Boston University
Electrical & Computer Engineering
EC463 Senior Design Project

Second Prototype Test Report

MOSS Wheelchair: Modular Open-Source Smart Wheelchair

by

Team 11
MOSS Wheelchair

Team Members

Sebastian Gangemi sgangemi@bu.edu
Aya Kassem ayak@bu.edu
Norbert Malik norbert@bu.edu
Maha Noor mahakdn@bu.edu

Equipment and Setup

Motor Controller:

A. Hardware:
   - Wheelchair
   - 2 50 W 24 V Brushed Motors
   - 2 Motor controllers
   - 2 24 V AGM Batteries
   - 2 Single-ended quadrature wheel encoders
   - 2 Single-ended to differential quadrature signal converters
   - Joystick
   - Arduino
   - NVIDIA Jetson Nano
B. Software:
   - Simple Arduino script
     - Controls RPM of each motor via a PWM signal sent to its respective motor drive
   - Simple NVIDIA Jetson Nano Script
     - Uses PySerial library
     - Communicates with Arduino to send commands to move forward, backward, and stop

Object Detection:

A. Hardware:
   - NVIDIA Jetson Nano
     - Flashed microSD card
     - Power adapter (2.5 A 5 V)
     - WiFi card
     - WiFi antennas
   - Raspberry Pi SC0024 IMX219 NoIR Camera
   - Objects you want to detect
B. Software:
   - Python 3.6
   - Jetson Inference
   - PyTorch with CUDA support
   - TorchVision
   - GStreamer

Robotic Arm:

A. Hardware:
   - 3D printed forearm and hand parts assembled
   - Strings to attach and move the arm and fingers
   - Adhesives and fasteners such as screws and bolts

    - 6 high torque servo motors
    - Arduino Uno
B. Software:
    - Arduino code that controls motors for finger and wrist movement (open and close, rotation)

Measurements Taken

Laptop Remote Control:

We tested the control of the wheelchair from a laptop's arrow keys with different weights ranging from no load to up to 190 lbs. The wheelchair was responsive with all the weights and would stop as soon as keys were released in all cases, resulting in 0 collisions. It would however take longer to accelerate when heavier people sat on it, although this issue could be fixed by implementing a gusset to increase the structural integrity and potential torque capabilities of the system and creating a new tuning file for the motors that would be specific to the person's weight range. The wheelchair itself is designed for users of approximately 120 pounds, so this is not recommended for this design, however, the gusset will be necessary for the chair to have the higher torque capabilities needed for sharper uphill travel.

Joystick Mode:

For the joystick mode, we wanted to see how the wheelchair would do if it were to be controlled with the joystick by a person who has never used the joystick. This would help us get a better understanding of how intuitive using the wheelchair would be. One of the instructors of the course sat on the wheelchair and used the joystick to control it. They were able to drive it fairly easily without colliding with any objects.

Object Detection:

For each object, we recorded:

- Whether the model detected the presence of an object (even if it was labeled wrong). We were interested in this measurement because in the case of obstacle detection and collision avoidance during navigation, detecting the presence of an object, no matter what the object is, is often enough to avoid obstacles or collisions. For example, we can stop the wheels' motors as long as an object is detected in front of the camera sensors, no matter what the object is. If the presence of an object is not detected at all, however, the wheelchair might end up colliding with that object.
- Whether the detected object was labeled correctly or not. In the case where we want to detect objects for everyday tasks such as picking objects up, pushing elevator buttons, opening doors, etc., the object must be detected correctly since the task executed by the wheelchair's robotic arm will be specific to the label of the object detected.
- Whether the object was detected in less than 1s.

- The following results were collected:

Object	Detected Object in Frame?	Labeled Object Correctly?	Label Given by Model (if mislabeled)
Person	Yes	Yes	N/A
Bottle	Yes	Yes	N/A
Backpack	Yes	Yes	N/A
Cellphone	Yes	Yes	N/A
Car (as they were passing by)	Yes	Yes	N/A

- The camera was at 20 fps, and objects were detected at approximately 300 ms

Robotic Arm:
The robotic arm was tested by checking if each finger is able to fully articulate when activated. Each of them was able to fully, and then we tested if they could all be activated at once and in various combinations. Whatever we had commanded the hand to do, it was able to successfully complete, with full articulation in each finger. The wrist too was able to rotate a full 180 degrees without problem. When tested for strength, the hand was able to provide strong resistance to pushing it back and could hold objects.

Conclusions

Motor Controller (Joystick and Laptop Control):
We were able to test the control of the motors with two different types of input, one of them being the joystick and the other being remotely and wirelessly controlling the wheelchair's motors from the arrow key of a laptop. In both cases, the wheelchair was able to navigate forward, backward, turn left and right as expected from the user without any collisions. The chair was also tested with multiple weights, showing that it was capable of responding to the commands given while supporting weights ranging from 0 to about 200 lbs, although changing the tuning file would be best for people over 20 lbs heavier than the weight the motors are currently tuned for. We also demonstrated the ease of use of the joystick by allowing one of the instructors who has never used it before to drive the wheelchair around with it.

As the motor itself is operating in RPM ranges >>500 RPM, in this prototype test we are seeing a much smoother response from the motor than our previous test, in which we only tested up to ≈ 600 RPM. The increase in RPM, as expected, has increased the reliability of the motor output significantly, with our data showing that the motor's output is consistently within 5% of the corresponding RPM input. While this level of accuracy is sufficient for the navigational components to begin integration with the motor controlling system, in the future we will be integrating EMF feedback from the motor drives to work in combination with the wheel encoders to even further improve the precision of the motor controlling system.

Object Detection:

The object detection test for our second prototype was similar to our first, but we have moved from detecting objects with a laptop to detecting them with just an NVIDIA Jetson Nano. Because the Jetson Nano was not compatible with our previous fine-tuned model from last semester, we only tested object detection with an Inception-V2 model pre-trained on the COCO dataset, which contains 80 classes of common objects. The test showed that the model detected the presence of an object in the frame 100% of the time and that it both detected an object and labeled it correctly 100% of the time when the object was within the COCO dataset. We also tested how well it did when the object was moving, and we confirmed it did well by showing that the model detected cars as they were passing by through the window. This showed that the speed of our camera and the speed of the detection would not be an issue. This final prototype test also allowed us to test the Raspberry Pi camera that we connected to the Jetson Nano, along with the Inference library working on the Jetson Nano. Successfully detecting objects from the COCO dataset validated our method. Future teams can build up on this model by creating their own custom dataset with more objects.

Robotic Arm:

The arm performed to satisfaction during the testing, successfully completing all of our testing requirements and displaying versatility in finger combination. We will begin iterations for a vertical moving platform for the robotic arm to be strapped to which will allow us to forego an elbow joint and further on a shoulder joint. This is because a motor strong enough to support the whole weight of the arm would be too large and expensive to fit into the arm, and a platform such as this also simplifies the project for recreation for others who would use the arm for their own purposes. Eventually, the platform itself would be on a mobile base, giving us horizontal movement for the arm. This will be worked on over the summer as well as by future teams. We also hope to simplify the design of the arm to make it easier and cheaper to be replicated by those who would be using the arm.