LightSight: LiDAR and sonar-based real-time obstacle detection

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Engineering Goal

A visually-impaired wheelchair user has difficulty navigating obstacles in their environment. Our engineering goal is to build, test, and deliver an obstacle detection device which alerts the user of obstructions to their movement path.

Background

STATISTICS

The American Federation for the Blind estimates 14.86% of individuals who are legally blind or have serious visual difficulties use a wheelchair (Simpson et al., 2005).

THE CLIENT

This product was designed for a visually impaired individual, who uses a manual wheelchair.

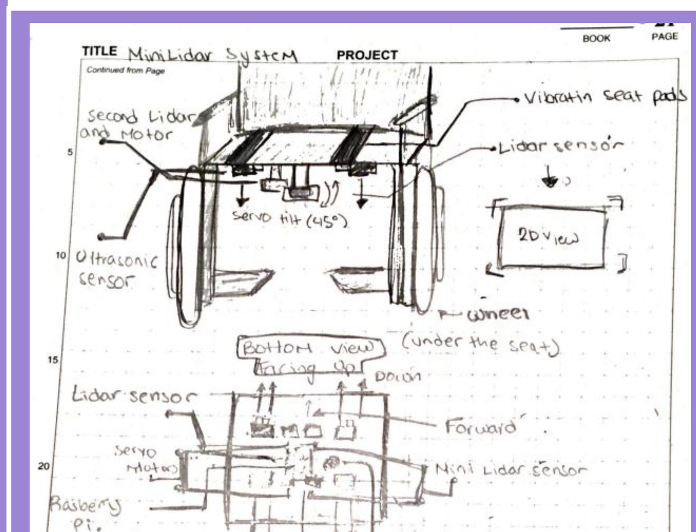
THE SOLUTION

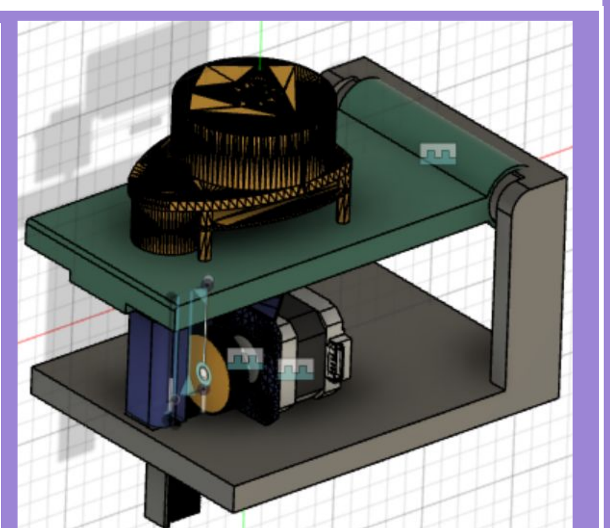
A LiDAR sensor will be mounted on a tilting mechanism above the head of the user. In addition, sonar sensors will be mounted below the wheelchair.

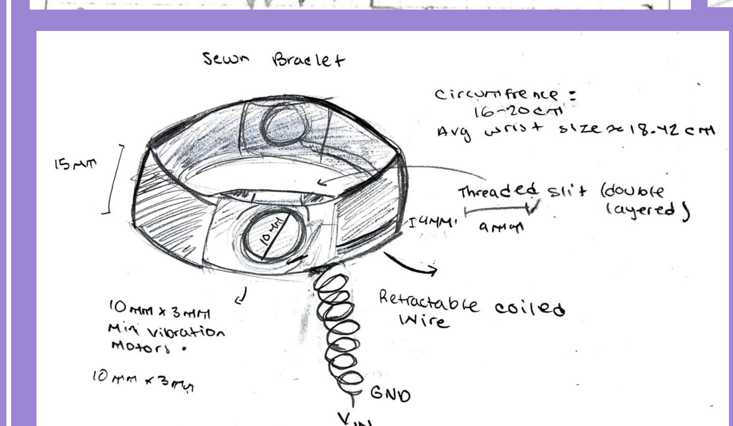
GOALS

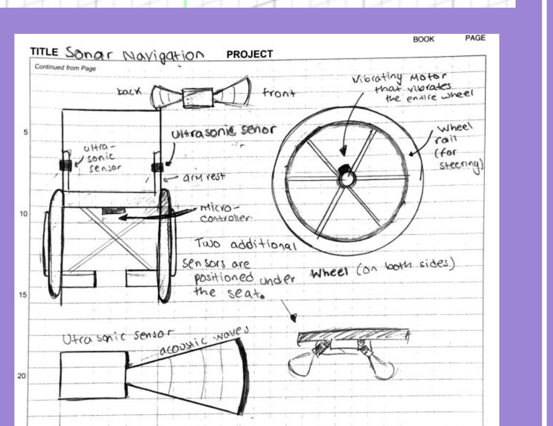
The goal is to increase independence and mobility for visually impaired wheelchair users.

Preliminary Designs









Decision Matrix

Requirement	Level	Type	Verison 1 - SONAR Only	Verison 2 - LiDAR Only	Verison 3 - SONAR and LiDAR
The device must be able to sense obstacles within a 1.5 meter range directly in front of the wheelchair.	1	functional	pass	pass	pass
The device must be capable of alerting visually impaired individuals.	1	functional	pass	pass	pass
The electronic system shall detect drops (ie. stairs, curbs, etc.) greater than 2" under the wheelchair in its front and back.	1	functional	fail	pass	pass
The device must be able to sense obstacles three-quarters of the way up from the floor to the top of the wheelchair.	2	functional	fail	fail	fail
The device shall propose a safe alternative path to the user before the object is incidentally detected.	2	functional	pass	pass	pass
The device shall be functional in dark conditions.	2	functional	pass	pass	pass
The device shall be able to notify the user in at least two ways (ex. sound and vibration)	2	functional	fail	fail	fail
Must sense 360° around the user.	2	functional	fail	pass	pass
The apparatus will be capable of providing a range of information to the user regarding the scope of the space between them and environmental obstacles.	3	functional	fail	fail	fail
The device will contain a remote alert system capable of notifying others in a separate environment about a detected collision.	3	functional	fail	fail	fail
The device shall scan and map the surrounding environment in three dimensions to assist with alternative route navigation.	3	functional	fail	pass	pass
The device will allow the user to program the range and type of information relayed to them.	3	functional	fail	fail	fail
The device must be able to attach to the wheelchair.	1	physical	pass	pass	pass
The device shall use a rechargeable energy source.	1	physical	pass	pass	pass
Wires and electric parts will be protected and waterproof.	2	physical	pass	pass	pass
The apparatus shall weigh less than 5lbs.	2	physical	pass	pass	pass
The device will be integrable with manual wheelchairs different from the client's.	2	physical	pass	pass	pass
The total price of the device must not exceed 125 USD, excluding already obtained and borrowed materials.	1	cost	pass	pass	pass
The user must be physically capable of operating a manual wheelchair.	1	user	pass	pass	pass
The device shall include a user manual detailing the operation and capabilities of the apparatus.	1	documentation	pass	pass	pass
The device will include documentation specifying the design, materials, and data collection/analysis.	1	documentation	pass	pass	pass
The device shall include figures/diagrams regarding its installation.	1	documentation	pass	pass	pass

Results and Testing

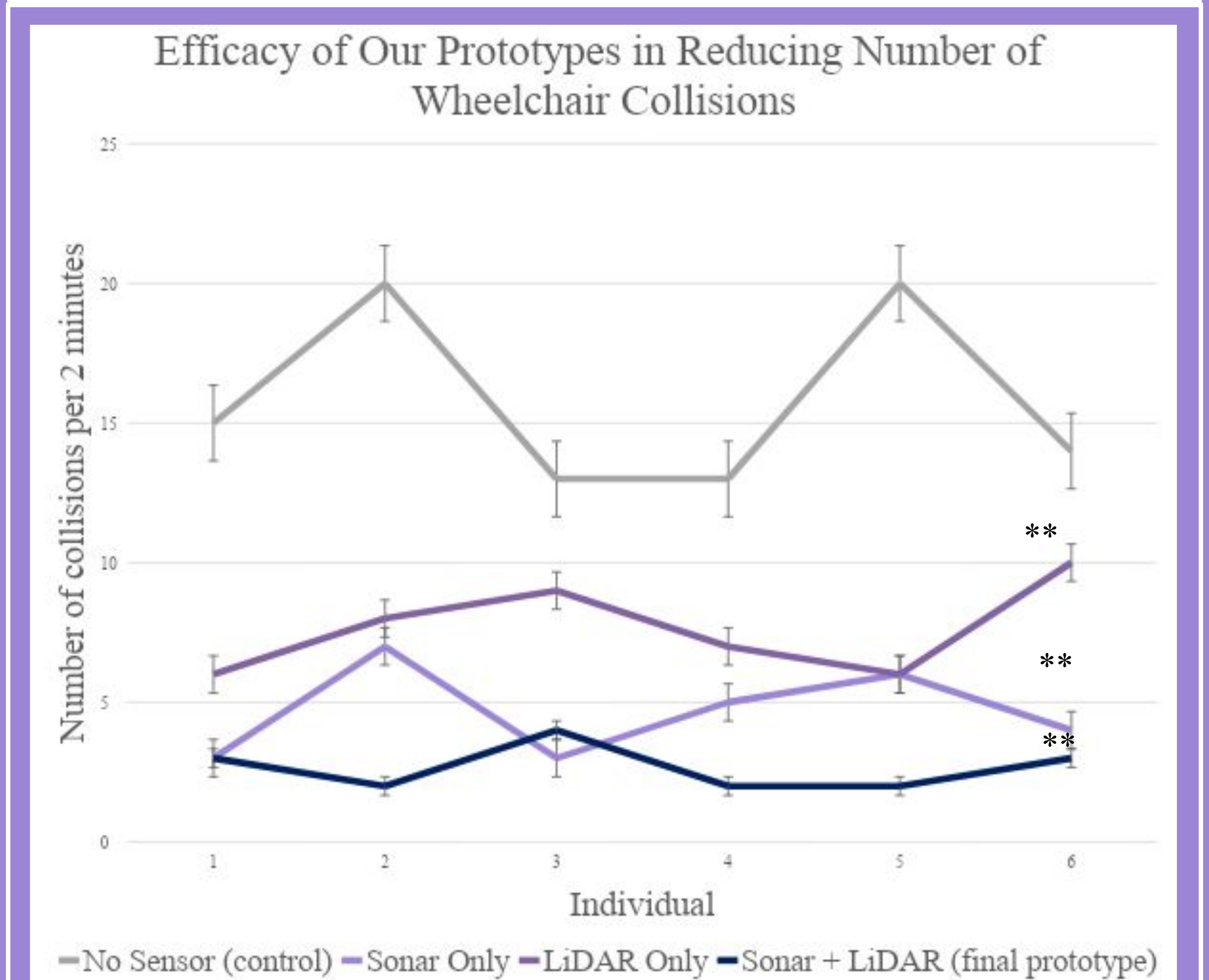


Figure 1: Iterations of prototyping and number of collisions for each. Significant p values for each prototype in comparison with control. Complete system had highly significantly less collisions (**p = 0.000002648).

Final Design

LiDAR sensor mounted above wheelchair, sonar connected to each footrest, two bracelets (left and right) with vibration modules in each.

Bracelets with Vibration Modules

Sonar Sensors on Footrests

LiDAR Sensor

Completed Prototype

Conclusion

Our system was successful in reducing the amount of wheelchair collisions in two minutes. The sonar and LiDAR system reduced collisions significantly (*p = 0.000002648). In addition, the complete system perform significantly better than both other iterations (*p = 0.022963, **p = 0.000053), proving to be the best option.

Our multifaceted approach means we have the ability to make updates and edits more easily. In addition, our Velcro attachment system would make the system more applicable to different wheelchairs.

Process

LiDAR and Tilting Mechanism

A LiDAR sensor was mounted on a tilting mechanism, connected to a stepper motor.

Sonar and Bracelet

Sonar sensors were connected to vibration modules, that were attached to a watch band.

Code and Parameters

Code was written according to desired distances before vibration occurred.

Printing Attachments

3D printing and CAD were used to design attachments for the LiDAR and sonar sensors.

Testing

The subsystems were combined and attached to the wheelchair to begin testing.

Data Collection

Data was collected through a series of tests run on a sample obstacle-filled pathway. Each group member was blindfolded and asked to navigate the path first using the wheelchair only. Then, the process was repeated with the prototype attached to the wheelchair. Number of collisions along with total time were collected for each run.

Future

- Enable real-time topography analysis and mapping of the user's environment to provide programmed routes
- Utilize mobile notifications to alert caretakers or loved ones of potential collisions
- Deploy electromagnetic or other automated braking system to protect users
- Optimize the apparatus for cost and production scale