# Project Proposal V1

## Team Members and Skills

Our team is made up of Mengxu Xie, Zihao Lin, and Daijie Bao.

**Member 1 Mengxu Xie**: 3D printing, Laser cutting, Computer aid design.

**Member 2 Zihao Lin**: Machine design, Circuit analysis.

**Member 3 Daijie Bao**: Algorithm design and programming, Computer aid design.

## Topic and Motivation

We want to investigate a navigation system designed especially for visually impaired or drivers with their senses preoccupied. The rapid development of the last decades has made work and education much more accessible for visually impaired individuals, but moving independently is still a major challenge that, at worst, can lead to isolation and decreased quality of life. Inspired by Karon E. MacLean, we think that haptics can serve as a great tool to assist visually impaired in avoiding obstacles and navigating themselves with aids such as accessible GPS devices. It can be imagined how life is being improved with advanced haptics technologies. Therefore, we decided to develop a headband which incorporates a distance detection system and a GPS navigation system for haptics. The headband can provide haptic feedback, for example, vibration, to the user wearing it during navigation. Navigation or GPS systems will no longer only depend on vision, which is not accessible to the visually impaired but also employs tactile sensation. We hope this project can provide a solution to the current challenge in blind navigation.

## Previous Work

### Paper Selection 1

**R. K. Katzschmann, B. Araki and D. Rus, "Safe Local Navigation for Visually Impaired Users With a Time-of-Flight and Haptic Feedback Device," in *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 26, no. 3, pp. 583-593, March 2018, doi: 10.1109/TNSRE.2018.2800665.**

**https://ieeexplore.ieee.org/document/8276628**

To help visually impaired users to sense obstacles in their immediate environment for local navigation, the authors developed a wearable device based on haptic feedback and sensor technology combined with planning algorithms. This device consists of a sensor belt made up of an array of time-of-flight distance sensors and a haptic strap made up of vibratory motors. The device has been tested and proven to significantly increase the ability of visually impaired people to avoid obstacles. For our headband project, this paper provides ideas on navigation algorithms and clarifies the types of devices we can use, while its final test results increase our confidence in the project.

## Paper Selection 2

**F. Barontini, M. G. Catalano, L. Pallottino, B. Leporini and M. Bianchi, "Integrating Wearable Haptics and Obstacle Avoidance for the Visually Impaired in Indoor Navigation: A User-Centered Approach," in IEEE Transactions on Haptics, vol. 14, no. 1, pp. 109-122, 1 Jan.-March 2021, doi: 10.1109/TOH.2020.2996748.**

**https://ieeexplore.ieee.org/abstract/document/9099604**

This paper proposed a travel aid system that contains an RGB-D camera, an obstacle avoidance processor, and a wearable device capable of providing normal or tangential force cues for navigating in unknown indoor environments. Their experiments with blindfolded subjects indicate that this system could be a helpful tool to train blind people to use travel aids.
The proposed navigation system utilizes a user-center approach which will be a good example for us to consider on the user experience side when we design our prototype. The obstacle avoidance approach could be a valuable reference for the distance detection algorithm design of our project.

## Paper Selection 3

**L. Kuang, M. Aggravi, P. R. Giordano and C. Pacchierotti, "Wearable cutaneous device for applying position/location haptic feedback in navigation applications," 2022 IEEE Haptics Symposium (HAPTICS), 2022, pp. 1-6, doi: 10.1109/HAPTICS52432.2022.9765619.**

**https://ieeexplore.ieee.org/abstract/document/9765619**

The paper presents a wearable device capable of applying position/location haptic feedback to the user’s skin. It also discusses a perceptual evaluation of the position/location feedback provided by the device when worn around the forehead, forearm, and hand. Some preliminary navigation tasks have been done to test the device.

Some results the paper highlighted is inspiring. Humans are usually more sensitive to changes in weak stimuli than they are to similar changes in stronger stimuli. The proportional law suggests that the differential threshold increases with increasing intensity I of the stimulus, which enlightens our project design in the intensity of headband vibration.

## Paper Selection 4

**Matthias Berning, Florian Braun, Till Riedel, and Michael Beigl. 2015. ProximityHat: a head-worn system for subtle sensory augmentation with tactile stimulation. In Proceedings of the 2015 ACM International Symposium on Wearable Computers (ISWC '15). Association for Computing Machinery, New York, NY, USA, 31–38.**

**https://dl.acm.org/doi/10.1145/2802083.2802088**

The paper explores the use of pressure in a wearable tactile display. Six modules evenly placed around the head determine distance to surrounding objects and provide discernable pressure to navigate hallways and find doors for users. The paper also managed to conduct sensitivity and perception experiments with their prototype.

The discussion about actuator pressure and spatial understanding from sensors can be beneficial to our project. It provides good insights on the relationship between applied pressure and distance from surrounding objects, in which several absolute pressure levels are discernible and differentiable to human skins.

## Paper Selection 5

**A. Cosgun, E. A. Sisbot and H. I. Christensen, "Evaluation of rotational and directional vibration patterns on a tactile belt for guiding visually impaired people," 2014 IEEE Haptics Symposium (HAPTICS), 2014, pp. 367-370, doi: 10.1109/HAPTICS.2014.6775483.**

**https://ieeexplore.ieee.org/abstract/document/6775483**

An intuitive vibration pattern design for providing navigation assistance to blind people is presented in this paper, along with an evaluation study of the Vibro tactile belt. As part of their application, they consider rotational motions as well as directional motions.
The vibration pattern of their design could help us to design the vibration feedback system of our headband. We could also add not only translation motion but also rotational motion into our motion-sensing design like they did in their application.

# Project Plan

Our current concept is developing a haptic head-worn system that incorporates distance detection and GPS navigation system. The haptics navigation headband uses pressure actuators around the head to convey spatial information. Our system determines the distance to surrounding objects with ultrasonic sensors and maps this information to an inward pressure. The sense of touch is used to augment our perception of reality especially for the visually impared. We mainly focus on vibrational signals for information transfer. When the sensor detects an object right in front of users within 5 meters, the headband will vibrate in the middle of users' head, and the vibration rate gets more intense if the object is closer to users. If the object positions on the right hand side of users, the corresponding area of the headband will vibrate on the right part of head. GPS can also be added to our system. If the navigation is not followed, the headband can remind users by haptic feedback in corresponding directions. At the end of the semester, we hope to design and make a prototype of the discussed system, including functionalities of distance detection, vibration, and being compatible with GPS.

In order to implement our design, we firstly decide on the material of the major body of our head band. We use PLA as the base material for the headband because it is lightweight, environmentally friendly, and with great potential for modification. 3D printing and laser cutting technology are used to guarantee the space of our headband to be capable of holding GPS and various other sensors. Any risk of the headband falling off should be prevented during manufacturing. Soft materials can be added to the surface area in contact with human skin. We want to make a safe, comfortable, and good-looking headband suitable for daily use. Furthermore, to ensure that the vibrations generated by the pressure actuator do not cause adverse reactions, we will add energy-absorbing materials around it.

For our software selection, Ardunio will be our first choice. With the concern of budget and time, Ardunio is ideal for our design project due to its accessibility and portability. Ardunio can cover central aspects of this project such as circuit design and software algorithm development. The programming experience of arduino used in class with Hapkit can also be applied to the project. Other devices we plan to utilize are ultrasonic sensors, pressure actuators and GPS devices, which can all be purchased online. Resource required for our headband will be the knowledge of existing GPS technology which we are short of.

**Checkpoint 1: Wednesday, October 19**

Preliminary Drawing/CAD of headband design

**Checkpoint 2: Wednesday, October 26**

Looking for appropriate sensors, actuators, and GPS device; Control Algorithm for ultrasonic distance sensor is developed

**Checkpoint 3: Wednesday, November 2**

Finalize our headband design; Control Algorithm for pressure actuator is developed

**Checkpoint 4: Wednesday, November 9**

Headband is 3D printed and laser cut; Control Algorithm for GPS device is developed

**Checkpoint 5: Wednesday, November 16**

Headband is assembled and control algorithms are tested with sensor, actuator and GPS device

**Checkpoint 6: Wednesday, November 30**

Debugging and Solving problems with sensor, actuator and GPS device

**Checkpoint 7: Wednesday, December 7**

Finish all the testing and prepare for the demo

**Final project demos: Tuesday, December 13 (Design Day)**
**User study protocol due: Monday, December 19**
**Final report: Monday, December 19**