University of Illinois at Urbana-Champaign

ECE445
Senior Design Laboratory

Project: Motor-Aided Wheelchair

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1 Introduction

1.1 Problem

- A wheelchair with a person sitting on it is heavy, so it takes a lot of effort to push, especially at the beginning (from rest to move).
- When moving a long distance, there might be several stops (for example, when fronting obstacles or traffic lights). Whenever you need to restart pushing the wheelchair, you need to exert extra force for acceleration, which is exhausting.

1.2 Solution

Our proposal is to build a motor-aided wheelchair to help people push, which exerts a smooth extra force according to the pusher's force. In this way, the pusher is able to exert a small portion of the total force, and the motor is able to compensate for the rest part, which saves the pusher a lot of effort.

1.3 Visual Aid

The external force from the handle is detected by load cells implemented into the handle. Depending on how large the force is, the motor will provide extra power to the wheels to aid the movement of the wheelchair. There is also a control panel installed on the wheelchair to order immediate stop of the wheelchair for emergencies.

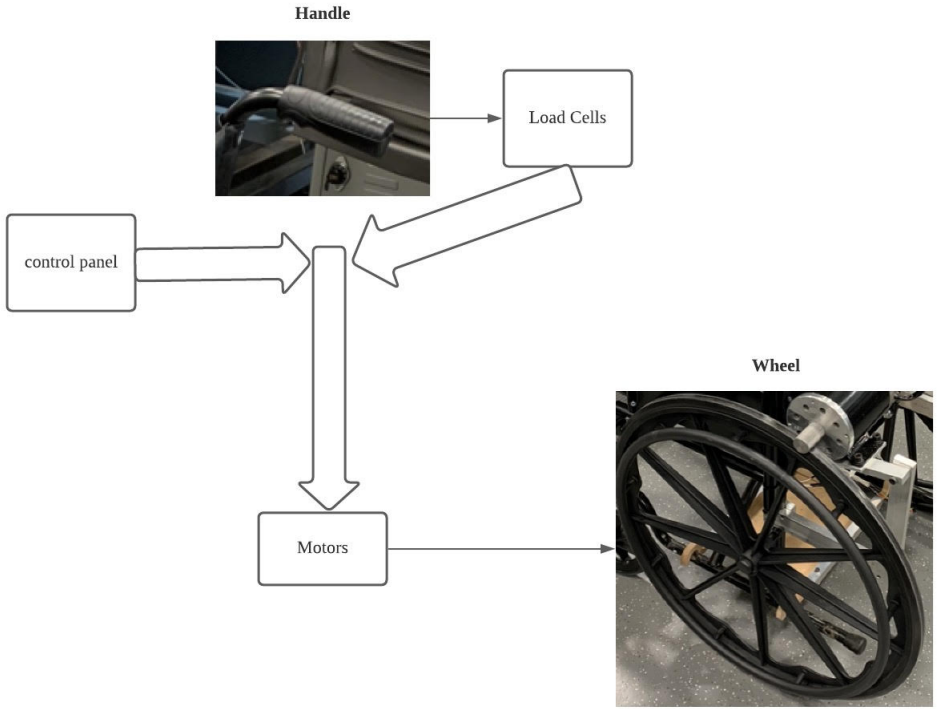

Figure 1: Visual Solution of Motor-aided Wheelchair

1.4 High-level requirements list

- The horizontal push force required to start the wheelchair is roughly 100N while the motors provide 4 times the force detected by the load cells.
- The maximum speed of the wheelchair is set to 1.5m/s, which will be restricted by a negative force by motors if the push force is causing speed to pass the speed limit.
- The person sitting in the chair is able to use the control panel to immediately stop the wheelchair with deceleration of $-1.5\ m/s^2$ when something goes wrong.

2 Design

2.1 Block Diagram

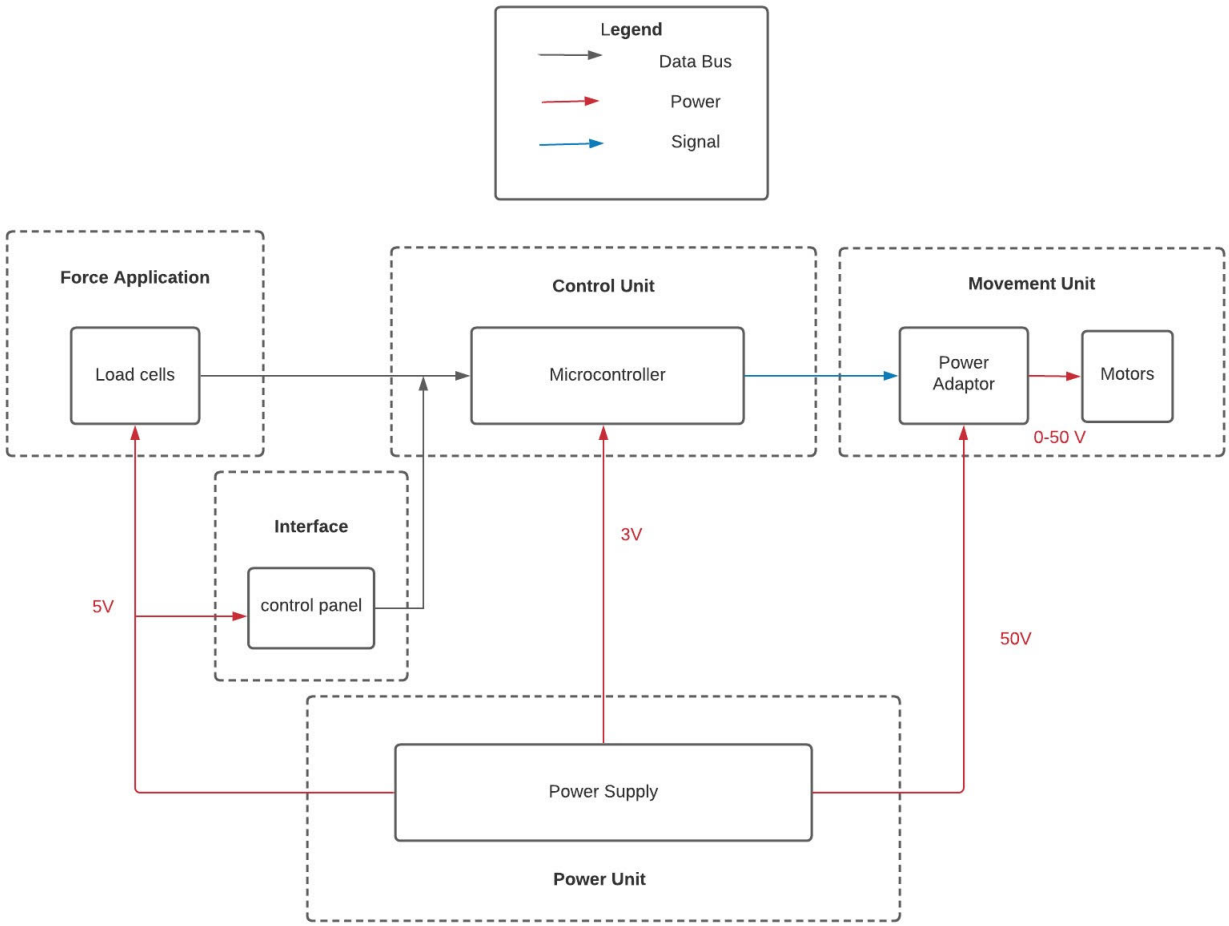

Figure 2: Block Diagram of Motor-Aided Wheelchair

2.2 Subsystems

- Force Application

  The force application unit is where our main input, push force, generates. When we push or pull the wheelchair, the force exerts on the handle will be detected by the implemented load cells. Load cells will be generating corresponding singles to the microcontroller. [1]

  Requirement 1: A handle joint that will be able to move forward and backward based on the force direction.
  Requirement 2: Power cells are able to detect the magnitude of the force exerted and give electrical signal to the microcontroller.

- Interface

  A control panel is provided for the person sitting in the wheelchair with stop command stop. The stop command on the control panel has the highest priority for safety concern, so that the person sitting in the wheelchair is able to stop it immediately. Deceleration will be set to -1.5m/s^2 until the wheel stops spinning. Since the maximum speed is 1.5m/s, it will take a maximum of 1s to stop the wheelchair after the stop command. This time period allows the momentum of the person sitting on the wheelchair to decrease so that he or she will not fall off.

  Requirement 1: A button that sends the stop signal to the microcontroller.
  Requirement 2: The stop signal has the highest priority.

- Control Unit

  The smooth function is implemented into the microcontroller. Based on force detection, achieved by load cells implemented in handles, the motor will provide corresponding extra power to the wheels to give the person who is pushing the wheelchair an extra help. The whole point of this function is to determine how much the extra force should be applied to the motor. Since we have corresponding motors related to corresponding load cells, we do not need to distinguish what is the motion status of the wheelchair. Instead, the power motor provides to the wheel is solely depending on how much force is exerted on the load cell. The motor will always, under safe circumstances, provide 4 times the power detected on the load cell. However, if the acceleration is detected to be too large, the motor will provide a negative force to limit the movement of wheelchair. The smooth function will also have a maximum acceleration, of 0.1m/s, limit locked for safety concern.[2]

  Requirement 1: Microcontoller need to always track the force applied on the handle and give the power adapter how much power should be applied to motors.
  Requirement 2: Smooth function will not only consider normal cases but also include the case where acceleration exceeds the limit of 0.1m/s.

- Power Supply

  Our power unit is divided into three parts. For the microcontroller, force application, and interface, they do not require much power to drive. So we only send 5 volts to the force application and interface, then 3 volts to the control unit. However, the running of motors will cost a large amount of energy, so we provide 50 volts.[3]

  Requirement 1: The battery should be able to power the force application unit at 5 volts.
  Requirement 2: The battery should be able to power the microcontroller at 3 volts.
  Requirement 3: The battery should be able to power the motors at 50 volts.
  Requirement 4: Our power supply should own a large amount of storage and also need to be rechargeable since we have to use our wheelchair for a long duration time after charging once.

- Movement Unit

  The power adapter receives 50 volts from the power supply, and is told by the microcontroller how much of the power should be distributed to the motors. Certainly, the more power distributed, the higher acceleration the wheels have.

  Requirement 1: The adapter is able to adjust the power distributed from 0 V to 50 V according to the instructions from the microcontroller.
  Requirement 2: The motors should be able to drive the wheelchair at 1.5 m/s.

2.3 Tolerance Analysis

The power supply of this project is one obstacle, because we need to power the wheelchair for a relatively long time, and powering such a wheelchair plus a person sitting in it is an exhausting job. Making sure that the energy stored is enough is a challenge. The coefficient of friction of the wheels to the ground is around 0.3 to 0.7. Assuming the coefficient is equal to 0.5, then the force needed to drive the wheelchair while a person sitting in is 0.5 * 150 kg * 10 m/s^2 = 750 N. Then the power needed to drive the wheelchair in the maximum speed limit is 750 N * 1.5 m/s = 1125 W. For an hour, the battery needs to store 1125 W * 3600s = 4050 kJ. Fortunately, this result is still reasonable. Plus the fact that the wheelchair is only delivering the most power at the start of pushing, this energy could be reduced a large amount.

3 Ethics and Safety

Since our project is a motor-aided wheelchair, we will definitely include patients' safety into our consideration. The relationship between patients' safety and motors' power will be a tricky problem to deal with. If the acceleration is too large, it will cause some serious danger to the patients. Also, according to the IEEE Code of Ethics[4], we do not want to damage the surrounding area, so that the function that determines how much power we allow to the motor will be carefully dealt with. Motors involved in this project require relatively high voltage and current, which might cause injuries to people doing experiments. However, with caution, we are confident to reduce the chance of such danger as much as possible. Also, power supply above 40 V will have the potential danger to the human body. Since we have such powerful motors and the wheelchair is a movable object, being cautious with power supply will be necessary. In addition, our smooth function will include a lot of complicated cases. When testing maximum speed, there are multiple steps testing the speed, which will have the potential for the wheelchair to go off the limit and damage the environment.

4 References

[1] Load Cells: Types, How It Works, Applications, & Advantages. (n.d.). Retrieved September 16, 2021, from https://www.encardio.com/blog/load-cells-types-how-it-works-applications-advantages/.

[2] Smooth rotation. (n.d.). Retrieved September 14, 2021, from https://www.machinedesign.com/archive/article/21812530/smooth-rotation.

[3]Power supply problem for 2 wheel drive robot. (n.d.). Retrieved September 14, 2021, from https://forum.arduino.cc/t/power-supply-problem-for-2-wheel-drive-robot/330397.

[4]IEEE - IEEE Code of Ethics. (n.d.). Retrieved September 14, 2021, from https://www.ieee.org/about/corporate/governance/p7-8.html.