Redliner: An Activity Monitor for Manual Wheelchair Users

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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

- 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
- 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.

$$\omega = \sqrt{\frac{\Delta a}{d}} \quad (1) \qquad \alpha = \frac{\partial \omega}{\partial t} \quad (2)$$

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

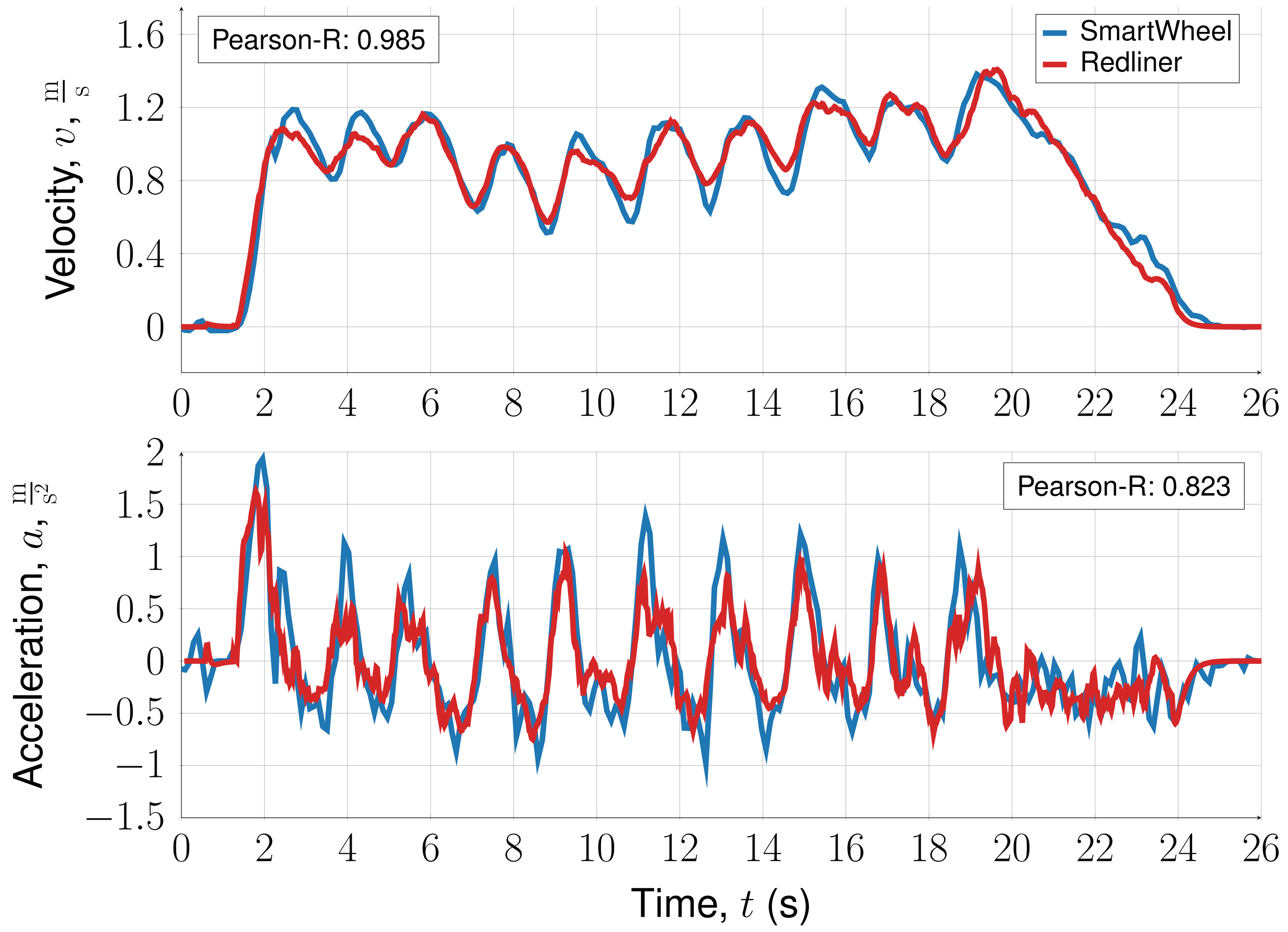


Figure 3: Velocity and acceleration traces for both SmartWheel and Redliner for 10 pushes on rough gravel.

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

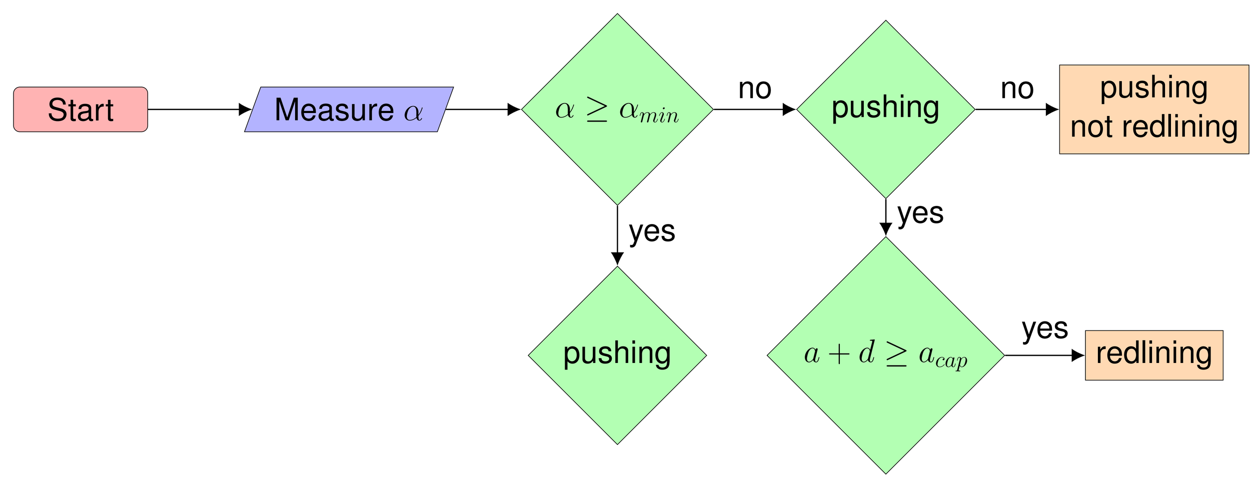


Figure 4: Push detection algorithm

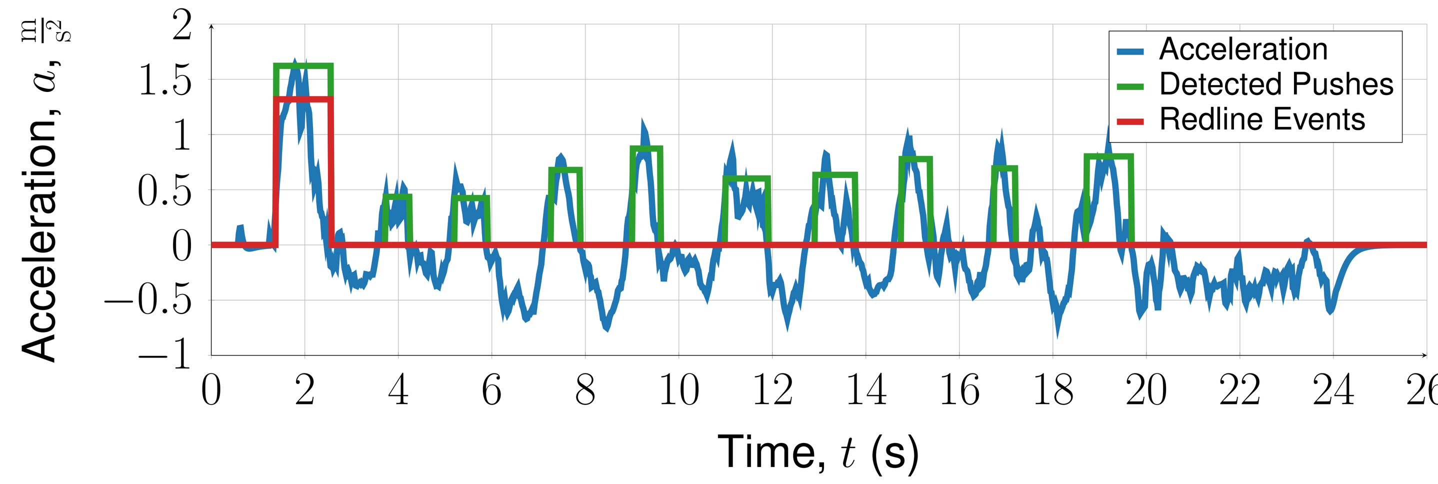
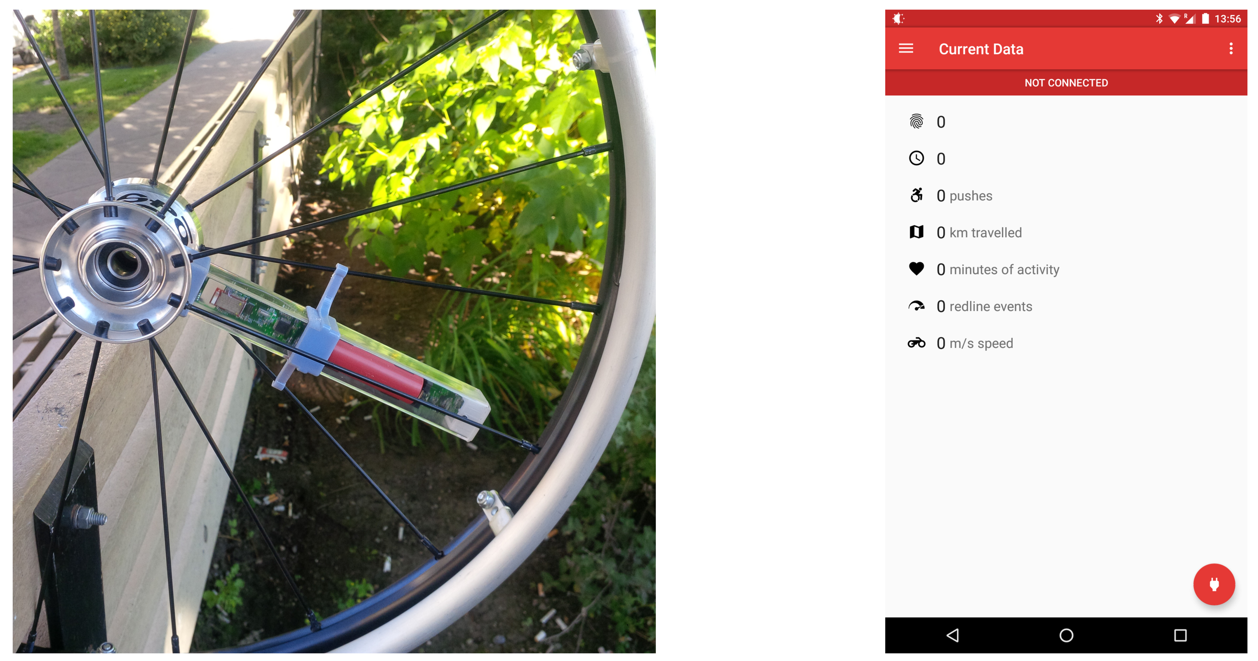


Figure 5: Acceleration, detected pushes, and redlines of 10 pushes on gravel as measured by Redliner.

- 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.

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