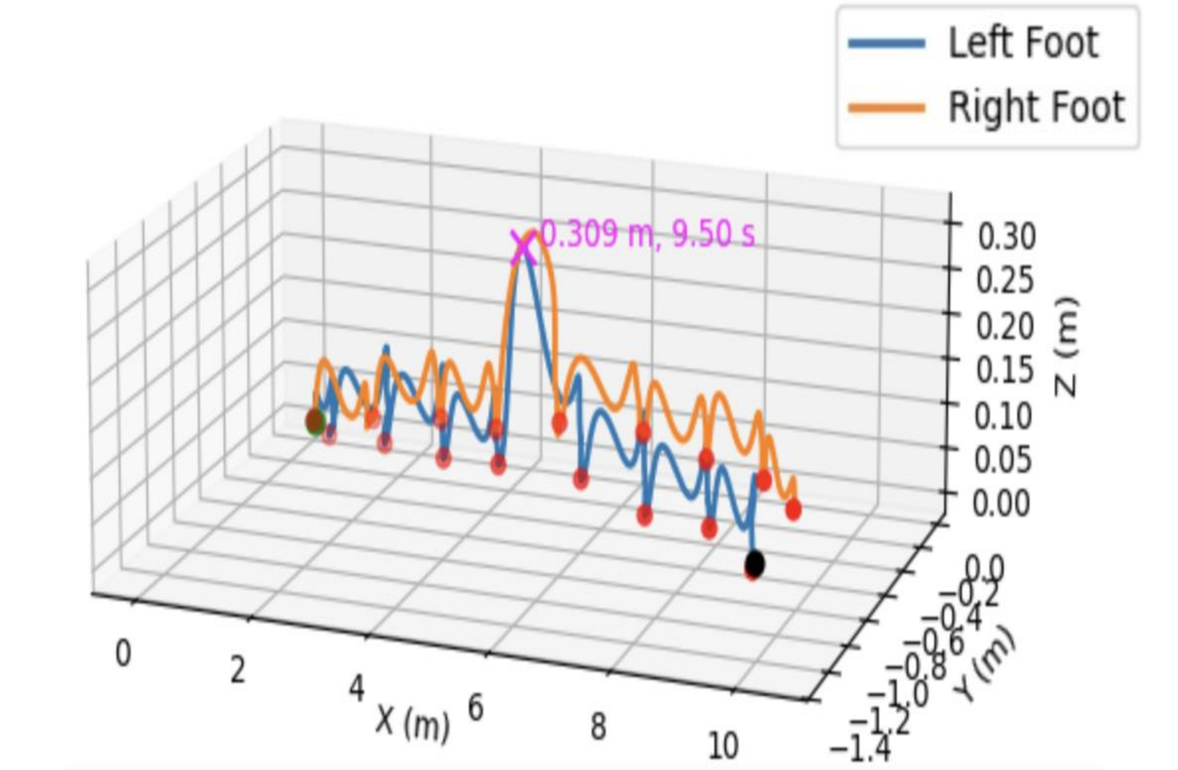

Figure 5. Trajectory Reconstruction. The pink X indicates the crossing point at height of 0.309 m and time of 9.50s

Innovation

- **Custom Pipeline:** Independent software with full control. Automatically detects and validates events for high-volume processing without vendor restrictions.
- **Practical & Scalable:** Deploy anywhere in hospitals, clinics, or home settings.
- **Cost-Effective:** $2,400/sensor vs. $100,000+ for traditional motion capture (such as Vicon). Automated processing eliminates manual analysis.
- **Improved Data Quality:** Automation minimizes human error for faster, more reliable measurements.

Expected Impact

- This framework identifies gait events and extracts objective biomarkers to identify fallers at discharge, enabling personalized early interventions during the critical first year post-stroke. By targeting high-risk fallers early, this approach can reduce fall-related injuries, decrease healthcare costs, and improve quality of life for stroke survivors.

Future Work

- Our **short-term goal** is to validate this framework in larger stroke populations, while our **long-term goal** is to evaluate its longitudinal predictive performance.

References:

1. Forster A, Young J. BMJ. 1995;311(6997):83-86.
2. Kanis J, Oden A, Johnell O. Stroke. 2001;32(3):702-706.
3. Tinetti ME, et al. J Gerontol. 1994;49(3):M140-147.
4. Walsh M, et al. Disabil Rehabil. 2017;39(7):631-640.
5. Prudence Plummer et al. JNPT. 2025; 10.1097

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