# Biometric Autonomous Droid (BAD-2024) Preliminary Project Proposal

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**Abstract**

Lafayette College's Engineering Division has requested that the 2025 senior class work to design a Biometric Autonomous Droid (BAD-2024) system for deployment on the fourth floor of the Acopian Engineering Center. The main objective of the proposed system is to create an autonomous wheelchair that is capable of navigating a single-floor indoor setting. The wheelchair will contain all of the items necessary for self-containment and autonomous operation for a finite time and over a limited range. This system is composed of a physical wheelchair, a joystick for navigation, a 24V battery, two motors, a comprehensive sensor system, self-driving capability, and an interactive interface. The proposed system is intended for indoor use only.

# 1 Motivation

In clinical settings, patient mobility is crucial for well-being. However, for the elderly population, those with disabilities such as Multiple Sclerosis (MS) or chronic conditions that impair mobility, navigating hospital floors poses a challenge. Traditional wheelchairs require that the patient use their strength to move about the floor or rely on a nurse or aide to assist throughout their journey. Constant assistance places strain on staff resources and availability and calls for an innovative, personalized solution: an autonomous wheelchair. At the intersection of mobile robotics and patient care, our senior design project has envisioned a biometric, autonomous droid in the form of a power wheelchair capable of safely transporting patients through single-floor, indoor environments such as hospitals or assisted living facilities. Our proposed technology would improve patient self-sufficiency while addressing and improving healthcare staff efficiency, allowing for personalized patient care management.

# 2 Design Objectives

## 2.1 Physical Structure

The mobile robot system for this project will consist of an autonomous wheelchair. The wheelchair and its associated parts are to be constructed of lightweight, durable material where possible. The structure underneath will be made predominantly of 80/20 aluminum. This material is structurally sound enough to support the maximum weight of the wheelchair and the electrical units underneath the chair.

The wheelchair should consist of a comfortable seat for the user, a headrest, armrests, and a foldable footrest. The seat should be about 20 inches wide to allow enough extra space for comfortability while letting the patient comfortably rest their arms on the armrests. The seat should also be about 20 inches long to allow every user to fit comfortably and allow for a roughly 90 degree bend in the knees. The backrest of the wheelchair seat should be no greater than 39 inches in height. This height allows the user, regardless of height, to sit comfortably with neck support while allowing the LiDAR sensor to have an unobstructed view above the patient's head. These measurements are consistent with commercially available power wheelchairs.

On the back of the wheelchair, handles will provide the ability for a nurse or caregiver to move the wheelchair manually while standing. The diameter of the handles is estimated to be 7/8 inches, a standard dimension.

The chair itself will be a dark, neutral color such as black in order to avoid a distracting appearance to bystanders and hide stains in case of spills. However, the base of the wheelchair will likely be a bolder color to help bystanders recognize there is a chair, and to avoid being hit or run over by the chair in case there is any sort of malfunction.

Figure 1: Proposed Wheelchair Design[1]

## 2.2 Battery and Motor

A critical part of any electric wheelchair is the motor and battery that drive the whole system. The battery will power the motor, sensors, controller, and interface. It will be required to be at least 24V with around 50Ah of battery life to ensure the wheelchair can last for a minimum of 8 hours of use. The battery may just be one 24V battery or two 12V batteries and should fully charge in 5 hours. For the motor it will be best if we go with a gear motor which is best of higher torque and lower RPM which is perfect because the wheelchair will be heavy, is only required to go 4mph, and require very minimal acceleration. Two motors will be needed for both left and right driving wheels. The motors will be rated at 24V, around 150-300 Watts. If we are considering a wheel size of 12” in diameter then the minimum RPM should be 112 revolutions per minute. The total torque required to push 400 lbs from stop will be around 200-300 Nm so for each motor the peak torque will be around 100-150 Nm with a continuous torque of about 8-15 Nm after that.

## 2.3 Sensors

### 2.3.1 Joystick

An analog joystick will be used on the wheelchair to allow the user to control the chair manually. Joysticks enable users to input any direction they want, allowing the user to control the wheelchair easily. Joysticks usually use either potentiometers or Hall Effect sensors to detect which direction the user is inputting. Potentiometers act like variable voltage dividers, so the input direction can be acquired by measuring the voltage at the output terminal of two potentiometers. One disadvantage of potentiometers is that they wear out over time because of contacts rubbing together. On the other hand, Hall Effect sensors use magnetic fields to determine the input direction and are much more reliable than potentiometers. We will have the joystick mounted to one of the arms of the wheelchair for ease of use. The joystick will be connected to the Raspberry Pi so that its directional data can be used to steer the wheelchair.

### 2.3.2 LiDAR Sensors

LiDAR (Light Detection and Range) is a sensor that measures the distance to objects. It works by sending out beams of light in all directions and then measuring the time it takes for the light to return to measure how far the object is[2]. The advantage of LiDAR over ultrasonic sensors (which do a similar thing with sound) is that LiDAR sensors work over longer ranges, are more accurate, and have a higher resolution. Some sensors only capture a 360-degree view on one plane (2D LiDAR), but more advanced sensors capture a 360-degree view over the height of an entire room (3D LiDAR). We aim to use one of the sensors to capture the whole room since it will give us better obstacle detection. The downside to those sensors is that they are expensive. LiDAR sensors, which only capture one plane, are still about $100, and the full-room view sensors are anywhere from $500 to $5000. We plan to use a sensor that costs around $500, mainly due to the cost of the sensors. The sensors in that price range seem to be either 2D LiDAR sensors or have a 90-degree vertical field of view, which makes capturing the entire environment around the chair more difficult. We might use a solution of having a 90-degree sensor looking in front of the wheelchair for obstacles, and then either other sensors or a cheaper 2D LiDAR sensor looking behind the chair for other obstacles. Most LiDAR sensors have a ROS2 driver for collecting data. ROS2 will be discussed later, but we plan on using it both for the LiDAR sensors and general communication between the robot's systems.

### 2.3.3 Ultrasonic Sensors

Ultrasonic sensors utilize high-frequency sound waves - typically above 20KHz which is beyond the hearing range for humans (hence the term ultrasound) - to detect objects and possibly measure distances. These low-cost and power-efficient devices emit ultrasonic pulses in a set direction - if there is an obstacle, the sensor's receiver will detect the reflected sound wave. The flight time of the sound wave can thus be used to approximate the distance to the obstacle. These are useful in detecting transparent objects (where optical sensors suffer) regardless of color or lighting conditions at a distance ranging from a few centimeters to meters, depending on the model. On the BAD, these would aid the patients in navigating narrow spaces, sensing crowded environments, and complement other sensors well. It is, however, to be noted that these sensors could be blocked by certain clothing materials that absorb ultrasonic waves and that one single sensor has a relatively low field of view. They can also have a short range, depending on the specific sensor.

### 2.3.4 PIR Sensors

Within a field of view up to 30ft, a passive infrared sensor detects infrared radiation (IR) emitted by all objects above absolute zero temperature and aids detection of humans and animals, who emit significant amounts of IR due to body heat. These sensors are passive since they do not emit signals themselves, but rather detect IR changes from the surrounding environment, making them ideal for low power consumption applications. Additionally, PIR sensors only detect the presence or movement of human objects without capturing any visual information which protects the patients' and surrounding people's privacy. On the BAD, they are not as efficient in detecting walls and static surroundings but complement ultrasonic sensors' weakness in reliable human presence detection, on which physical / algorithmic adjustments can be automated.

### 2.3.5 Optical Sensors

Optical rotary encoder discs can be made with different numbers of slots within the 360-degree perimeter. As the motor shaft rotates, the optical encoder converts light pulses into electrical pulses, which are then transmitted to a motion control system. A motion control system coupled to an optical encoder is designed to count the number of pulses the encoder generates to determine the rotational position of a shaft, its speed, its rotational direction, and its rate of acceleration. Optical encoders typically have three output channels. Two channels provide count and direction signals, while another channel is used to make sure of the accuracy of the overall count. It emits a pulse once every 360 degrees. The one we are using is built into the motor itself and data from the encoder goes directly to the Controller.

### 2.3.6 Optical Fingerprint Sensors

Mainly used for biometric authentication systems, optical fingerprint sensors can verify authorized hospital staff / personnel to make changes or set destinations for the BAD based on unique patterns in each person's fingerprint. Typically, these sensors illuminate the fingertip with a light source, such as LED, of which an image is captured and processed to identify unique features - if they match those that have been previously stored, the user is then authenticated. These cost-effective, easy-to-integrate sensors are durable even under heavy use from varying skin moisture levels. Apart from user authentication, these optical fingerprint sensors can:

(i) leverage personalized settings as different patients might need adjustably different physical wheelchair configurations;

(ii) ease the hospital staff (physicians, nurses, caregivers. . . ) in securely accessing appropriate medical data (health records, care instructions. . . ); and

(iii) make the BAD more user-friendly.

### 2.3.7 IMU

An IMU (Inertial measurement unit) sensor is a sensor that detects acceleration and gyroscopic changes in 3D space[3], and they often have a temperature sensor as well. It reports the acceleration and gyroscopic changes on each of the 3D axes, which can be summed up to get information about the sensor's orientation. 6-axis IMUs include the accelerometer and gyroscope, but 9-axis IMUs also include a magnetometer, which can tell the heading like a compass. Some IMUs also have freefall detection. The use of the IMU is to aid with the self-driving so that the wheelchair knows which direction it is heading. The IMU can also be used to tell if the chair is going up a ramp, and if the ramp is too steep, it can alert the user and stop trying to go up the ramp. If we got an IMU with freefall detection, it could also tell if the chair has fallen somewhere to alert caretakers that something has gone catastrophically wrong.

## 2.4 Compute and Communication

### 2.4.1 Raspberry Pi

The Raspberry Pi will be the computation brain of the wheelchair. A Raspberry Pi is a small, general purpose computer[4]. All the sensors onboard the chair will be connected to the Raspberry Pi using either USB or the GPIO pins on the Pi. The Raspberry Pi will also be connected to a WiFi network to send LiDAR data to the base station computer. The reason that we are sending the LiDAR data off the wheelchair is that LiDAR data is computationally heavy to process, and Raspberry Pi's are not very powerful computers. By sending it off, we can use a more powerful computer to process the data quickly before sending it back to the Raspberry Pi. ROS2 will be used to facilitate sending the data over WiFi, and it will be discussed later. The Pi will also be in charge of sending the commands to the speed controller to tell the motors how to spin to move in the direction and at the speed that we want.

### 2.4.2 Base Station Computer

The base station computer will be a key component of the navigation system. It will be responsible for processing all of the LiDAR data since LiDAR data is computationally heavy. The computer will be plugged into the wall next to the charging station. This will allow it to use more powerful components without consuming any battery on the physical chair. The computer will have a powerful CPU and a GPU to be flexible enough to support our implementation of 3D mapping. The computer will also need an Ethernet connection to ensure low latency for communication between it and the wheelchair since the mapping needs to be fast so the wheelchair can react in time. We are also evaluating using the Lafayette High-Performance Cluster (HPC) as a base station computer since it would be more powerful and flexible than any computer we could buy. Using the HPC would have some drawbacks, mainly in its lack of configuration around the network and potential latency issues.

### 2.4.3 WiFi Communication and ROS2

ROS2 is a communication library used in many different robotic applications[5]. It operates on a publisher-subscriber model, with nodes publishing or subscribing to data on different topics. These topics have a specific data type, which ensures that data is consistent across various devices that it runs on. ROS2 runs over a local network to work on ethernet and WiFi. It is a soft real-time system, meaning that although it is not technically real-time since it can lose data, it is fast enough to be considered real-time[6]. We can also account for it not being true real-time by having critical functions like emergency obstacle detection running locally on the chair. We plan to use ROS2 to send the raw data from the sensors to the base station computer to process the data and send it back to the wheelchair in the form of commands. We will probably need our own local WiFi network set up because the schools network has lots of software running on it to manage students, but this also causes problems with ROS. Whatever network we use will need to have enough range to cover the entire operating area of the wheelchair and be fast enough to allow for low-latency communication between the wheelchair and the base station to ensure near real-time operation of the wheelchair.

### 2.4.4 Physical Location System with Bluetooth Beacons

One challenge we face is figuring out where the wheelchair is physically on the floor. In autonomous cars, GPS determines the vehicle's geographic location to know where it is and where it needs to go. We probably can't use GPS because it doesn't work well indoors, while our chair is only designed for use indoors. Our idea is to have many beacons stationed around the floor, which the wheelchair can use to figure out its rough location. We can use a protocol like WiFi or Bluetooth because the chair can read the signal strength to the transmitter and then guess how far away it is based on the strength. It's the most exact system, but it would be close enough to get the chair where it needs to go. WiFi has a much better range than Bluetooth, but it is a more expensive system since we need to put access points everywhere we want a beacon. There is also an additional challenge because most WiFi systems automatically swapping the access point it is connected to and only connecting to one access point. On the other hand, Bluetooth has less range but is cheap to implement, and Bluetooth centrals can connect to multiple peripherals. This would allow the chair to connect to multiple beacons at once and determine the approximate location of each to figure out where the wheelchair is on the floor.

### 2.4.5 Database Storage

The type of database used for this project will be a NoSQL Database. These databases are better for storing large amounts of data than relational databases. The database will store graphical information from our sensors on a large scale. One possible application to use is Firebase. Firebase offers a cloud-based real-time database for a relatively cheap price.

We need to store data for algorithm usage and learning. Data will still be sent directly to the wheelchair controls to avoid latency. Stored data will be used to improve future wheelchair operations. A use case of this could be the wheelchair saving computation time when recognizing an object that has been detected before.

We should only store processed data to save on overall cost. This will also reduce latency between the physical sensors and the cloud database. An example could be storing processed X, Y, and Z data from the LiDAR sensor.

## 2.5 Self-Driving Mapping Architecture

Google Cartographer[7]: is an open-source library developed for real-time simultaneous localization and mapping (SLAM) in 2D and 3D environments. It is designed to provide high-quality mapping and localization in real-time without the need for GPS, making it ideal for indoor navigation tasks like those required for a self-driving wheelchair.

Figure 2: Example of 2D Lidar Scan

### 2.5.1 Inputs

- Lidar Sensor Data: 2D or 3D Lidar Scans
- Odometry Data (Optional but Beneficial): Data from wheel encoders (to measure wheel rotations to estimate movement). Helps improve localization accuracy.
- Inertial Measurement Unit (IMU) Data (Recommended): Data from accelerometers and gyroscopes. Provides data on acceleration and angular velocity.
- Time Synchronization: All the sensor data must be accurately timestamped. Synchronization ensures data corresponds to the same time frame.

### 2.5.2 Outputs

- 2D Occupancy Grid Maps: They represent the environment as a grid with information about occupied and free spaces. Used for path planning and obstacle avoidance.
- Pose Estimation: Real-time estimation of the wheelchair's position and orientation within the map. Provides continuous updates on the wheelchair's location.
- Trajectory Information and Path History: Records the path taken over time.

### 2.5.3 Activities

- SLAM Integration: The cartographer performs SLAM by integrating sensor data to build a map and simultaneously localize the wheelchair within that map.
- Initial Pose Estimation: Uses odometry and IMU data to predict the next poses. Provides an initial guess for scan matching.
- Scan Matching: Compares the current LiDAR scan with the existing submap. Searches over possible positions to find the best alignment. Converts scan into probability grids representing obstacle likelihood.
- Submap Creation: Groups Lidar scans into manageable chunks called sub maps. Each submap covers a portion of the environment. New scans are inserted into active submaps based on pose estimates.
- Map Updating: Updates the global map using optimized poses. Ensures the map remains accurate over time.
- Determines the Wheelchair's Position:

  i) Pose Estimation: Position and Orientation Calculates the wheelchair's x, y (and z in 3D) coordinates and orientation angles (yaw, pitch, roll). Uses a global map frame and local frames to define positions.

ii) Path Planning: Uses the pose estimates to plan paths from the current location to the destination. Obstacle Avoidance. Updates the map with new obstacles and adjusts the path accordingly Feedback Control

## 2.6 Obstacle Recognition

Lidar-Based Object Tracking with clustering and temporal analysis[8] method leverages Lidar sensor data to identify, track, and classify obstacles in real-time, enabling responsive control actions such as stopping or rerouting.

### 2.6.1 Inputs

We use the same inputs used for the Cartographer Library described above.

### 2.6.2 Outputs

- Dynamic Obstacle Alerts: We either have boolean signals or detailed obstacle information. The purpose is to indicate the presence of moving obstacles requiring immediate attention.
- Static Obstacle Data: Positional information within the occupancy grid map. Represents stationary objects for path planning and navigation.
- Control Commands: Gives us stop signals or/and reroute instructions. Its goal is to direct the wheelchair's control system to take appropriate actions based on obstacle classification.

### 2.6.3 Functions

- Noise Filtering: Utilizes statistical outlier removal to eliminate spurious Lidar points, ensuring data quality.

- DBSCAN (Density-Based Spatial Clustering of Applications with Noise):[9] It segments the preprocessed Lidar point cloud into distinct clusters, each representing a potential obstacle.

## 2.7 Interface

For the user interface of the wheelchair, we will use a touchscreen mounted onto the arm of the wheelchair. The screen will be mounted on the opposite arm of the joystick. We will use the Raspberry Pi Touch Display 7" screen. This screen will provide users with relevant information including battery life, destination, and wheelchair status. Through the touchscreen, the user should be able to set their destination to allow self-driving algorithms to assist the user. The physical screen will be mounted and adjustable for ease of use. The screen will be connected to and receive/ send data to the Raspberry Pi located on the wheelchair. Lastly, the contents of the screen will provide a simple-to-read display.

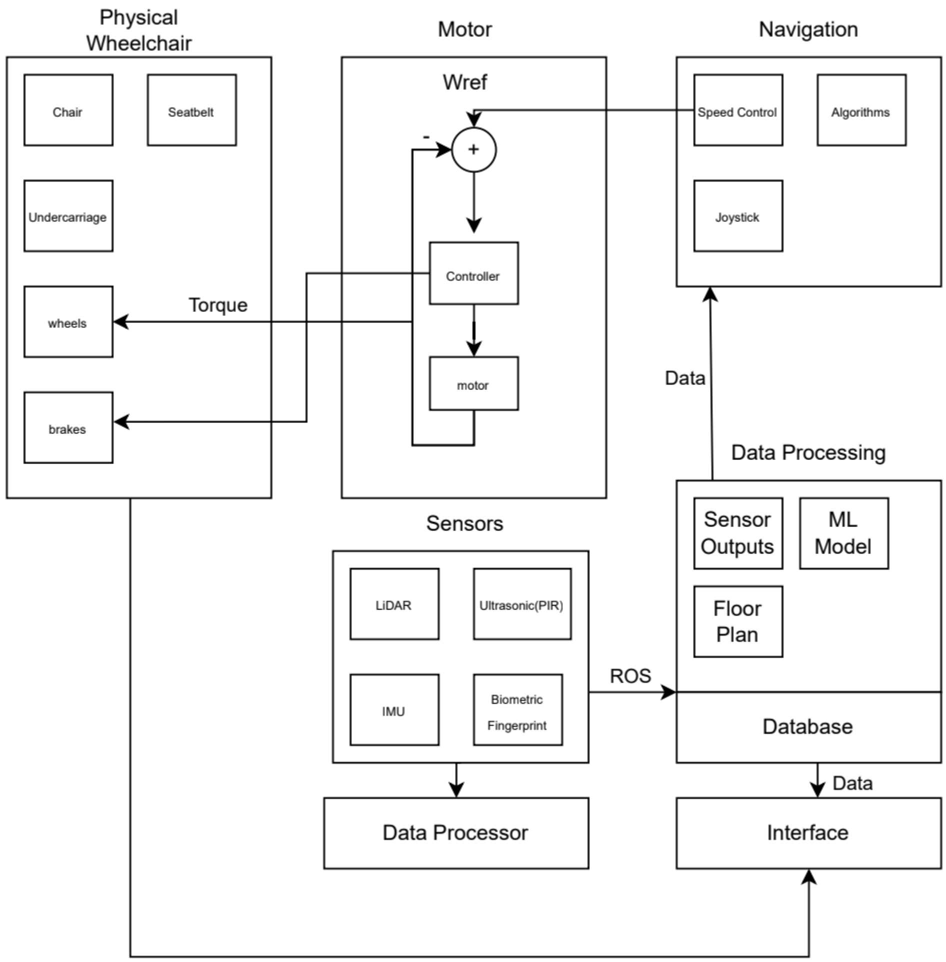


Figure 3: Overall System Block Diagram

# 3 Design Metrics and Constraints

- Weight: The total weight of the wheelchair and occupant should not exceed 400 pounds in total.
- Dimensions: The maximum physical dimension of the chair, excluding the passenger, must not exceed 1 meter in the horizontal plane. The height measured from the floor to the top of the chair (excluding the LiDAR sensor) should not exceed 65 inches.
- Wheel size: The drive wheels should be larger than the castor wheels in order to obtain

a stronger drive. The estimated dimension of the drive wheels is 12 to 16 inches in diameter, and 2 to 3 inches in thickness, while the estimated dimension of the front castor wheels is 8-10 inches in diameter.

- Wheel construction: The tires of the wheels should be constructed of rubber material in order to increase the friction between the wheels and the ground beneath. Both front and rear wheels must be capable of supporting up to 400 pounds in order to ensure that the patient and rest of the wheelchair are supported.

- Navigation: The wheelchair is only to be used indoors, and is only to travel on a single floor. It should not be used or directed to transport a patient on stairs.

- Patient: The autonomous wheelchair is designed for adult use only. Passengers must be at least 18 years of age. Regarding patient ability, the wheelchair is designed for patients who fall in the 0-8.5 range on the Extended Disability Status Scale for Multiple Sclerosis. This encompasses normal neurological function to those who are essentially restricted to bed or chair or perambulated in a wheelchair.[10]

- Speed: The maximum forward or reverse speed of the robot must not exceed 2 meters per second. The maximum acceleration or deceleration in normal powered operation should be no greater than 1 $m/s^2$. The acceleration or deceleration in normal powered operation must be no greater than 3 $m/s^2$ during emergency power-off. On an inclined surface up to a 6 degree slope, the wheelchair must be able to carry its maximum working load while maintaining a forward speed of at least 1.5 $m/s$.

- Charging: With a designated space for charging, the wheelchair will be designed to complete charging through our very own custom charging port. The charging station will be manual, needing assistance of a third party. This will reduce charging complexity, lower cost and straightforward procedure.

# 4 Relevant codes and standards

For this project, the safety of the building team, clients, and users is essential. Our design team intends to follow several safety standards and guidelines, including ISO 7176 Wheelchair Standards. The relevant standards by which the group will comply are ISO 7176-1, ISO 7176-2, ISO 7176-3, ISO 7176-6, ISO 7176-9, ISO 7176-10, ISO 7176-14, and ISO 7176-25.

# 5 Concepts Applied From Other Courses and Concepts to Learn

- ECE 414: Embedded Systems: This course taught how to program microcontrollers using the C programming language. The course also explained how to get data from different sensors and use them to have our programs respond to different inputs.
- CS 205: Software Engineering: This course provided foundational knowledge on back-end database management and front-end application development.
- CS 320: Database Management Systems: This course is relevant for backend database management and NoSQL databases.
- CS 406: Operating Systems: This course will help us calculate how processes are scheduled to ensure latency and efficiency.
- ECE 322, 323: Solid States 1 & 2: This course sequence is important for hardware design and a strong foundation for circuitry.
- ECE 331, 332: Signal and Systems, Communications Systems: These courses provide foundations on relating time and frequency domains for processing signals as well as basic communication protocols, including wave modulation, error correction, and more.

- PHIL 245: Bioethics: The principles of bioethics are essential to keep in mind throughout the duration of this project in order to ensure the safety and wellbeing of the client/patient that the wheelchair is designed for.
- ME 210: Manufacturing and Design: For the duration of this course, the main project was to design and build a small drag race car in the span of 3 months. At the same time, the class taught about the devices in the workshop and how to use them to create parts for the car.
- ME 480: Control Systems and Mechatronics: In this course, finite state machines and algorithms to add to existing machines. This also includes using algorithms to improve or regulate the performance of machines.
- Concepts to learn:
  - Through the machine shop, we will learn how to mechanically attach pieces together, so we can put together the physical pieces of the wheelchair. We will be taught how to do this in the safest way possible.
  - Algorithms for LiDAR and self-driving
  - PCB Design for custom circuit boards

# 6 Preliminary operation manual

## 6.1 Getting in and out of chair

The user should stand in front of the wheelchair and sit back onto the wheelchair potentially using the armrests as support. The user then moves their feet onto the footrest, adjusting as needed. Then push back into the wheelchair now that the feet are on the footrest and adjust the seating position until comfortably seated. The user can adjust the headrest as well.

To put on the seat belt, the user should be in a seated position, and bring the two sides of the seat belt together and join them in the middle. To release, the user can squeeze the sides of the seat belt buckle and detach the two sides of the belt. To get out the wheelchair, the user should move their feet off of the footrest. If needed, adjust forward in the seat before moving feet off of the footrest. Then once the feet are placed securely on the ground, the user can use the armrests to propel themselves into a standing position.

A nurse or caregiver can also move the chair when a patient is sitting in it. The nurse would grab the handles on the back of the wheelchair and push forward or pull backwards depending on desired direction of movement. This would override the self-driving system.

## 6.2 Charging

There will be a designated space on the floor of the building to charge the wheelchair system by plugging it into the wall. This must be done by either the user or the healthcare staff who is assisting the patient.

# 7 Preliminary Safety Analysis

- Battery: do not touch battery leads, do not touch the battery when in and after use, do not touch wiring.

- Motor: Shall not exceed the acceleration of 1 $m/s^2$, shall not exceed the acceleration of 3 m/s2 when emergency stop, do not touch the motor when in operation.

- Navigation: the group will ensure the safety of all members by minimizing the number of members who are present for navigation testing.

- Weight: the BAD-2024 system should not exceed 400 pounds in weight, the user's weight should not exceed 200 pounds in weight.

- General Safety Concerns: the group will adhere to lab safety rules at all times. These include wearing closed toed shoes, tying back loose clothing and/or hair, and wearing safety glasses when appropriate.

# 8 Unit testing Procedures

## 8.1 Battery

1. Battery use: Ensure that the battery is for continuous use.
   - PASS: When in continuous use, the battery lasts 10 miles.
   - FAIL: The battery does not last 10 miles.
2. Battery temperature: Ensure that the battery does not overheat.
   - PASS: Battery does not overheat in continuous use.
   - FAIL: Battery exceeds temperature regulations in continuous use.
3. Battery Power: Ensure the battery has sufficient power.
   - PASS: Battery has enough power to turn on all electronics.
   - FAIL: Battery is unable to provide power to all electronics.

### 8.1.1 Motor

1. Motor Operations: Ensure operations are within a safe range.
   - PASS: Motor can operate at a safe speed and acceleration
   - FAIL: Motor exceeds speed and acceleration limits outlined.
2. Motor Temperature: Ensure that the motor does not overheat.

- PASS: Motor does not overheat in continuous use.
- FAIL: Motor overheats in continuous use.

3. Motion: Ensure that the motor can power the wheelchair and user.

- PASS: Motor can push and stop the wheelchair and passenger.
- FAIL: Motor is unable to push and stop the wheelchair and passenger.

### 8.1.2 Controller

Ensure that the motor controller executes function without error.

- PASS: The controller controls motors without error.
- FAIL: The controller makes errors during motor control.

## 9 Estimated Costs

Based on our initial research, we are estimating a budget of $5000. All of the items we have researched fall into three categories: physical, electrical, and sensors/compute. Physical items include things like a chair, wheels, and a seatbelt. Electrical items include the motors, motor controller, and batteries. And sensor/compute items include the Raspberry Pi, the base station computer, and LiDAR and other sensors.

## 10 Website Access

To display information about the project and updates about our Senior Design Project, we have created a website. Here you can find information about the design team members, the work of each sub-group within the project, and documentation about preliminary designs and proposals. This website will be updated on a regular basis by administrators Nam Vu and Laxman Poudel. The website can be found at this link.

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