VibeGuide

Introduction to Engineering and Design, Section C1

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Introduction

The VibeGuide is a wearable navigation device that converts visual and auditory cues into intuitive vibrational feedback. The system consists of two ankle bands that connect to a smartphone via Bluetooth, allowing users to receive turn-by-turn directions without looking at a screen or listening to audio instructions. The device vibrates on the left or right ankle when a turn is approaching, while both bands vibrate simultaneously to indicate a stop or alert. By keeping the user's eyes on the road and hands free, this design promotes safer, more independent travel for cyclists, runners, and visually impaired individuals. Our company aims to create a sense of *Safe Guidance without Distraction;* our founders are Chris Ferreira (Circuitry Lead), Andrew Mei (Design Lead), Carly Menchaca (Project Manager), and Linqian Yang (Coding Lead).

To understand the need for this device, consider how the Global Positioning System (GPS) has transformed the way people navigate and interact with their environment. It has been around since the 1960s, when the Advanced Research Projects Agency launched the world's first global satellite navigation system, Sputnik, the first artificial satellite to transmit radio signals. (Aerospace, 2025). Since then, GPS has advanced into a sophisticated system capable of providing real-time, highly accurate positioning and navigation data. Astronomically, it provides highly accurate, real-time navigation for cars, smartphones, and even wearable devices. It has become integrated into numerous sectors, including transportation and logistics, as well as mobile technology and wearable devices. Despite these advances, GPS navigation continues to pose challenges for certain groups, particularly for cyclists, who divide their attention between traffic conditions and navigation prompts.

Modern GPS applications such as Google Maps, Strava, and Bikemap have made navigation more accessible; however, their reliance on constant visual or auditory attention introduces significant safety risks. Cyclists, in particular, are at risk of inattentional blindness, a phenomenon in which an individual looks at the road but fails to register important visual cues due to cognitive overload (Mutual of Enumclaw Insurance, 2020). This issue becomes even more prominent considering that over 800,000 Americans commute by bicycle every day (The League of American Bicyclists, 2024). For these commuters, maintaining focus on the road is critical, yet most navigation systems still require screen interactions or voice prompts, forcing riders to divert their attention momentarily.

Figure 1 illustrates how cyclists use smartphones mounted on handlebars or handheld to follow GPS routes. Although convenient, this behavior compromises safety by drawing attention away from traffic, pedestrians, and other potential hazards. Even brief distractions can have serious consequences, especially in urban settings with complex intersections and high traffic density. (Mutual of Enumclaw Insurance, 2025). These findings underscore the urgent need for navigation solutions that minimize visual and auditory distraction while maintaining accessibility and usability.

Figure 1: Cyclists Using Phone for Navigation (Northern Times, 2022).

Existing wearable technologies offer partial solutions but remain inadequate for users. Devices such as Garmin cycling computers or Apple Watches offer navigation capabilities but are often expensive, weather-sensitive, and require regular charging. Furthermore, these devices still rely on visual displays or audible cues. The Haptic Directional Guide, a haptic feedback-based navigation tool developed by WearWorks (2022), demonstrates the potential of vibration-based guidance. However, its limited compatibility with iOS devices and tendency to drain smartphone batteries restrict its practicality. These gaps in functionality and accessibility reveal a clear opportunity for innovation in the wearable navigation market.

From a broader perspective, the VibeGuide aligns with significant trends in the wearable technology industry. In 2024, the market was valued at $70.30 billion, with an annual growth rate of 16.8% (MarketsandMarkets, 2024). Such figures demonstrate strong consumer interest in devices that enhance safety, connectivity, and everyday functionality. As cycling gains popularity as both a sustainable mode of transportation and a recreational activity, the need for specialized wearable devices tailored to cyclists' unique needs becomes increasingly evident.

Our VibeGuide addresses this issue by replacing visual and auditory navigation cues with intuitive vibrational feedback, which integrates engineering and human sensory principles. Each band contains a 10mm coin vibration motor that functions through an eccentric rotating mass (ERM) mechanism, in which an off-center weight produces mechanical oscillation when spun by a small motor. This principle follows Newton's second law ($f = ma$), as the vibration force increases with the motor's rotational acceleration. The vibration frequency, between 180–200 Hz, falls within the human tactile sensitivity range (approximately 0.4–500 Hz), ensuring clear yet comfortable feedback.

The materials used to construct a single VibeGuide were an Arduino UNO R3, a mini slide switch, a 9V battery, a breadboard, an HM-6 Bluetooth Module, a 10mm Coin Vibration Module, jumper wires, velcro, and felt fabric. Figure 2 depicts the circuit diagram below.

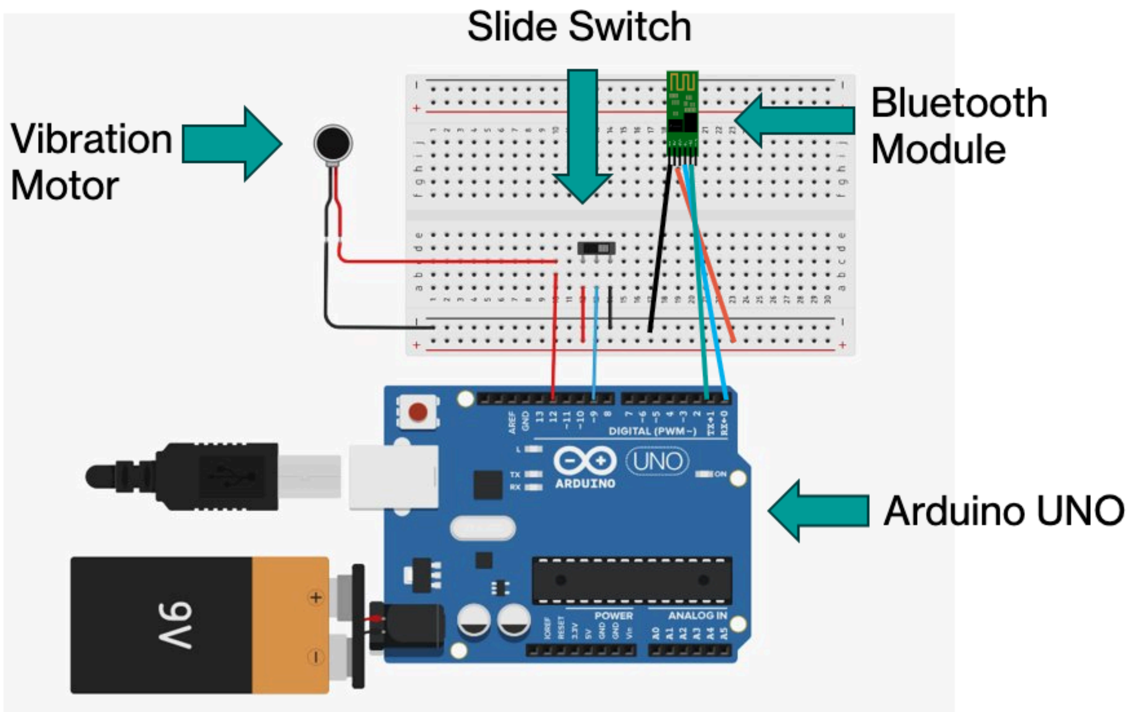

Figure 2: Circuit Diagram

The Bluetooth Low Energy (BLE 5.0) module enables wireless communication between the ankle bands and the smartphone, maintaining a stable 10-meter range while conserving power. Each circuit uses an Arduino UNO R3 microcontroller, powered by a 9V battery, to control the vibration motor. The battery provides sufficient voltage and current for consistent feedback intensity during long rides. The entire assembly is enclosed in felt fabric, chosen for its flexibility and skin comfort. As shown in Figures 3-5, the Computer-Aided Drawing (CAD) model provides insight into the layout inside the casing.

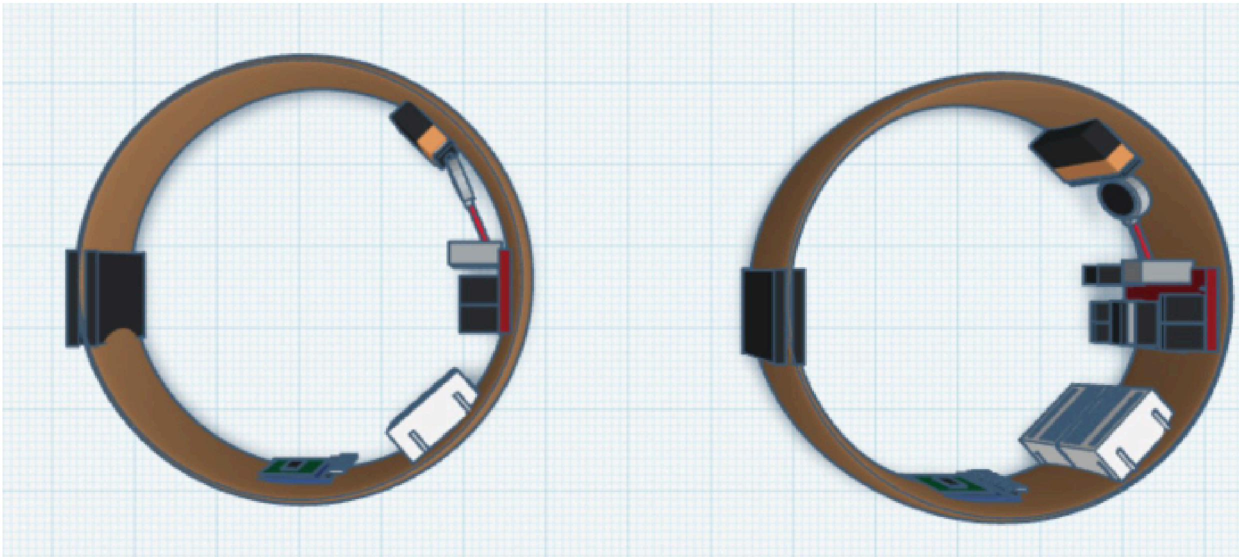

Figure 3: CAD Model (Top View)

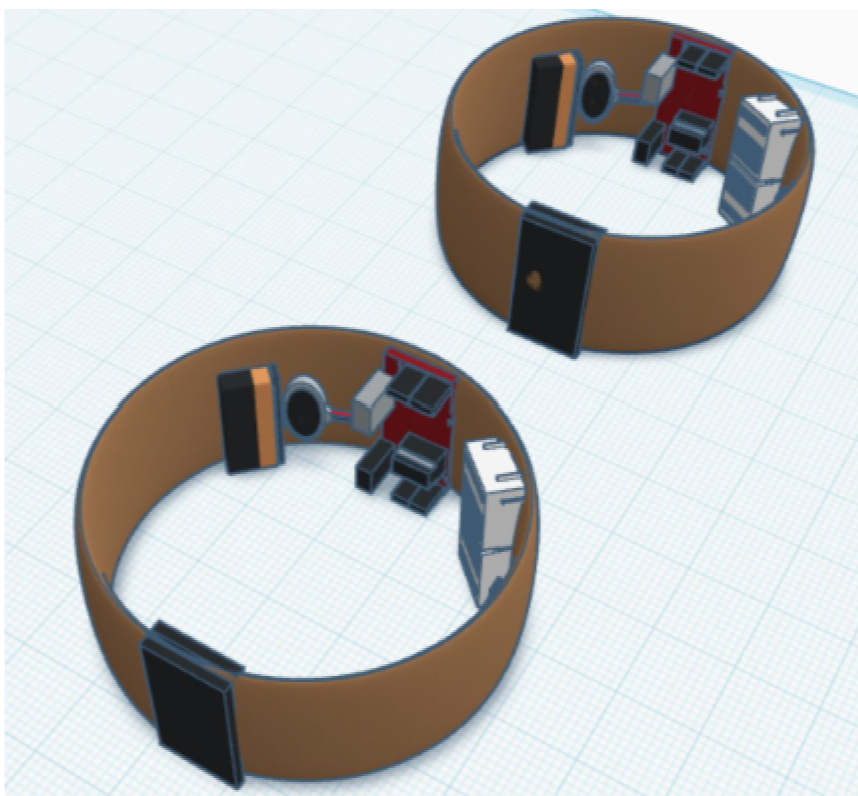

Figure 4: CAD Model (Isometric View)

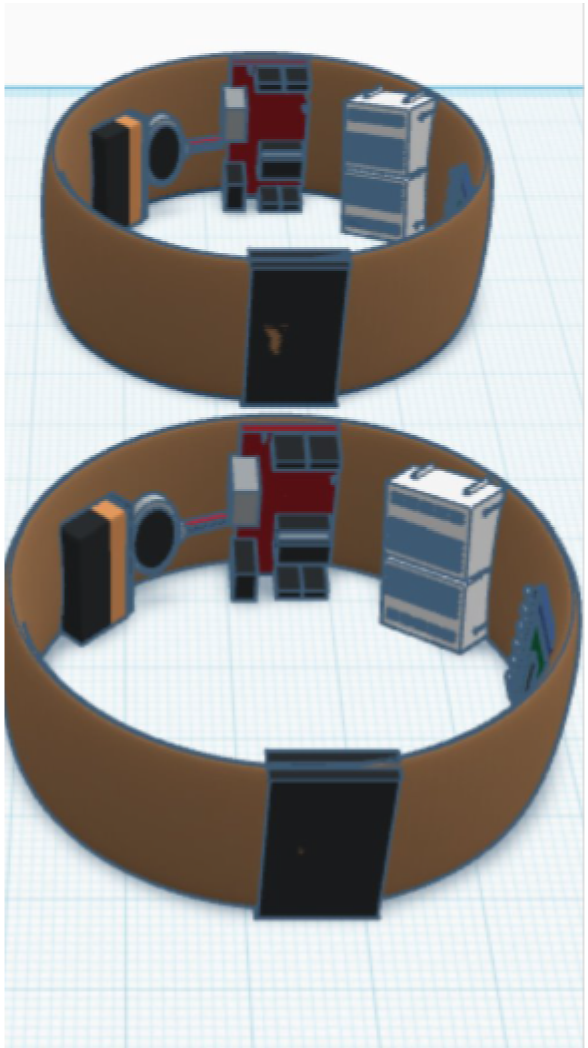

Figure 5: CAD Model (Side View)

Table 1 shows the breakdown of the product's final cost.

Table 1. Final Cost

Item	Quantity	Cost/Unit ($)	Total Cost ($)
Arduino Uno R3	2	24.00	48.00
HM-6 Bluetooth	2	7.99	15.98

Module			
10mm Coin Vibration Module (ERM Type)	2	1.30	2.60
Fabric	2	5.00	10.00
9V Battery	2	1.98	3.96
Mini Slide Switch	2	3.00	6.00
Total	–	–	86.54

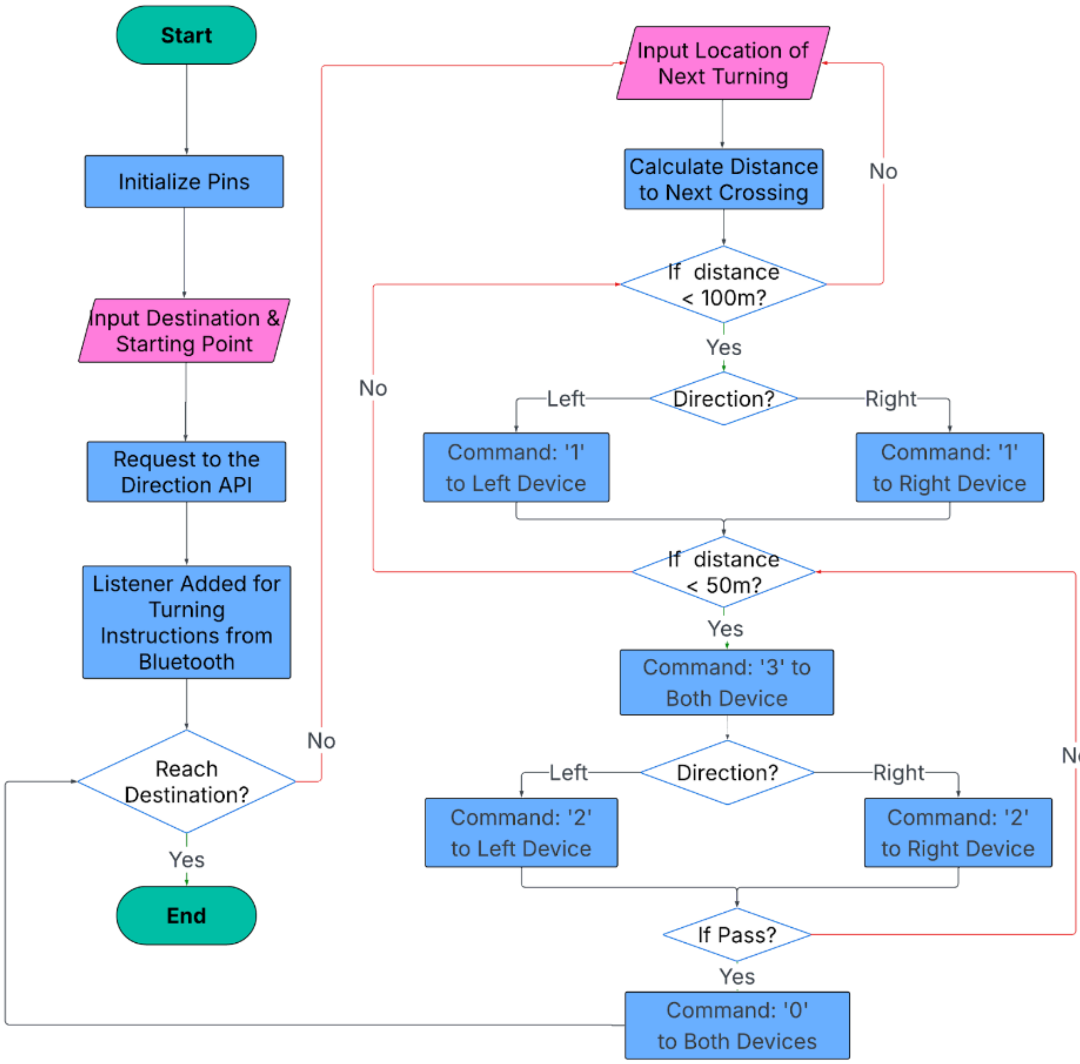

Figure 6: Coding Flowchart

Navigation logic relies on the Google Maps Platform APIs, including the Navigation SDK, Routes API, and Distance Matrix API. When the user inputs a destination, the smartphone software ("HapticNav") retrieves the current location and calculates an optimal route. As the user travels, the system marks turning points and monitors the distance traveled. At 100 meters before a turn, the corresponding ankle band emits a low-intensity vibration to alert the user. At 50 meters, the vibration intensifies, signaling an immediate turn. If the user passes the crossing, vibrations stop, indicating they should continue straight or wait for rerouting. These haptic patterns follow human-factors engineering principles by providing consistent, intuitive, and low-cognitive-load feedback that enhances situational awareness, shown in Figure 7.

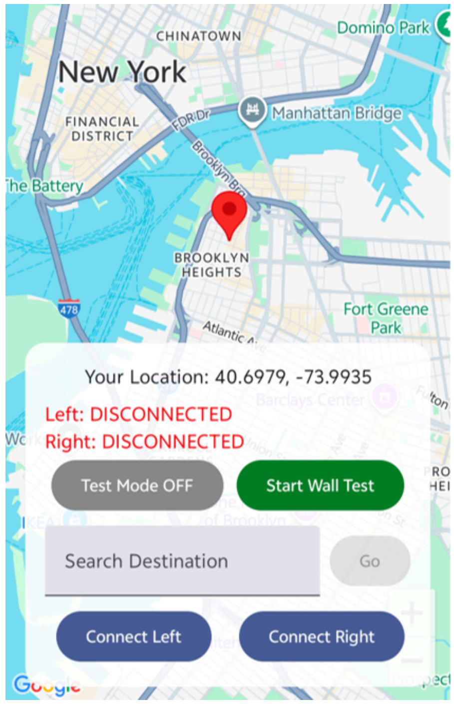

Figure 7: Google Maps Simulator

By integrating GPS reliability with tactile feedback, the VibeGuide offers a safe, practical, and user-centered navigation solution. Its combination of lightweight design, real-time vibrational cues, and durable casing for everyday wear demonstrates how a single-function wearable device can improve cyclist safety while addressing gaps in the current market.

Procedure

The prototype assembly began by placing the Arduino UNO R3 and breadboard on a flat workspace to facilitate organization of the wiring layout. The power line was first connected through a mini slide switch, enabling the device to be turned on and off during testing. After establishing the power routing, the vibration motor was connected to its designated digital output pin, while its ground was attached to the breadboard's negative rail. Next, the Bluetooth module was wired to the Arduino's communication pins, and jumper wires were added to complete the remaining signal connections. Pins RX and TX are connected to their designated RX and TX slots on the Arduino UNO R3. Once all wiring was in place, a test sketch was uploaded to confirm that the vibration motor functioned correctly. After successful testing, the components were soldered onto a protoboard. The soldered assembly was then placed into a casing made of felt fabric with proper stitching. Finally, Velcro was attached to the casing to allow individual size adjustments, as shown in Figure 8.

Figure 8: Side view of Final Prototype

The software was prepared and uploaded using the Arduino IDE. Before coding, the correct board type and port were selected so the program would compile and upload properly. In the sketch, the output pin controlling the vibration motor was defined, and serial communication was initialized so the Arduino could read the direction signal sent from the smartphone. The Bluetooth module didn’t require custom libraries, but the code set the baud rate to match the module’s default communication speed. A simple decision structure was added to activate the motor at different intensities in response to the received signal. After uploading, the Serial Monitor was briefly used to verify that the board could read incoming characters without errors.

During testing, the team encountered occasional connectivity issues between the VibeGuide's Bluetooth module and the smartphone. These issues were traced to incorrect wiring and broken components, which caused pairing conflicts. To resolve this, the correct wiring was ensured, and new elements were added. After this adjustment, the system consistently maintained a stable connection and delivered accurate directional feedback during testing.

Milestone/Final Product Requirements

For Benchmark A, the requirements centered on establishing the preliminary design and planning framework for the VibeGuide prototype. The engineering notebook was expected to be updated through Week 7, documenting all tasks and answering the assigned questions. The project schedule in the SLDP Drive needed to remain current, clearly tracking progress, assignments, and deadlines. Required technical outputs included a CAD model showing the intended ankle-band design and component placement. A detailed Fritzing circuit diagram illustrating all key electronic connections—lastly, a Lucidchart code flowchart outlining the planned navigation logic. Before physical assembly could begin, all team members were required to complete soldering training. Additionally, to conduct preliminary research on suitable hypoallergenic housing materials. Meeting these requirements ensured teams were prepared for component procurement, assembly, and early-stage testing.

For Benchmark B, the project requirements focused on advancing the prototype to a stage in which both the ankle units and the directional feedback system were thoroughly planned and ready to demonstrate functionality. The engineering notebook needed to be updated through Week 10, with all entries and questions completed. Teams were required to visit Protolab in person to have their emblem approved by a TA before benchmarking. The CAD file had to be updated to include two ankle-band units, each with designated spaces for the battery, Arduino microcontroller, Bluetooth module, slide switch, vibration motors, and the necessary circuitry. The system requirements also specified the use of Google Maps API for destination input, continuous route mapping, and directional signaling. The design had to support left-turn, right-turn, stop, and straight-ahead vibration patterns. All components were required to be housed in durable, adjustable casings, with each unit remaining under 450 grams. The project schedule needed to stay fully updated. Additionally, teams were required to produce Arduino code for motor control, a complete code flowchart that shows data processing and decision pathways, and an updated Fritzing circuit diagram that includes all relevant components.

For Commissioning, requirements included maintaining the engineering notebook through Week 12 with all previous questions completed. Teams were required to obtain a printed emblem from the Open Lab cubbies and bring it to the commissioning session. The commissioning system's expectations included a functioning interface in which destination input triggered route mapping via the Google Maps API, along with smartphone-based real-time location tracking and Bluetooth communication with the ankle bands. The vibration logic needed to be fully defined: alternating vibrations for left and right turns, dual vibrations for stop signals, and no vibration for continuing straight, with increasing intensity as the user approached a turn. The project schedule in the SLDP Drive had to remain fully updated—the CAD file needed to show both wearable ankle units with correctly allocated spaces for all components. The Fritzing circuit diagram was necessary to reflect the finalized circuit. All components were required to be soldered and enclosed in portable, durable, adjustable casings, with the complete system weighing under 400 grams.

In terms of human resources and training, teams were expected to utilize available mentorship for guidance on task planning, clarification of benchmark expectations, and technical questions. All members were required to complete MakerSpace soldering training to assemble circuits safely. Additional relevant training could include sewing and embroidery for fabric components, as well as 3D printing experience for emblem production or backup casing solutions. These training requirements ensured teams had the necessary skills to progress through the design and fabrication stages of the VibeGuide prototype.

Results

In benchmark A, the project was required to include a CAD model of the ankleband device with space for vibration motors, a battery, a microcontroller, and a wireless module, as shown below in Figure 9.

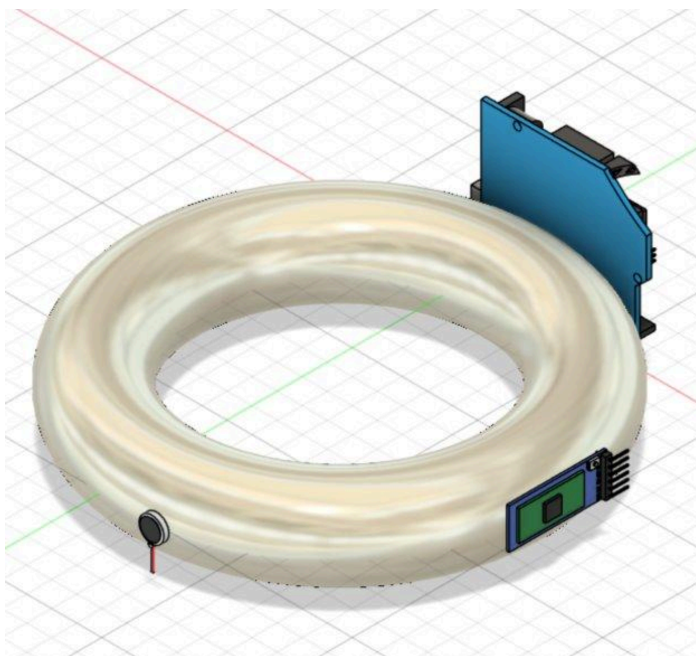

Figure 9: First CAD Model

A detailed code flowchart showing how Google Maps API and sensor data drive navigation cues to the phone, and motors was also necessary, along with a complete circuit diagram including all electronic components. Additionally, a final circuit diagram was created. A creative CAD emblem was submitted, as shown in Figure 10. All members completed soldering training to create a compact protoboard design. Research was conducted on existing products, materials, and real-time location-mapping methods as part of planning device testing. Lastly, a purchase request was made after reviewing available lab and makerspace materials.

Figure 10: 3D Model of Company Emblem

In benchmark B, the emblem needed to be approved in the Protolab ahead of benchmarking, along with an updated the CAD model to include two ankle-band units housing the battery, microcontroller, Bluetooth module, slide switch, vibration motors, and all circuitry, and demonstrate route mapping via Google Maps API with continuous location updates and vibration cues for turning, stopping, or continuing. The unit should be lightweight, sturdy, user-friendly, and securely fastened, and the SLDP project schedule must remain fully updated with statuses, assignments, and deadlines. The flowchart was also required to be updated to reflect the new code, including updates to the directional vibration logic for the ankle band. Finally, the circuit diagram was also revised to include all required components such as the microcontroller, Bluetooth module, vibration motors, slide switch, and supporting circuitry.

At this point, a functional prototype was developed and is shown in Figure 11, with thorough research indicating that it would be more user-friendly despite its increased weight. In addition, research showed that the best material for the product would be fabric, due to its lightweight, comfortable feel, and easy accessibility.

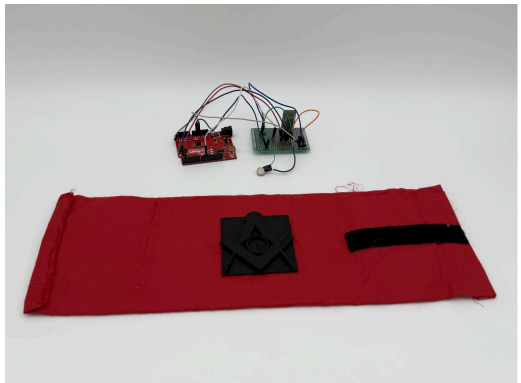

Figure 11: Casing and components

Furthermore, a complete CAD model update was required due to the material change. In addition, the circuit evolved to include a slide switch. The submitted emblem was also approved at Protolab and has started printing. Moreover, to better notify users, the code flowchart was updated to increase vibrational frequencies based on distance from the turn. Finally, a working navigation interaction between the Google Maps API and the navigation system was demonstrated, with the right band correctly vibrating to signal right turns.

To commission the project, the final prototype was required to be reliable and user-ready. During the evaluation, the created ankle band operated as intended, with correct vibration signals and stable Bluetooth communication. Furthermore, the casing remained durable during movement. As a result, the device met all usability and performance requirements. Due to the success in benchmark A and benchmark B, the prototype of the haptic navigational system was successful. As a result, the commissioning of the project confirmed full system readiness.

Throughout the design process, many challenges were faced. Because the simple circuit had to be adequately secured and placed into a compact yet comfortable casing, there were frequent issues involving soldering and casing. Furthermore, integrating the Google Maps API with the Arduino UNO involved many synchronization issues and required frequent code debugging. Furthermore, finding a way to power the device correctly while minimizing component damage required significant troubleshooting. By addressing these issues, the team better understood the project's design, which ultimately enhanced the prototype's reliability.

Conclusion

In summary, the final design of the VibeGuide was priced at $120 for consumers, making it more affordable and accessible than other wearable navigation devices. This price reflects the entire prototyping process the team went through, from initial CAD modeling and circuit drafting to assembly, soldering, vibration testing, refining casing designs, and integrating live Bluetooth navigation communication. Through this iterative process, the team successfully developed a functional wearable prototype capable of hands-free navigation via directional haptic feedback. While the VibeGuide meets its core design goals, some limitations remain, including the comfort and long-term durability of the casing materials, the weight distribution of internal components, and the reliance on a non-dedicated mobile interface for navigation commands.

Looking ahead, there are many opportunities for future improvements on the physical and software sides. The physical design can be improved by making the fabric more comfortable and durable. A change in material to create a more solid and protective casing will better secure the circuit components while maintaining comfort for the user. In addition, organizing the components internally could improve the weight distribution, making the bands more balanced. In place of the Velcro, a silicone band or buckle would provide a better, more adjustable fit. In addition, including a locking mechanism would enhance stability and long-term wearability.

On the software side, developing a mobile app dedicated to the device would allow users to customize features according to their personal preferences. A VibeGuide mobile app enables users to adjust vibration levels, monitor battery life, and ultimately create a better, more user-friendly experience, depicted in Figure 12, which is the potential mobile app icon.

Furthermore, integrating navigation apps such as Google Maps and Waze offers users greater flexibility in navigating.

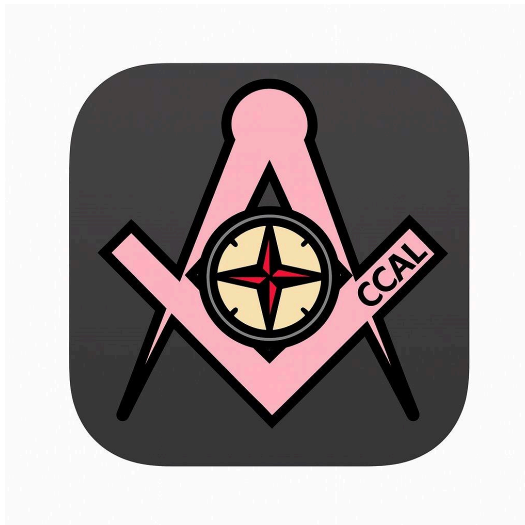

Figure 12: Potential Mobile App Icon

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