Received: 3 March 2026 | Revised: 28 April 2026 | Accepted: 19 May 2026 | Published online: 3 June 2026

Smart Wearable Technology
2026, Vol. 00(00) 1–6
DOI: 10.47852/bonviewSWT62029511
BON VIEW PUBLISHING

RESEARCH ARTICLE

Ultrasonic Obstacle Detection Device

Rishab Ray[1,*] **and Sushant Indupuru**[1]

[1] *Independent researcher, USA*

Abstract: This paper presents the design and first prototype of an Ultrasonic Obstacle Detection Device, a wearable assistive system intended to help visually impaired individuals, especially children in urban areas such as Kolkata, navigate more safely and independently. The device employs dual HC-SR04 ultrasonic sensors with a 15° field of view, positioned at a 61.325° outward angle from the device centerline to minimize blind spots, paired with two vibration motors mounted on a wrist strap to provide haptic feedback. The system is powered by a 3.7 V, 1000 mAh Li-Po battery and controlled by an Arduino Nano integrated on a custom printed circuit board. When an obstacle is detected within 3.35 m, vibration intensity increases proportionally as the object approaches, with independent left/right feedback corresponding to each sensor. Controlled experiments with blind participants demonstrated reliable direction identification, smooth vibration-distance mapping, and consistent activation thresholds. The prototype operated for approximately 25 min per charge, and participants reported that the device was intuitive and comfortable to use. Future work will focus on extending battery life, improving ergonomics, and increasing the vertical field of view.

Keywords: wearable device, obstacle detection, assistive technology, visual impairment, navigation aid

1. Introduction

For people who are blind or visually impaired, safely navigating dynamic environments remains a daily challenge. According to the World Health Organization, at least 2.2 billion people worldwide experience visual impairment [1]. In busy cities like Kolkata, children with blindness often depend on others to cross streets or avoid moving vehicles, creating significant safety and independence barriers. Traditional aids such as white canes and guide dogs offer valuable tactile and auditory information but are limited in detection range and directional awareness [2, 3].

The Ultrasonic Obstacle Detection Device was developed as a low-cost, compact solution that translates spatial information into intuitive tactile cues. Using ultrasonic sensing for distance measurement and vibration feedback for directional awareness, the system provides a real-time warning of nearby obstacles without requiring continuous auditory focus. Ultrasonic sensors have been widely adopted in assistive navigation systems due to their low cost, reliability, and ability to detect objects regardless of lighting conditions [4, 5]. Haptic feedback through vibration has emerged as an effective alternative to audio cues, particularly in noisy environments where auditory information may be compromised [6, 7]. This project represents the first iteration of a longer-term goal to develop an affordable, durable, and comfortable assistive tool to help visually impaired children navigate complex environments more safely. The motivation for this device is not abstract. In densely populated urban environments like Kolkata, visually impaired children frequently navigate streets shared with autorickshaws, cyclists, pedestrians, and informal market stalls, often without consistent access to trained guides or structural accommodations. The socioeconomic context is critical: guide dogs require ongoing expense, training, and cultural familiarity that limits adoption; many commercially available electronic travel aids are priced far beyond the reach of the families most likely to need them [2]. A device with a core component cost of $17.67 is therefore not merely a design constraint but a deliberate design objective.

For context, the International Monetary Fund estimated India's per capita GDP at approximately $2700 USD in 2023 [8]. At that income level, a navigation aid priced at hundreds of dollars represents a barrier that is functionally prohibitive for the majority of families with visually impaired children in cities like Kolkata. The Calcutta Blind School, where prototype testing took place, serves students from a range of economic backgrounds, making it an ideal setting to evaluate whether a low-cost device can meet real-world navigation needs. Scaling this design through local printed circuit board (PCB) fabrication and bulk component sourcing in India could reduce per-unit cost further, making community-level distribution feasible.

2. System Design and Implementation

The device is built around an Arduino Nano microcontroller mounted on a custom-designed PCB, as shown in Figure 1 (a, b). Two HC-SR04 ultrasonic sensors [9], each with a 15° field of view, are placed 3 cm apart and angled outward by 61.325° from the device centerline to provide broad coverage with no blind spots. Each sensor controls a dedicated vibration motor positioned on either side of the wrist strap. When an obstacle enters the detection range of one sensor, the corresponding motor vibrates; the vibration strength increases as the obstacle approaches. The left and right vibrations operate independently, allowing users to distinguish obstacle direction.

---

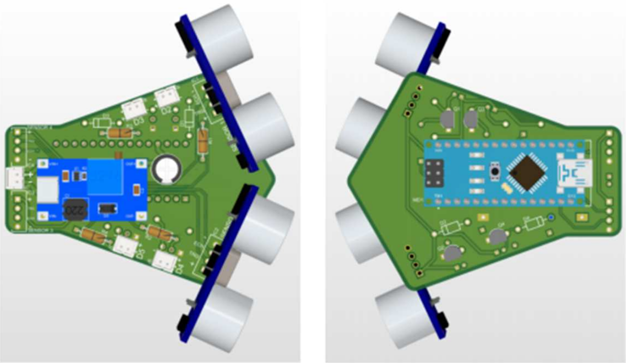
[*] **Corresponding author:** Rishab Ray, Independent researcher, USA. Email: risray700@gmail.com

The system is powered by a 3.7 V, 1000 mAh lithium polymer battery, regulated through a buck–boost converter to ensure stable voltage for the microcontroller and motors. The entire circuit is enclosed in a small, lightweight wrist-mounted housing designed for comfort and portability. Figure 1 (c and d) shows the assembled device with its protective case and the internal component arrangement. The total cost of core electronic components for the prototype was $17.67, with a one-time $3.48 battery charger not included in the per-unit device cost. Core electronic components include resistors, diodes, transistors, and standard connectors for sensor and motor integration.

The firmware continuously reads the ultrasonic echo data, converts distance measurements into pulse-width modulation (PWM) signals, and adjusts motor vibration intensity accordingly. The system can also be configured to activate based on approach velocity thresholds, enabling discrimination between slow and fast-moving objects. The HC-SR04 sensor operates by emitting an 8-cycle burst of ultrasound at 40 kHz and measuring the time delay of the returning echo [10]. The detection range spans from 5 cm to 3.35 m, with maximum vibration intensity triggered at approximately 0.5 m. Latency between distance detection and motor activation was negligible during testing, allowing for real-time feedback.

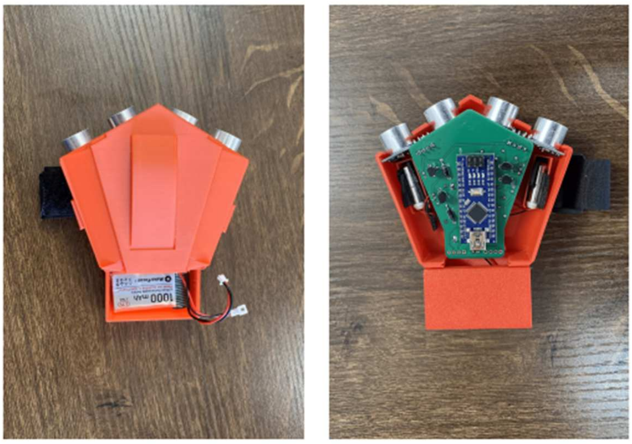
The 61.325° outward angle of the two sensors was determined by the PCB layout and sensor mounting geometry. This ensures broad lateral coverage without minimal cross-sensor interference, which would otherwise cause spurious echo returns when both sensors fire in close temporal proximity. Distance measurements are converted to motor vibration intensity using a linear mapping function. The firmware samples each sensor at 100 ms intervals, alternating between left and right to prevent acoustic interference, giving each side an effective update rate of 200 ms. Raw distance readings are smoothed using a 3-sample rolling average before conversion. The PWM output floor is 0, and the ceiling is 50 out of the 8- bit maximum of 255, spanning the active detection range of 5–350 cm, consistent with the 335 cm maximum detection distance observed during testing [9]. This intentionally conservative ceiling keeps motor vibration within a perceptible but comfortable range during sustained use. The analogWrite values are written directly to the motor pins without additional transition smoothing, ensuring that vibration intensity responds immediately to distance changes.

Figure 1
Ultrasonic Obstacle Detection Device prototype and assembly



(a) Top view: dual HC-SR04 sensors angled at 61.325° from centerline.

(b) Bottom view: Arduino Nano, custom PCB, and circuit components.



(c) Complete device with protective case.

(d) Internal component layout and wiring without case.

Approach velocity is estimated from successive distance readings. Because each sensor updates every 200 ms, instantaneous velocity is computed as the change in smoothed distance between two consecutive readings for a given side divided by the 200 ms inter-sample interval, yielding a velocity estimate in centimeters per second. This estimate is then compared against the configured threshold of 5 mph (approximately 223 cm/s). If the estimated approach velocity exceeds this value, the corresponding motor is activated regardless of absolute distance. This method is computationally inexpensive and well-suited to the Arduino Nano's processing constraints, though it is sensitive to noise near the threshold boundary, as discussed in Section 5.

3. Experimental Evaluation

3.1. Participants and environment

The prototype was tested with four blind participants (2 male, 2 female) in a controlled indoor environment. Each participant held the dual-sensor device at chest height, aligned with two parallel tape lines on the floor that represented the left and right detection paths. A sighted volunteer, referred to as the "walker," approached the participant along these paths while remaining unseen behind a barrier. Similar evaluation methodologies have been used in prior studies of assistive navigation devices [11, 12].

3.2. Directional detection

In the directional detection trials, the walker began 4 m away and walked toward the participant along either the left or right path, stopping at a distance of approximately 0.5 m. Participants completed eight randomized trials each (four per direction) and were asked to state whether the approaching walker was on their left or right side. The microcontroller recorded the exact distance at the first vibration and the PWM output for each motor.

3.3. Speed threshold detection

A second experiment tested whether the device could discriminate between slow and fast-moving objects. The device firmware was configured to activate vibration only when the detected approach velocity exceeded 5 mph. The threshold of 5 mph was selected to distinguish normal pedestrian walking speeds of 3–4 mph from faster-moving hazards such as cyclists or joggers, providing a margin that reduces nuisance activations from slow ambient movement while reliably triggering for higher-risk approach speeds. The same layout was used, and the walker carried a handheld odometer to verify walking speed. In the "slow" condition, the walker moved at a pace below 5 mph; in the "fast" condition, they walked above that threshold. Participants performed eight randomized trials each, with speed conditions randomized so that the participants were not aware of which speed was being used. The participant reported after each trial whether they felt vibration or not. Correct responses consisted of reporting vibration when velocity exceeded the threshold (fast trials) and no vibration when velocity was below the threshold (slow trials).

3.4. Self-guided wall approach

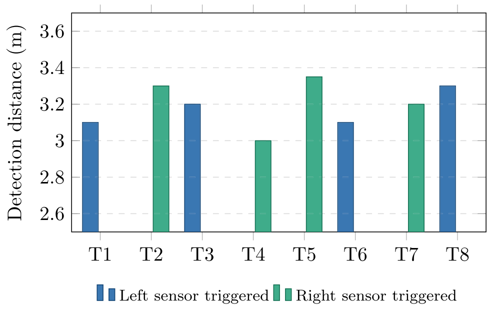
In a final set of trials, participants wore the device on their right wrist, secured with a harness, and walked independently toward a flat wall positioned 5 m away. They were instructed to stop when they felt the vibration or believed they were close to the wall. Five trials were conducted for each participant. The distance at which vibration was first felt was recorded by the sensors, along with the PWM output and participant feedback.

4. Results

Directional Detection: Participants completed eight randomized trials each (four per direction) using the directional method. Mean accuracy across the four subjects was 93.8% (SD = 7.2%), significantly above the chance level of 50% by one-sample *t*-test, $t(3) = 12.1$, one-tailed $p \approx 0.0002$. Individual accuracies ranged from 87.5% to 100%, demonstrating consistently near-perfect performance across participants. As shown in Figure 2, the best-performing participant (100% accuracy) consistently detected obstacles between 3.00 m and 3.35 m, with no meaningful asymmetry between left- and right-sensor trials. Participants could easily differentiate left versus right obstacles based on the vibration side. This performance is comparable to or exceeds results reported in other haptic navigation studies [6, 13].

Figure 2

First-vibration detection distance across eight randomized trials for the best-performing participant (100% accuracy). Trials marked T1–T8 were presented in a randomized left/right order; blue bars indicate left-sensor activations and green bars indicate right-sensor activations



Speed Threshold Detection: Participants performed eight randomized trials each with the speed threshold method. Mean accuracy across the four subjects was 75% (SD = 10%), significantly above the chance level of 50% as assessed by a one-sample *t*-test, $t(3) = 4.90$, one-tailed $p = 0.0085$. Individual subject accuracies ranged from 62.5% to 87.5%, demonstrating consistent above-chance performance across participants. Per-trial accuracy, shown in Figure 3, was at or above the 75% group mean in six of eight trials, with only T3 and T6 falling below that threshold.

Self-Guided Wall Approach: Participants consistently detected obstacles within the expected range. Individual mean detection distances were 2.8 m, 3.1 m, 3.1 m, and 3.2 m, with an overall mean of 3.05 m (SD = 0.17 m). Figure 4 illustrates that per-trial mean detection distances remained tightly clustered around the 3.05 m group mean across all detection distances (m), subjects correct (%), and five trials, with individual participants showing similarly stable trajectories. Participants observed a steady increase in vibration intensity as they approached the wall, and their subjective distance estimates closely matched the sensor data. Participants expressed high confidence (average 4.6/5) that the vibrations accurately indicated obstacle proximity.

System Performance: The proportional increase in vibration strength provided a clear sense of approach, improving users' ability to judge distance intuitively [14]. The detection range consistently spanned from 5 cm to 335 cm, with maximum vibration intensity triggered at approximately 0.5 m. Latency between distance detection and motor activation was negligible during testing, allowing for real-time feedback.

Figure 3

Per-trial accuracy averaged across all four participants in the speed threshold detection task (n = 4 per-trial bar). Blue bars indicate trials at or above the group mean of 75%; amber bars indicate trials that fell below it. The dashed reference line marks the 75% group mean

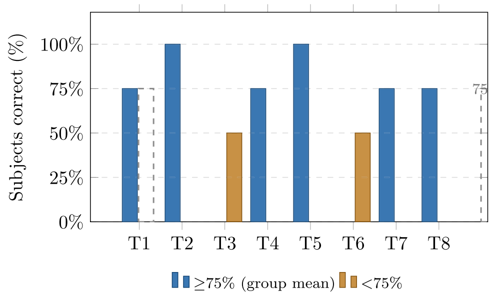
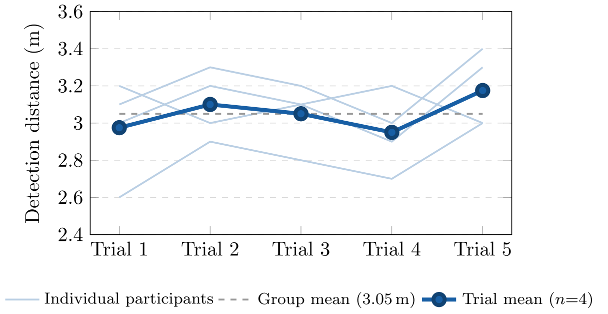


Figure 4

First-vibration detection distance across five successive self-guided wall-approach trials. Faint lines show the trajectory of each individual participant; the bold line with markers shows the per-trial mean across all four participants (n = 4 per point). The dashed reference line marks the overall group mean of 3.05 m (SD = 0.17 m)



5. Discussion

The results indicate that the Ultrasonic Obstacle Detection Device can effectively enhance obstacle awareness and direction recognition for visually impaired users. The haptic feedback system was intuitive even for first-time users, requiring minimal explanation or training. The dual-sensor configuration eliminated blind spots while providing precise directional cues. The simplicity of the hardware and the low overall cost demonstrate that meaningful assistive technology can be achieved with accessible components and straightforward design principles [15, 16]. At 133 g including battery, case, and wrist strap, the prototype is substantially lighter than wearable assistive navigation systems reported in the literature, which commonly range between 420 and 580 g [17], and requires no body harness or specialized fitting beyond a standard wrist strap.

The 1000 mAh battery provided approximately 25 min of continuous operation under typical use. Participants reported that the wrist-mounted design was comfortable but mildly fatiguing when held for extended periods. They also suggested that a chest-mounted or head-mounted design might offer better usability for longer sessions. Charging the battery was somewhat inconvenient due to the connector placement, which will be improved in future revisions. The device housing was fabricated from Polylactic Acid (PLA), a plant-derived thermoplastic considered biocompatible for skin-contact use and FDA-approved for multiple biomedical applications [18]. However, PLA is rigid and non-breathable, and future iterations will explore flexible materials such as thermoplastic polyurethane or silicone for improved comfort during extended wear.

Nevertheless, several limitations were identified. The device's field of view is limited to the horizontal plane, restricting detection of obstacles at varying heights, such as low-hanging signs or steps [3]. The short battery life also limits practical use in real-world scenarios. Additionally, while the wrist-mounted configuration is functional, prolonged handheld use proved tiring for participants, suggesting the need for alternative mounting options. Prior research has demonstrated the use of belt-mounted haptic systems as practical alternatives to handheld designs for blind navigation [12] and has suggested that wearable body-mounted configurations can reduce fatigue during extended use [19]. It should also be noted that the sample size of four participants limits the statistical power and generalizability of these findings, and future studies with larger and more diverse cohorts will be necessary to draw broader conclusions about device performance across the target population.

The gap between directional detection accuracy (93.8%) and speed threshold detection accuracy (75%) reflects a fundamental difference in what each task demands from both the sensor system and the user. Directional detection is a binary spatial judgment grounded in a physically unambiguous signal: vibration occurs on the left wrist or the right wrist, and that lateralization is a direct, one-to-one mapping of which sensor was triggered. There is no inference required on the part of the participant. The signal is anatomically localized, and the cognitive load is minimal. Speed threshold detection, by contrast, requires the participant to make an absence judgment. In the slow-walker trials, a correct response meant reporting no vibration, which is cognitively harder than detecting a positive signal [20, 21]. False positives likely arose because participants occasionally felt residual motor noise or ambient vibration and interpreted that as a threshold crossing [22, 23]. Additionally, the velocity estimation performed by the firmware relies on successive echo intervals, which introduces measurement variance, especially at walking speeds near the 5 mph boundary [10]. Small fluctuations in gait rhythm or sensor noise near the threshold boundary can cause inconsistent activation, making it inherently harder to achieve the same ceiling accuracy as direction detection. This suggests that future firmware revisions should implement a hysteresis window around the velocity threshold, requiring the approach speed to exceed the cutoff by a defined margin before activating vibration, which would reduce false positives near the boundary without meaningfully delaying activation for clearly fast-moving objects [24].

The directional accuracy achieved in this study is competitive with and in some cases exceeds reported benchmarks in the haptic assistive navigation literature. Khusro et al. [6] report directional identification accuracies in the range of 80–88% using vibrotactile wristbands in indoor navigation tasks, and Leporini et al. [13] document mean task completion rates of approximately 85% in haptic-guided wayfinding experiments [6, 13]. The 93.8% directional accuracy achieved here is notable given that participants received no prior training and completed trials in a single session, suggesting that the wrist-lateralized feedback modality is particularly intuitive compared to more complex spatial encoding schemes used in some prior systems, such as frequency-coded or pattern-coded vibration.

Critically, many prior systems achieving comparable accuracy rely on more expensive hardware. Sonar-based systems with digital signal processors, camera-augmented depth systems, or multi-actuator arrays commonly used in the literature carry per-unit costs of several hundred to several thousand dollars. The $17.67 total component cost of this prototype places it in a category of its own for pure cost-efficiency, and the accuracy numbers suggest that the performance trade-off from using low-cost HC-SR04 sensors over more sophisticated depth cameras or LIDAR is smaller than might be expected for a first iteration. This supports the hypothesis that for the specific use case of short-range binary obstacle warning, the information bandwidth of a simple ultrasonic sensor is sufficient, and the limiting factor is feedback design rather than sensing precision.

6. Future Work

The next phase of development will focus on improving ergonomics and sensor coverage. Mounting the device on a headband or chest plate would free the user's hands and align the sensing direction with the natural field of movement [25]. Expanding the vertical field of view through additional sensors or wider-angle transducers would allow detection of overhead and ground-level obstacles. Increasing battery capacity and redesigning the charging circuit will extend runtime and convenience.

A key firmware improvement will be the implementation of a hysteresis window around the velocity detection threshold. As discussed, the 75% accuracy observed in speed threshold trials likely reflects false positives arising from sensor noise and gait variability near the 5 mph boundary. Requiring the approach speed to exceed the cutoff by a defined margin before activating vibration, and similarly requiring it to fall below a lower bound before deactivating, would reduce spurious activations without meaningfully delaying feedback for clearly fast-moving objects. This change is low-cost to implement in firmware and represents one of the highest-yield improvements available for the next iteration. On the accessibility front, future work will explore partnerships with local PCB fabricators and component distributors in India to reduce per-unit cost through bulk sourcing. A manufactured version of the device targeted at government assistive technology programs or non-governmental organization (NGO) procurement channels would need to meet durability and repairability requirements beyond those of the current prototype, and iterative field testing at institutions such as the Calcutta Blind School will be essential to validating design changes against real-world usage patterns. Long-term plans include integrating multiple sensor pairs for 360°coverage and exploring adaptive vibration patterns for richer spatial feedback. Additional trials with more participants in real outdoor environments will provide further insights into real-world usability and durability [26].

7. Conclusion

This study demonstrates the feasibility and effectiveness of a low-cost ultrasonic-based haptic navigation aid for visually impaired individuals. The Ultrasonic Obstacle Detection Device successfully conveyed directional and distance information through simple vibration cues, enabling users to detect and respond to approaching obstacles. Testing confirmed consistent range detection, reliable directional feedback, and strong user confidence in the system's output. While this prototype represents only the first iteration, it lays a solid foundation for a practical assistive device that can enhance safety and independence for visually impaired children navigating crowded environments. Future improvements in sensor coverage, comfort, and battery life will further refine the design and extend its usefulness in real-world applications.

Acknowledgment

The authors would like to thank the participants at the Calcutta Blind School who volunteered their time to test this prototype.

Ethical Statement

The authors declare that all potential respondents were fully informed about the survey and participation was voluntary.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

The data that support the findings of this study are openly available in the GitHub repository at https://github.com/sushantindupuru/blind-assist-device.

Author Contribution Statement

Rishab Ray: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration. **Sushant Indupuru:** Software, Validation, Resources, Data curation, Writing – original draft.

References

[1] World Health Organization. (2026). *Blindness and vision impairment*. https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment

[2] Kuriakose, B., Shrestha, R., & Sandnes, F. E. (2022). Tools and technologies for blind and visually impaired navigation support: A review. *IETE Technical Review*, *39*(1), 3–18. https://doi.org/10.1080/02564602.2020.1819893

[3] Messaoudi, M. D., Menelas, B. A. J., & Mcheick, H. (2022). Review of navigation assistive tools and technologies for the visually impaired. *Sensors*, *22*(20), 7888. https://doi.org/10.3390/s22207888

[4] Dos Santos, A. D. P., Suzuki, A. H. G., Medola, F. O., & Vaezipour, A. (2021). A systematic review of wearable devices for orientation and mobility of adults with visual impairment and blindness. *IEEE Access*, *9*, 162306–162324. https://doi.org/10.1109/ACCESS.2021.3132887

[5] Nikanfar, S., Hebri, A., Ram Nambiappan, H., Nale, G., Siddiqua, M., Farhanipad, F., & Makedon, F. (2025). A survey on assistive technologies for visually impaired Individuals: Recent innovations, limitations, and future directions. In *Proceedings of the 18th ACM International Conference on Pervasive Technologies Related to Assistive Environments*, 429–434. https://doi.org/10.1145/3733155.3734895

[6] Khusro, S., Shah, B., Khan, I., & Rahman, S. (2022). Haptic feedback to assist blind people in indoor environment using vibration patterns. *Sensors*, *22*(1), 361. https://doi.org/10.3390/s22010361

[7] Tang, S., & Huang, G. (2025). Navigation assistance via haptic technology for blind or low-vision users: A scoping review. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *69*(1), 1–6. https://doi.org/10.1177/10711813251360706

[8] International Monetary Fund. (2023). *World economic outlook*. https://www.imf.org/en/Publications/WEO

[9] Elec Freaks. (2013). *Ultrasonic ranging module HC - SR04*.

[10] Abreu, D., Toledo, J., Codina, B., & Suárez, A. (2021). Low-cost ultrasonic range improvements for an assistive device. *Sensors*, *21*(12), 4250. https://doi.org/10.3390/s21124250

[11] Budrionis, A., Plikynas, D., Daniušis, P., & Indrulionis, A. (2022). Smartphone-based computer vision travelling aids for blind and visually impaired individuals: A systematic review. *Assistive Technology*, *34*(2), 178–194. https://doi.org/10.1080/10400435.2020.1743381

[12] Ricci, F. S., Liguori, L., Palermo, E., Rizzo, J. R., & Porfiri, M. (2024). Navigation training for persons with visual disability through multisensory assistive technology: Mixed methods experimental study. *JMIR Rehabilitation and Assistive Technologies*, *11*(1), e55776. https://doi.org/10.2196/55776

[13] Leporini, B., Rosellini, M., & Forgione, N. (2022). Haptic wearable system to assist visually-impaired people in obstacle detection. In *Proceedings of the 15th International Conference on PErvasive Technologies Related to -Assistive Environments*, 269–272. https://doi.org/10.1145/3529190.3529217

[14] Bouteraa, Y. (2021). Design and development of a wearable assistive device integrating a fuzzy decision support system for blind and visually impaired people. *Micromachines*, *12*(9), 1082. https://doi.org/10.3390/mi12091082

[15] Saquib, Z., Murari, V., & Bhargav, S. N. (2017). BlinDar: An invisible eye for the blind people making life easy for the

blind with Internet of Things (IoT). In *2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology*, 71–75. https://doi.org/10.1109/RTEICT.2017.8256560

[16] Chava, T., Srinivas, A. T., Sai, A. L., & Rachapudi, V. (2021). IoT based smart shoe for the blind. In *2021 6th international conference on inventive computation technologies*, 220–223. https://doi.org/10.1109/ICICT50816.2021.9358759

[17] Tapu, R., Mocanu, B., & Zaharia, T. (2020). Wearable assistive devices for visually impaired: A state of the art survey. *Pattern recognition letters*, *137*, 37–52. https://doi.org/10.1016/j.patrec.2018.10.031

[18] Ranakoti, L., Gangil, B., Bhandari, P., Singh, T., Sharma, S., Singh, J., & Singh, S. (2023). Promising role of polylactic acid as an ingenious biomaterial in scaffolds, drug delivery, tissue engineering, and medical implants: Research developments, and prospective applications. *Molecules*, *28*(2), 485. https://doi.org/10.3390/molecules28020485

[19] Dos Santos, A. D. P., Loureiro, M., Machado, F., Frizera, A., & Medola, F. O. (2025). NavWear: Design and evaluation of a wearable device for obstacle detection for blind and visually impaired people. *Disability and Rehabilitation: Assistive Technology*, *20*(6), 1800–1814. https://doi.org/10.1080/17483107.2025.2477681

[20] Green, D. M., & Swets, J. A. (1966). *Signal detection theory and psychophysics*. USA: Wiley.

[21] Hautus, M. J., Macmillan, N. A., & Creelman, C. D. (2021). *Detection theory: A user's guide*. USA: Routledge. https://doi.org/10.4324/9781003203636

[22] Verrillo, R. T. (1985). Psychophysics of vibrotactile stimulation. *The Journal of the Acoustical Society of America*, *77*(1), 225–232. https://doi.org/10.1121/1.392263

[23] Birnbaum, D. M., & Wanderley, M. M. (2007). A systematic approach to musical vibrotactile feedback. In *Proceedings of the International Computer Music Conference*, 1–8.

[24] Gustafsson, F. (2000). *Adaptive filtering and change detection*. USA: Wiley. https://doi.org/10.1002/0470841613

[25] Barontini, F., Catalano, M. G., Pallottino, L., Leporini, B., & Bianchi, M. (2021). Integrating wearable haptics and obstacle avoidance for the visually impaired in indoor navigation: A user-centered approach. *IEEE Transactions on Haptics*, *14*(1), 109–122. https://doi.org/10.1109/TOH.2020.2996748

[26] Tachiquin, R., Velázquez, R., Del-Valle-Soto, C., Gutiérrez, C. A., Carrasco, M., De Fazio, R., . . . , & Vidal-Verdú, F. (2021). Wearable urban mobility assistive device for visually impaired pedestrians using a smartphone and a tactile-foot interface. *Sensors*, *21*(16), 5274. https://doi.org/10.3390/s21165274

How to Cite: Ray, R., & Indupuru, S. (2026). Ultrasonic Obstacle Detection Device. *Smart Wearable Technology*. https://doi.org/10.47852/bonviewSWT62029511