



Background

- Wheelchair users have a need for daily activity monitoring
 - Manual wheelchair users are highly susceptible to repetitive stress injuries [1]
 - Repeated propulsion forces over 80% of maximum capacity results in injuries [2]
- Typical existing activity monitors (Fitbit®, etc.) **don't work** with manual wheelchair users
- SmartWheels are the gold standard [3, 4]
 - Prohibitively expensive for users
 - Require chair modification (swap wheels)



Figure 1: A SmartWheel instrumented wheelchair wheel.

Objective

- Create an **inexpensive** activity monitor for **manual wheelchair users** which continuously monitors the following:
 - Number of propulsion strokes
 - Average travel velocity
 - Amount of time spent active
 - Estimated distance travelled
 - Number of “redline events” (when propulsion force exceeds 80% of maximum capacity)

Method



Figure 2: Original Redliner prototype, assembled using breakout boards

- Velocity and acceleration are calculated using the following, where Δa is the differential centripetal acceleration at two radial points on the wheel and d is the distance between the points.

$$\omega = \sqrt{\frac{\Delta a}{d}}$$

- Utilize Newton's laws of motion to estimate propulsion force using kinematic data and Kalman filtering
- Create a simple prototype to perform the measurements for analysis
- Collect and compare synchronous propulsion data between SmartWheel and Redliner across varied terrain:
 - Linoleum
 - Grass
 - Gravel
 - Pavement

$$\alpha = \frac{\partial \omega}{\partial t}$$

Results

- Velocity and acceleration data from both Redliner and SmartWheel were collected and compared (see Figure 3 for a sample)
 - Both traces are highly correlated between Redliner and Smartwheel data
 - Redliner velocity data is accurate enough to adequately estimate:
 - * Distance travelled
 - * Average velocity
 - Redliner acceleration data is accurate enough to adequately estimate:
 - * Time spent active
 - * Number of pushes
 - * Redline events

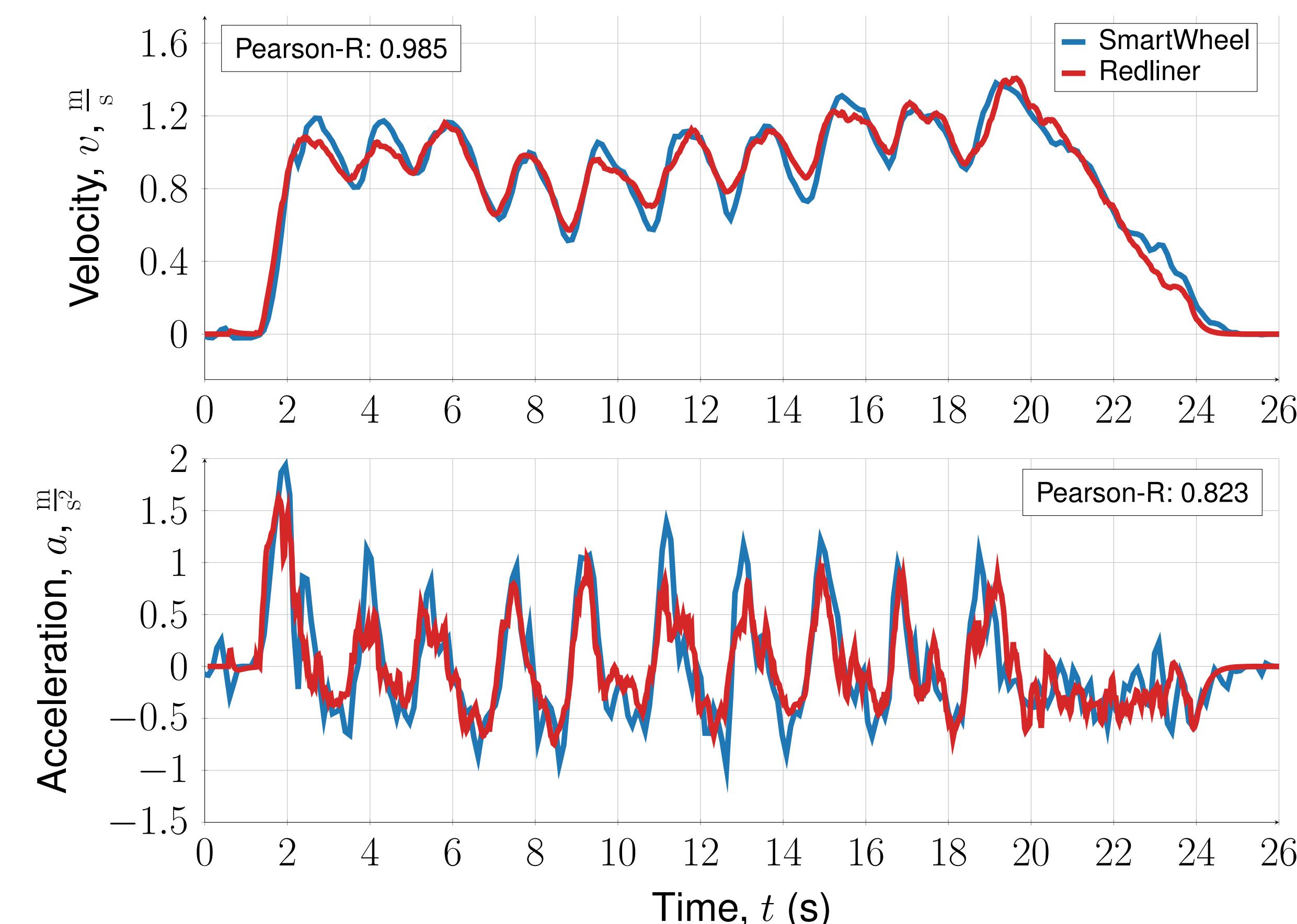


Figure 3: Velocity and acceleration traces for both SmartWheel and Redliner for 10 pushes on rough gravel.

- To detect pushes an algorithm was developed (Figure 4), with sample results shown in Figure 5.

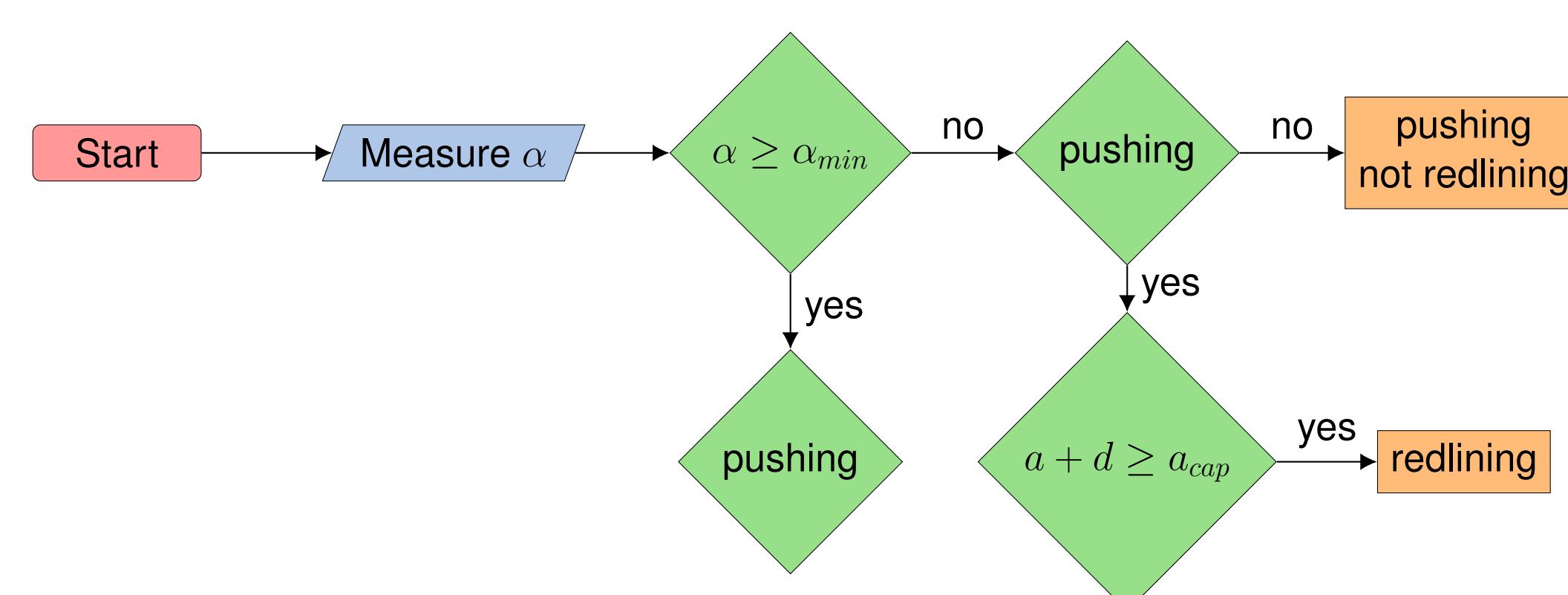


Figure 4: Push detection algorithm

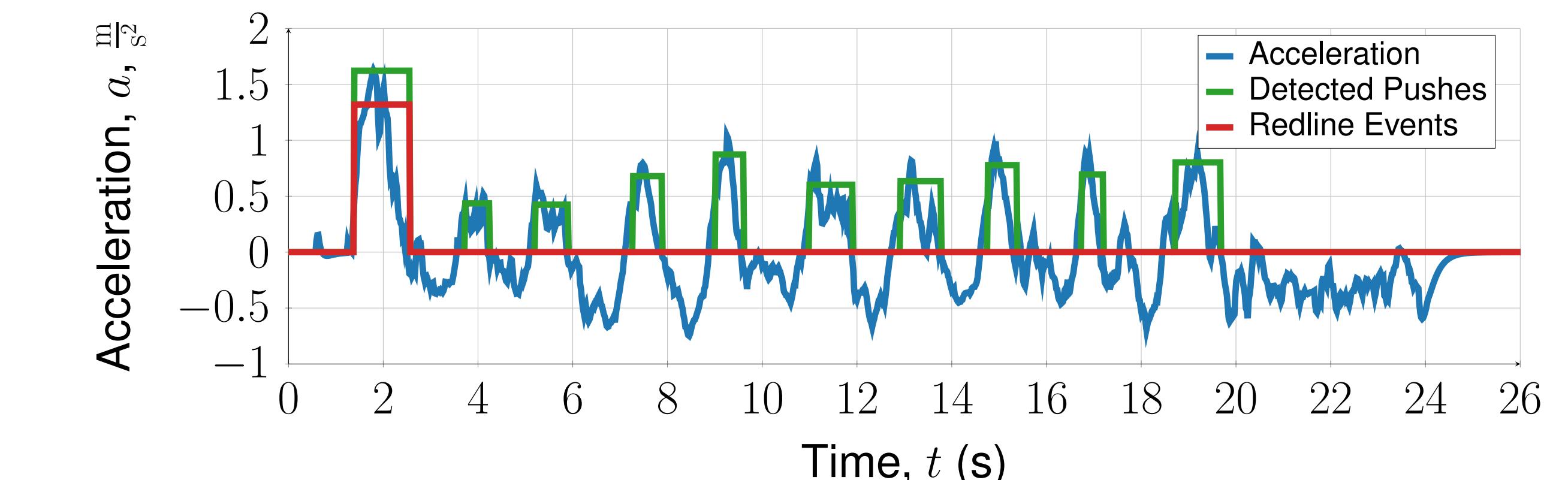
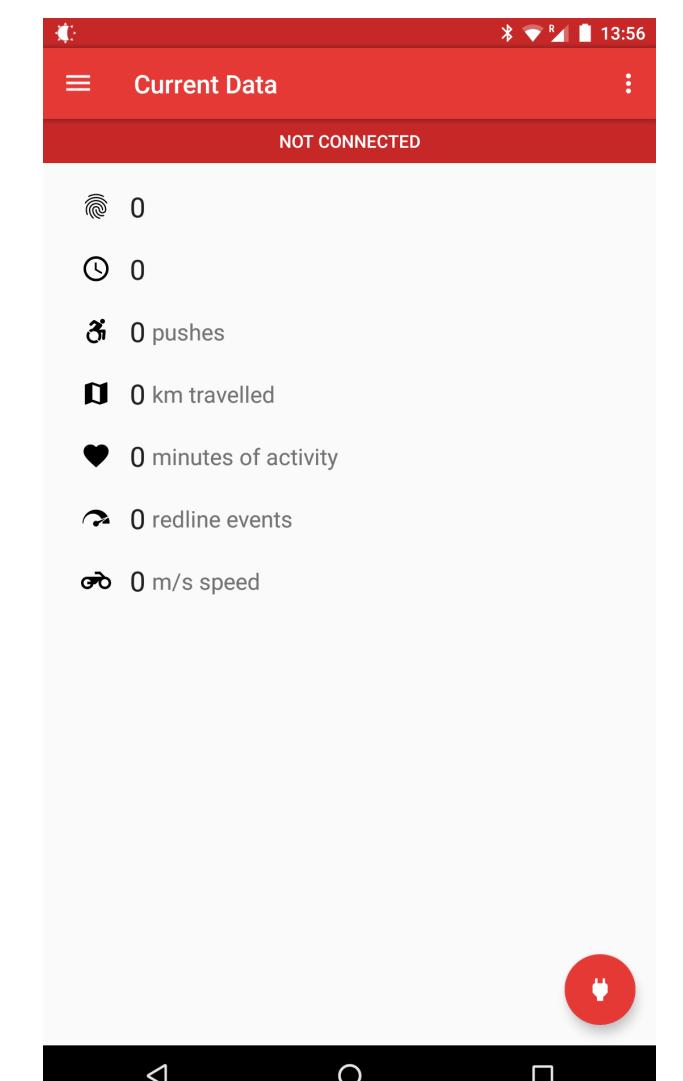


Figure 5: Acceleration, detected pushes, and redlines of 10 pushes on gravel as measured by Redliner.

- Redliner Inc. has been created to move the project forward
 - New prototypes and software developed
 - More extensive testing



(a) Second Redliner prototype version using a custom PCB built for further testing.



(b) Android app developed to interact with Redliner and upload data to a cloud-based dashboard.

Figure 6: Ongoing commercial development of Redliner

Conclusions

- Redliner is a new activity monitor for manual wheelchair users
- Redliner has been validated against expensive SmartWheel devices
- Redliner should be available as a commercial device soon

References

- [1] JL Mercer, M Boninger, A Koontz, D Ren, T Dyson-Hudson, and R Cooper. Shoulder joint kinetics and pathology in manual wheelchair users. *Clinical Biomechanics*, 21:781–789, 2006.
- [2] L Hills. Every push matters. Master's thesis, University College London, June 2011.
- [3] KT Asato, RA Cooper, RN Robertson, and JF Ster. Smartwheels: Development and testing of a system for measuring manual wheelchair propulsion dynamics. *IEEE Trans Biomed Eng*, 40:1320–1324, 1993.
- [4] R Cowan, M Boninger, BJ Sawatzky, BD Mazoyer, and RA Cooper. Preliminary outcomes of the smartwheel users group database: A proposed framework for clinicians to objectively evaluate manual wheelchair propulsion. *Archives of Physical Medicine and Rehabilitation*, 89(2):260–268, 2008.

Acknowledgements

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