



## 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

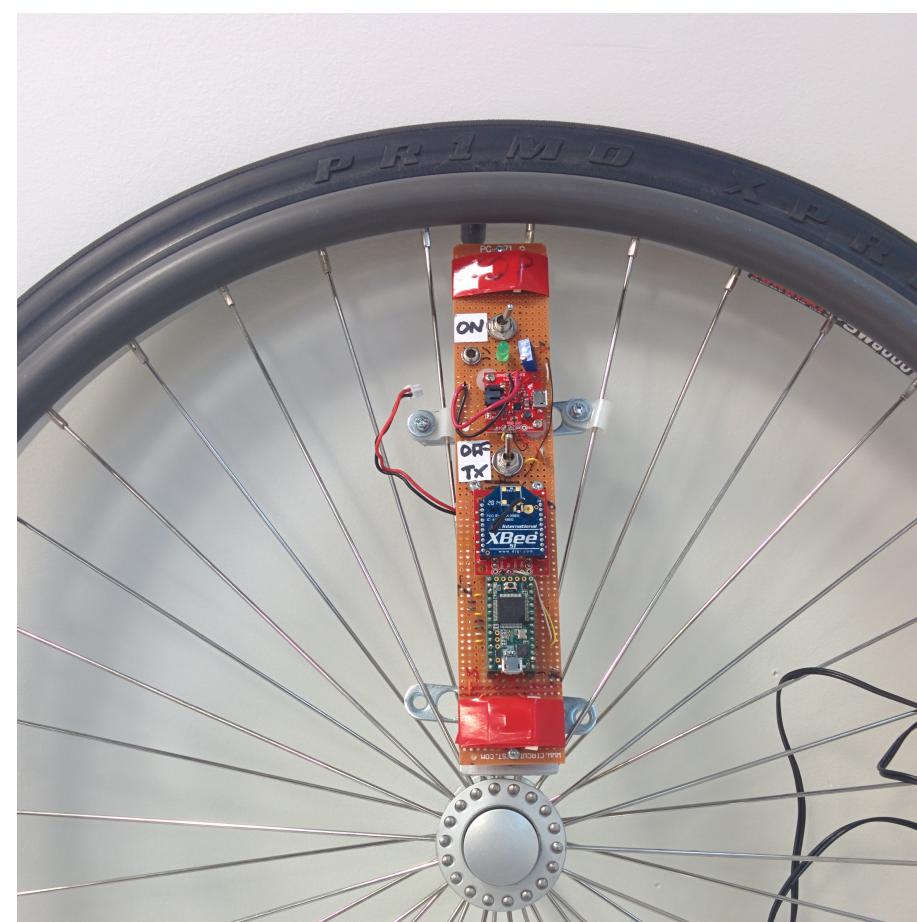


Figure 2: Original Redliner prototype, assembled using breakout boards

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

$$\omega = \sqrt{\frac{\Delta a}{d}} \quad (1)$$

$$\alpha = \frac{\partial \omega}{\partial t} \quad (2)$$

## 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

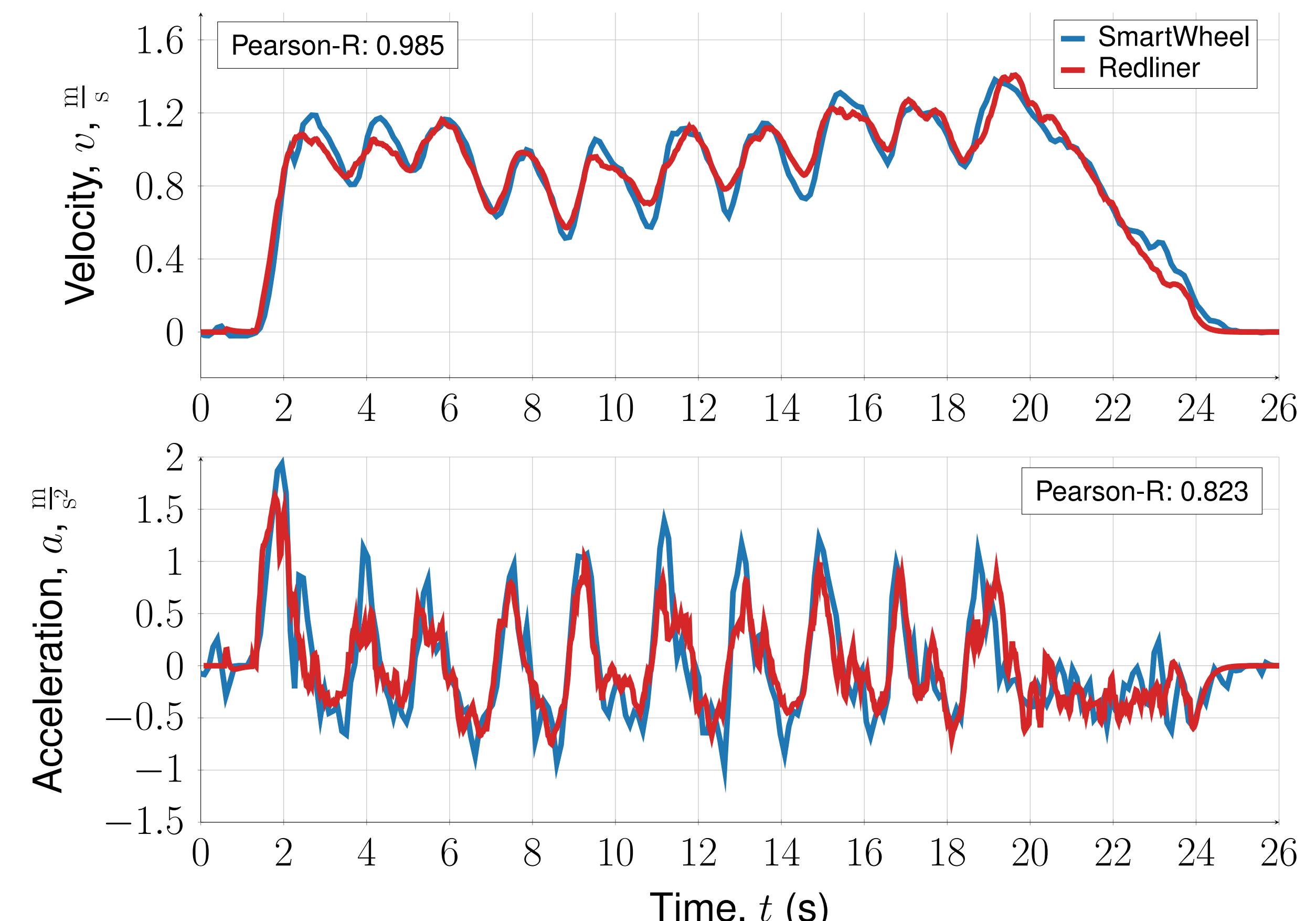


Figure 3: Velocity and acceleration traces for both SmartWheel and Redliner for 10 pushes on rough gravel.

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

Start

Figure 4: Push detection algorithm

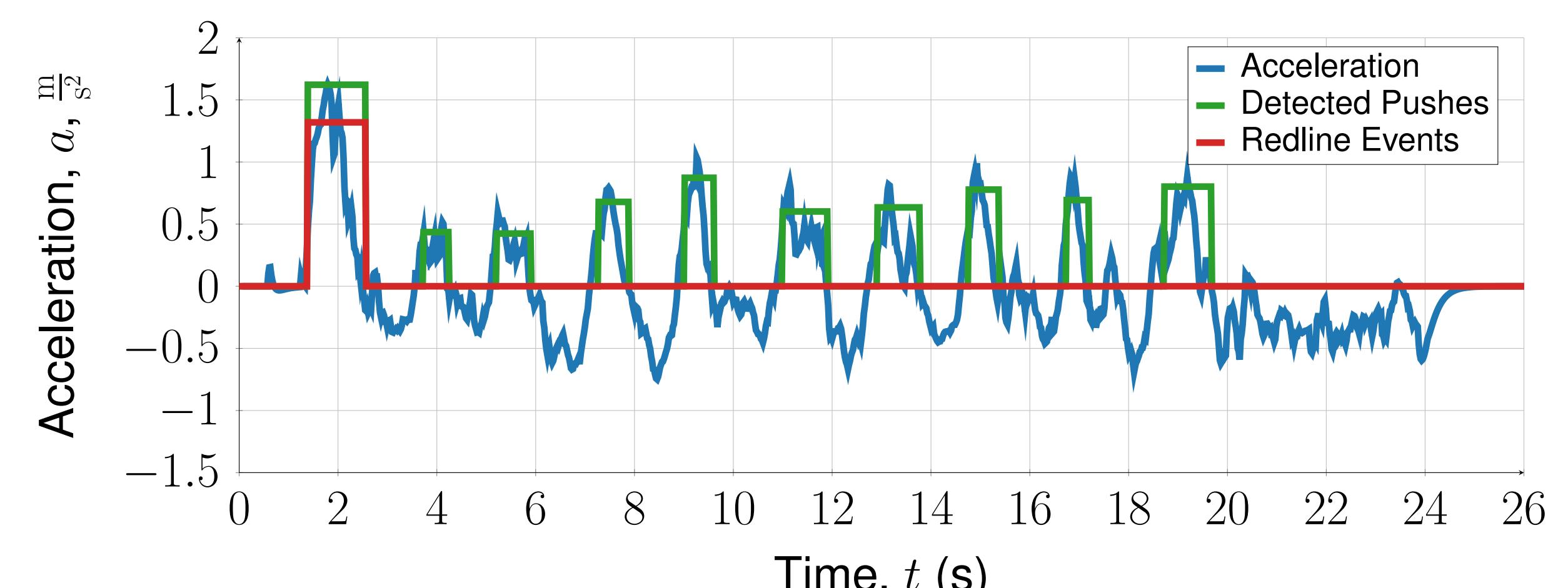
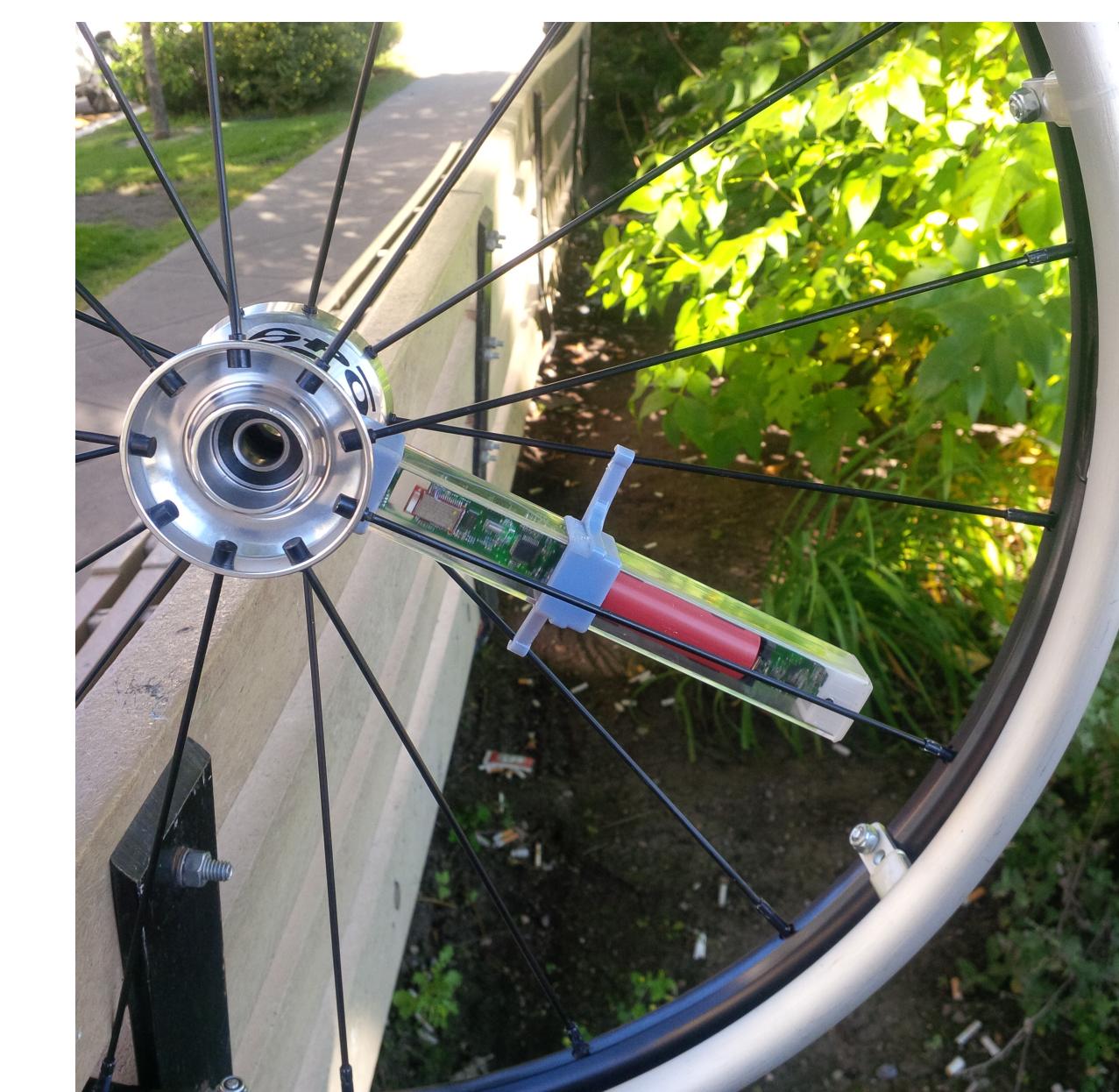
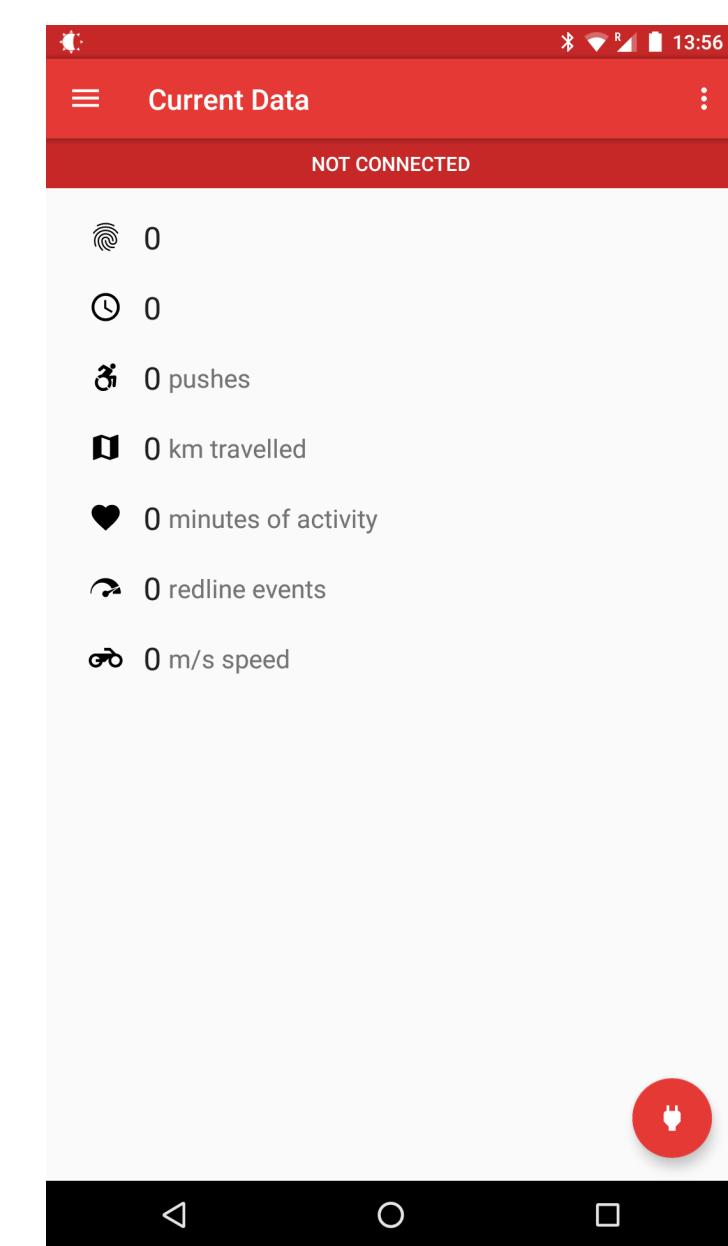


Figure 5: Acceleration, detected pushes, and redlines of 10 pushes on gravel as measured by Redliner.

With these results, a commercial entity—Redliner Inc.—has been created to move the project forward, which has resulted in new prototypes and software being developed.



(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 is moving forward as a commercial entity to produce and sell the devices

## 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.

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