Development and preliminary evaluation of a versatile gait event detection algorithm using wearable inertial sensors

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INTRODUCTION

- Children and adults with lower-limb impairments commonly experience atypical walking (gait) patterns as they re-learn how to walk, requiring technologies to detect and/or measure these gait abnormalities.
- Inertial sensors can provide wearable and cost-effective gait analysis, compared to expensive lab technology.
- Objectively determining gait patterns can help quantify an individual's rehab progress, provide biofeedback, or even improve control of their assistive device.
- Gait parameters (e.g. stride duration) are used to assess gait patterns, which can be calculated by identifying gait events (i.e. heel strike and toe-off).

J. Tomasi, "Development and Evaluation of a Sensor System to Monitor the Stance-Phase Control Function of the Automatic Stance-Phase Lock (ASPL) Mechanism," Thesis, 2016.

Previous Research:
- single locomotion mode (level ground walking or stair ascent/descent)
- able-bodied participants [1,2]

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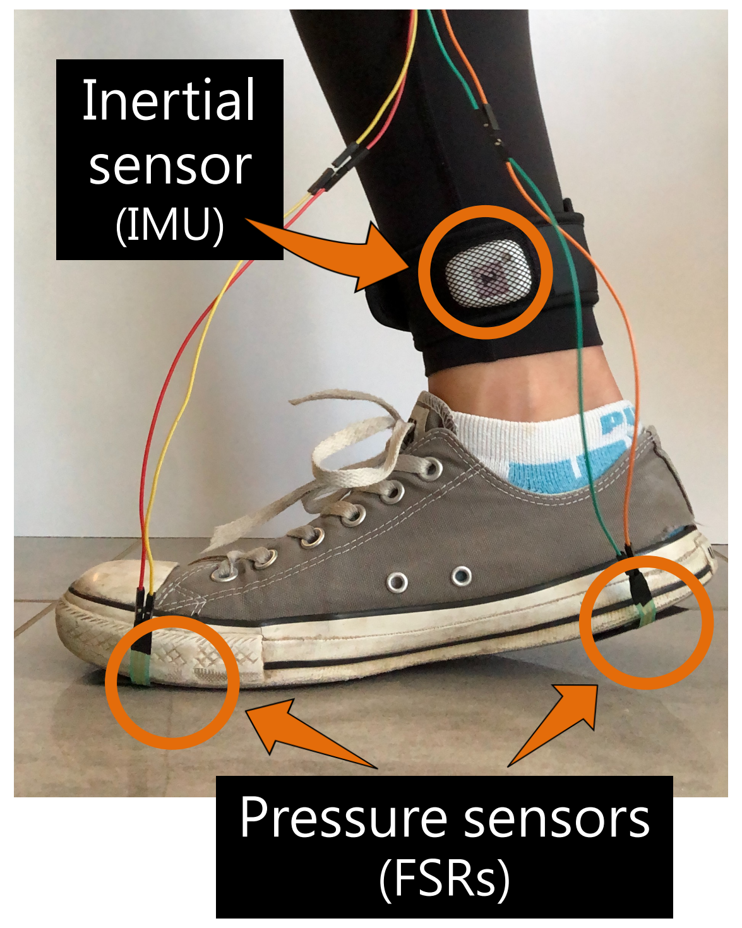
Our Focus:
- multiple mode types
- simulate impairments

PROJECT AIM

Develop a versatile gait event detection algorithm for those with lower-limb impairments that analyses wearable inertial sensor signals

PRELIMINARY SETUP

- A preliminary assessment of algorithm performance was performed on walking trial data.
- Angular velocity signals were collected from inertial sensors.
- Pressure sensors adhered under the foot were used for validation (a common practice).
- Two walking trial samples were collected for each data type and walking mode combination:



Walking Trial Data
1. No alterations
2. Wearing ankle weight to simulate gait deviation due to lower-limb impairment [3]

Walking Trial Modes
1. Level ground walking (LGW)
2. Stair ascent (SA)
3. Stair descent (SD)

An **inertial sensor system** can provide an accessible solution to assess **multi-mode walking patterns** of individuals with **lower-limb impairments.**

METHODS

A Matlab algorithm uses the angular velocity signal to identify heel strike (HS) & toe-off (TO) events ([1,2] used for initial reference):

Filter signal: 7th order median filtering and 2nd order 25 Hz Butterworth filter →

Iterate through data points

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Search for first TO as the first maximum peak

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Detect HS as the next maximum peak after signal has descended across y=0 line and ascended back up

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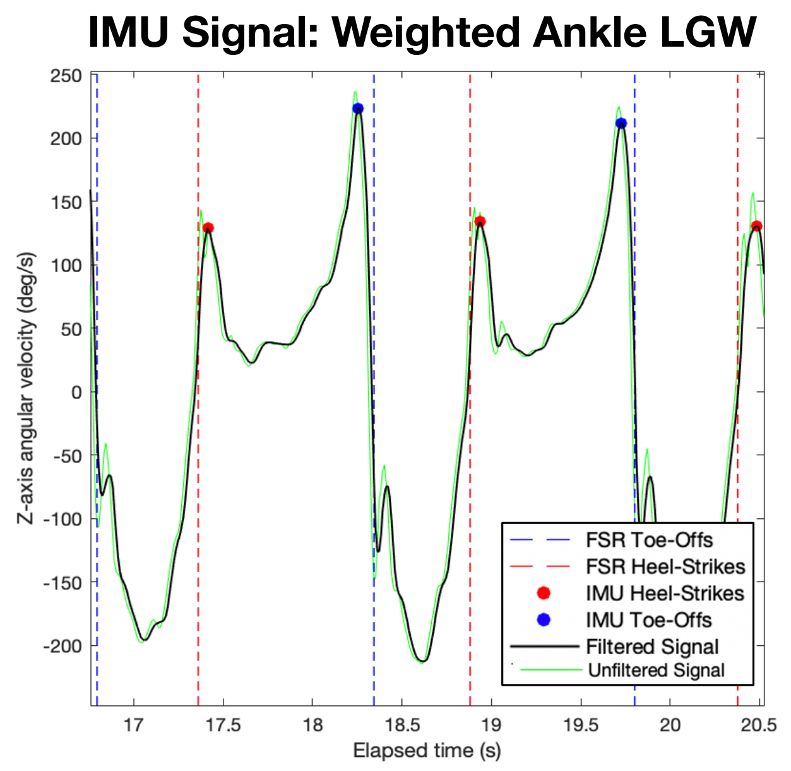
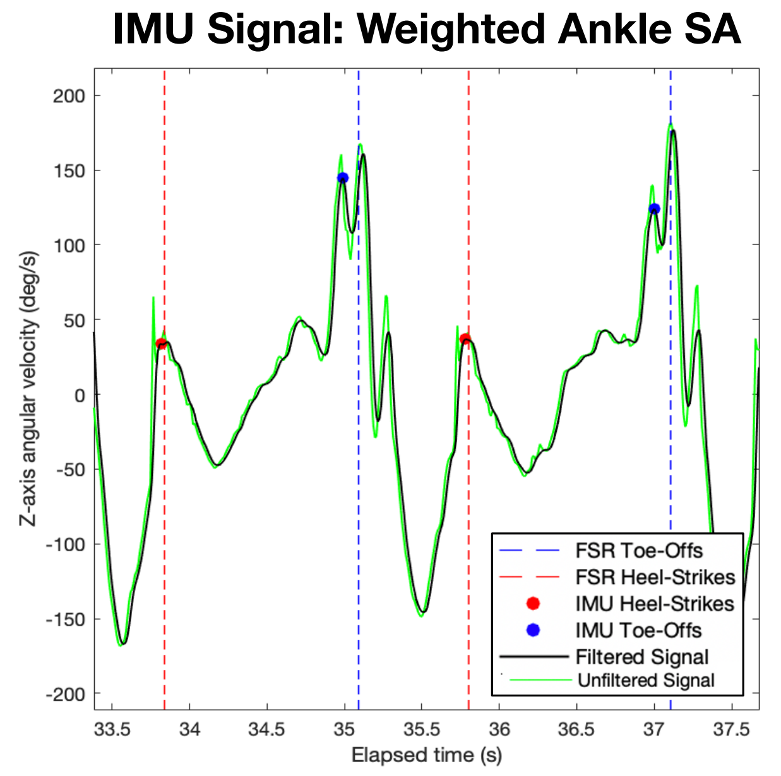
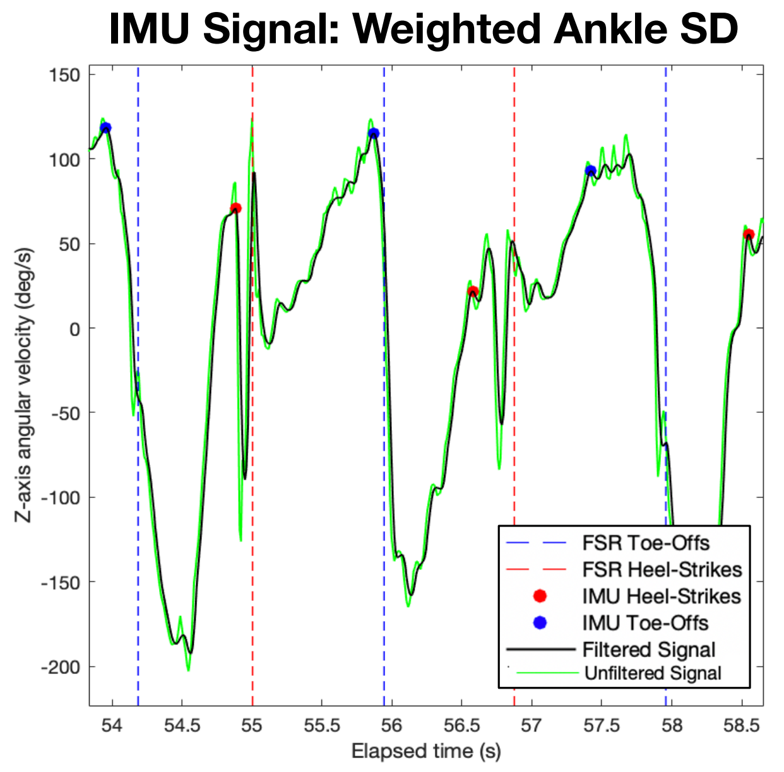
Wait some iterations to avoid false TO detection







Algorithm conditions remained general in order to be applicable for multiple locomotion modes.

RESULTS

- Event detection timing was compared between the algorithm and the pressure sensor data.
- The accuracy of the algorithm's ability to recognize the occurrence of an event was 99%.
- The timing errors (absolute mean differences as a percentage of the average gait cycle ± standard deviation) between the two sets of data were calculated:

	Level Ground Walking		Stair Ascent		Stair Descent	
	HS (%)	TO (%)	HS (%)	TO (%)	HS (%)	TO (%)
Unimpaired	7.87 ± 4.13	4.71 ± 4.15	3.24 ± 2.76	4.84 ± 8.39	13.63 ± 3.39	14.56 ± 5.75
Weighted ankle	3.57 ± 2.73	6.38 ± 2.53	2.49 ± 3.45	6.14 ± 1.31	11.50 ± 4.10	18.15 ± 8.07

CONCLUSION & RELEVANCE

- Although 99% of gait events were detected, future work should include refining the algorithm to improve timing error and performing a validation study of the algorithm compared to a gold-standard, especially on participants with lower-limb impairments.
- Assessment of gait patterns using a wearable system provides a wireless, multi-mode, and cost-effective solution to objectively monitor the gait rehabilitation process of children and youth with disabilities.

(Image: North News & Pictures ltd), "Bladerunner legs transform life of boy who lost his to meningitis," 08-Oct-2014. Available: https://www.mirror.co.uk/news/uk-news/brave-boy-who-lost-legs-4403456.

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