Fall-Triggered Hip Protectors

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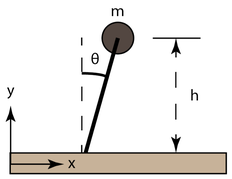
"We'll blow your pants off"

Abstract

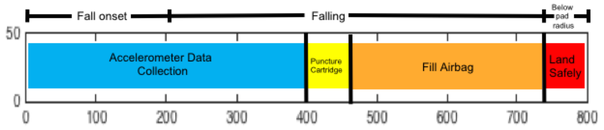
Falls and fall-related fractures are common in the elderly and lead to negative health outcomes. Current methods for preventing hip fractures use bulky hip pads. Hip pads are uncomfortable and hard to put on, so are rarely used. A device is required which is comfortable and will prevent fall-related injuries. Our design team created a device that detects falls and deploys an airbag to dissipate impact force. The final prototype determines fall occurrence using a threshold and shape-detection algorithm. When a fall is detected, a solenoid releases a CO_2 cartridge. The CO_2 cartridge is punctured and gas from the cartridge fills an airbag. Finally, the user makes contact with the ground and the airbag gradually deflates. Future iterations of the design will focus on validating the force dissipation of the airbag and modifying the prototype to make it suitable for mass production.

Motivation

- Falls are common as 2.5 million elderly adults are treated every year for fall-related injuries[1]
- More than $34 billion spent annually to treat such injuries[2]
- Falls lead to increased morbidity and decreased quality of life
- Current designs are bulky and uncomfortable



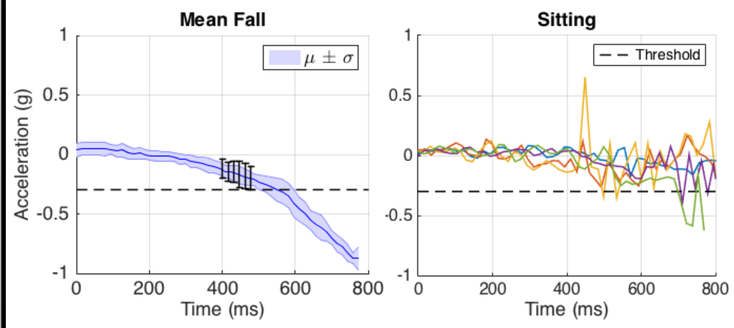
- Modeled falling using an inverted pendulum
- Estimated fall time of 800 ms
- Maximum of 300 ms to fill airbag after detection



Design Criteria

- Operate continuously for ≥ 12 hours
- Detect fall and deploy protection in ≤ 800 ms
- Identify at least 95% of falls and 93% of ADLs
- Appropriate for the wear and tear of daily life
- Cost: < $500 with manufacturing cost of < $150
- Withstand up to 10 kN of force
- Reduce impact force to < 1 kN

Fall Detection

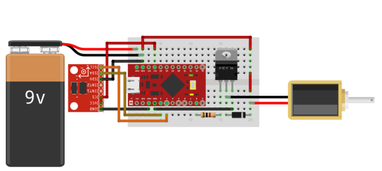


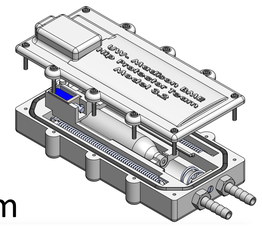
- Collected data for falls and activities of daily living (ADLs) over 30 trials
- Found that a hard threshold is not comprehensive
- Combined threshold with a shape-detection algorithm that makes use of a multi-window approach

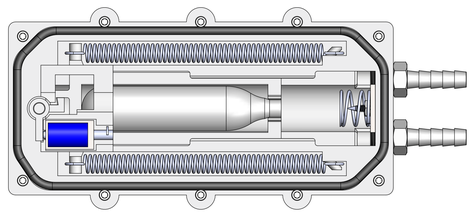
Airbag Deployment

Circuit Design

- Implement algorithm on Arduino Micro
- Powered by two 9-V batteries
- Solenoid draws too much current
- TIP120 transistor switch and diode







Deployment Mechanism

- Fall detected → Activate solenoid to release latch and puncture CO_2 cartridge
- Extension springs provide the kinetic energy
- Compression spring ensures cartridge opening is not occluded after puncture
- 3D-printed using fused deposition modeling

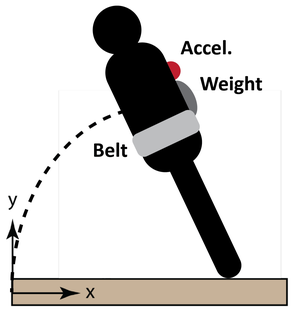
Testing and Results

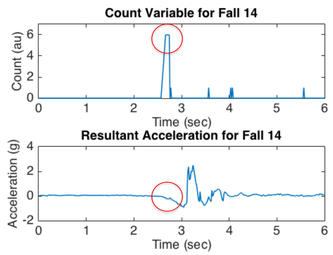
Deployment Timing

- Used Kinovea video analysis software to determine fill time
- Compartments covering the hips inflate in 250 ms
- Entire airbag fills in 500 ms

Force Testing

- Used accelerometer and data acquisition setup from Wisconsin Structures and Materials Testing Laboratory
- Airbag design reduced impact force by ≈25%
- Standard hip protector pads decrease impact force by 20-30%[3]





Algorithm Testing

- Fall detection occurred ≈300 ms before impact
- Obtained a true positive rate of 100% and a true negative rate of 93.3%

Belt and Airbag Design

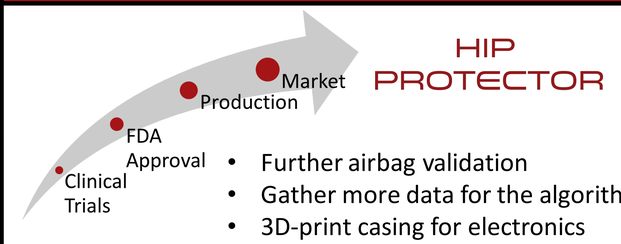
Airbag Design

- Polyethylene vacuum-sealed bag
- Nine compartments protecting the greater trochanters and tailbone
- Brass hose barbs connect ¼-inch polyvinyl tubing to deployment mechanism
- 3 psi pressure relief valve dissipates force

Belt Design

- Nylon, cotton canvas, nylon webbing, foam
- Clasp for easy attachment
- Magnetic cover for easy access to the cartridge
- Magnetic base to allow for repackaging of airbag

Future Work



- Further airbag validation
- Gather more data for the algorithm
- 3D-print casing for electronics

Acknowledgements

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- Jacob Zeuske
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References

1. J. A. Stevens, P. S. Corso, E. A. Finkelstein, and T. R. Miller, "*The costs of fatal and non-fatal falls among older adults*," Injury Prevention, vol. 12, no. 5, pp. 290–295, 2006. [Online].
2. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. Web–based Injury Statistics Query and Reporting System (WISQARS) [Online]. Accessed February 20, 2016.
3. A. C. Laing, F. Feldman, M. Jalili, C. M. J. Tsai, and S. N. Robinovitch, "*The effects of pad geometry and material properties on the biomechanical effectiveness of 26 commercially available hip protectors*", Journal of Biomechanics, vol. 44, no. 15, pp. 2627 – 2635, 2011. [Online].