STATERA: An Adaptive System for Fall Prevention using Galvanic Vestibular Stimulation

Authors: Ishan Kasam (CEO), Tanay Mangal (CIO), Arnav Prabhudesai (CMO), Nichelle Thinagar (CTO), Chris Xu (CTO).
Advisor: Dr. Crowthers

Introduction

- Falls are the **leading cause of injury** for adults aged 65+, with over **14 million older adults**, about **1 in 4**, reporting a fall each year. *(CDC, 2026)*
- Falling once **doubles the chance of falling again**, making early balance intervention especially important. *(CDC, 2026)*
- Vestibular dysfunction affects about **35.4% of U.S. adults aged 40+**, or roughly **69 million Americans**. *(Agrawal et al., 2009)*
- Vestibular dysfunction increases fall risk by disrupting posture, gaze stability, and spatial orientation. *(Agrawal et al., 2009)*

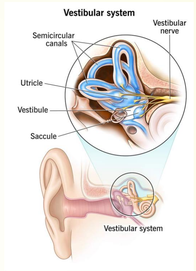


Figure 1: Vestibular system anatomy showing the semicircular canals, utricle, saccule, and vestibular nerve within the inner ear.

Problem Statement

There is no low-cost wearable device that can detect early balance loss and provide real-time vestibular feedback to help prevent falls before they occur.

Engineering Goal

Create a wearable device that uses IMU motion sensing and galvanic vestibular stimulation to detect instability and assist balance correction in real time.

Competitor Analysis

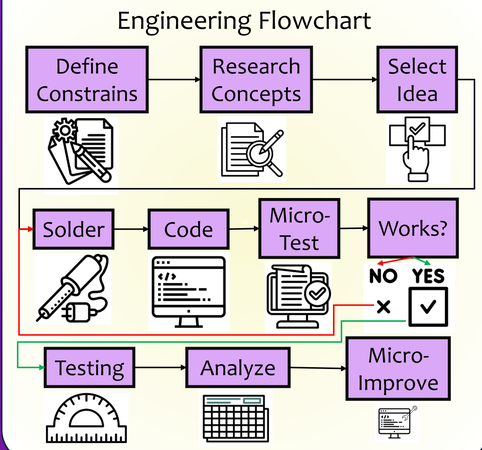
Device	How it Works	Strengths	Limitations
Cane	One-point ground support	➢Cheap ➢Portable	➢Requires arm ➢Worsens natural balance
Walker	Multi-point body support	➢Very stable ➢Popular	➢Bulky ➢Slow ➢Limits mobility
Watches and Phones	Detect fall-like motion with IMUs with Alerts	➢Wearable ➢Portable ➢Alerts	➢Alerts Afterwards ➢No prevention

Decision Matrix

Criteria / Requirements	Level	Idea 1	Idea 2	Idea 3
Wearability and Comfort (40)	L1	37	35.5	**35.5**
Fall Prevention Effectiveness (30)	L1	27	30	**30**
User Safety (15)	L1	12	15	**15**
Non-Invasive Design (15)	L2	15	13.5	**15**
Mobility Preservation (15)	L2	15	15	**15**
Cost Accessibility (15)	L2	15	13.5	**13.5**
Usability and Appearance (15)	L3	15	15	**15**
Ajustable Assistance(10)	L3	10	10	**10**
Total (155):		146	147.5	**149**
Topsis (1):		0.808	0.89	**0.894**

Methodology

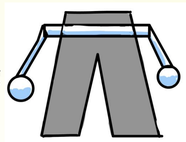
Engineering Flowchart



Ideas

Idea 1

Auto balancing fluid ballasts that use IMUs to detect falling orientation and correct.



Idea 2

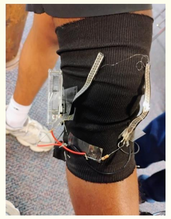
AFO which corrects to prevent falls after detecting one using IMUs.

Idea 3

Using a measurement system to detect falls which then used Galvanic Vestibular Stimulation to prevent falls.

Evolutions Of Design

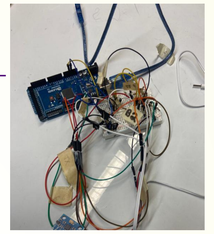
Design 1: Flex Sensor Detection



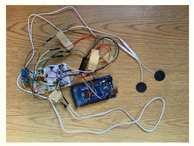
Pros:	Cons:
➢ Easy to use ➢ Noninvasive	➢ Very poor fall detection capabilities ➢ Wire management difficulty

Design 2: 1 IMU Detection

Pros:	Cons:
➢ Simple ➢ Effective fall detection ➢ Easy mounting	➢ Many false positives ➢ Hard to detect falls early



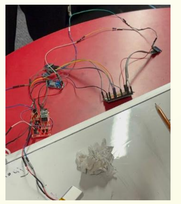
Design 3: 3 IMU Detection



Pros:	Cons:
➢ Robust fall detection ➢ Few false positives ➢ Low latency	➢ Bulky mounting ➢ Not “stylish”

Design 4: PCB

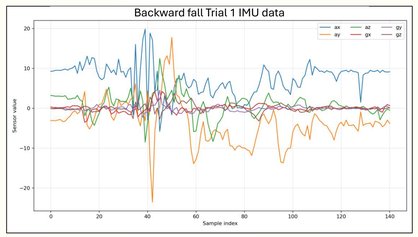
Pros:	Cons:
➢ Strong fall detection capabilities as before ➢ Sleek design and stable mounting	➢ Complex development and integration

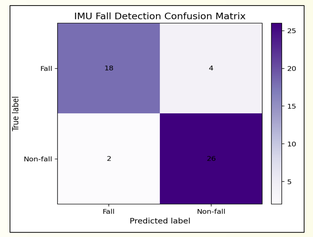


Design Study I

IMU Fall Detection Accuracy

Purpose: To see if the IMU can classify whether certain actions are falls or just walking noise.

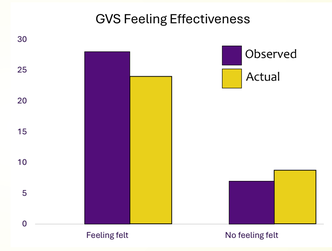




Design Study II

GVS Functionality Accuracy

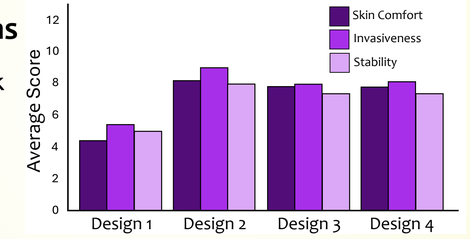
Purpose: To see if the GVS system can preventing falls while not causing unintentional falls.



Design Study III

Comfort Across Designs

Purpose: To track the comfort through the progression of the design.



CONCLUDING STEPS

Conclusion

- IMU-detected falls varied widely in nature, highlighting that robust pre-fall detection will require extensive training data
- The glasses-mounted form factor proved comfortable and viable for real-world, everyday use
- Fixed-current GVS can modulate balance to varying degrees by adjusting charge duration alone
- GVS shows strong potential as a viable, non-invasive approach to fall prevention, warranting further development and clinical exploration

Future Work

- Further improve fall detection algorithm to better classify different types of movements.
- Improve upon the adaptability of the system in terms of the current applied.
- Improve upon the physical design for comfort and wearability based on extensive feedback from the target audience.

KEY REFERENCES

Agrawal, Y., Carey, J. P., Della Santina, C. C., Schubert, M. C., & Minor, L. B. (2009). Disorders of balance and vestibular function in US adults: Data from the National Health and Nutrition Examination Survey, 2001–2004. *Archives of Internal Medicine, 169*(10), 938–944. https://doi.org/10.1001/archinternmed.2009.66

Centers for Disease Control and Prevention. (2026, January 27). Facts about falls. National Center for Injury Prevention and Control. https://www.cdc.gov/falls/data-research/facts-stats/index.html

Hauger, A. V., Kassoe, A., Dalgaard, P., & Klokker, M. (2022). Thresholds for vestibular and cutaneous perception and oculomotor response induced by galvanic vestibular stimulation. *Frontiers in Neurology*. https://pubmed.ncbi.nlm.nih.gov/36034303/

Marchand, S., Langlade, A., Legois, Q., & Séverac Cauquil, A. (2025). A wide-ranging review of galvanic vestibular stimulation: From its genesis to basic science and clinical applications. *Experimental Brain Research, 243*(5), 131. https://doi.org/10.1007/s00221-025-07078-9

Melo, R. S., Marinho, S. E. S., Freire, M. E. O., Souza, R. A., Damasceno, H. A. M., & Raposo, M. C. F. (2022). Galvanic vestibular stimulation and its applications: A systematic review. *Brazilian Journal of Otorhinolaryngology, 88*(Suppl 3), S137–S148. https://pmc.ncbi.nlm.nih.gov/articles/PMC9760994/

Valter, Y., Vataski, L., Allred, A. R., Hebert, J. R., Brunyé, T. T., Clark, T. K., Serrador, J., & Datta, A. (2025). A review of parameter settings for galvanic vestibular stimulation in clinical applications. *Frontiers in Human Neuroscience, 19*, 1518727. https://doi.org/10.3389/fnhum.2025.1518727

Wilkinson, D., Nicholls, M., & Kothari, N. (2009). Safety of repeated sessions of galvanic vestibular stimulation following stroke: A single-case study. *Brain Injury, 23*(12), 950–955. https://pubmed.ncbi.nlm.nih.gov/19921173/

World Health Organization. (2008). *WHO global report on falls prevention in older age*. https://www.who.int/publications/i/item/9789241563536