Mr. Clean Board

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1 Introduction

1.1 Objective

In many of today's academic and professional settings whiteboards and blackboards are commonly used. In collegiate environments, professors write their lecture notes on these boards. During class time, the professors must balance their time between writing notes on the board as well as addressing the class directly. Often, the board space is limited causing the professor to take time out of the lecture to erase the board. Furthermore, it is a common courtesy that the board is cleaned at the end of class. Sometimes, the professor overlooks this because they are caught up interacting with their students at the end of class. This is often a minor inconvenience to the next class in the room.

To address this issue, we propose a small robot named Mr. Clean Board. This robot's sole function will be to erase any white board or chalk board quickly and efficiently. This robot will allow the professor to simply push a button during class to erase the board while they address students or check their notes. After class, the professor may simply hit the start button and not worry about cleaning the board. Ultimately, this robot will be a convince for the professors by allowing them to give more time during lectures to their students.

1.2 Background

As students at the University of Illinois at Urbana Champaign, we have attended hundreds of lectures and discussions in our time as undergraduate students where both whiteboards and blackboards are used. During this time, we have seen many inconveniences: erasing the board before class, erasing the board two to three times during class, getting chalk dust all over one's hands and clothes, and, although uncommon, professors covering their mouths to avoid breathing in the dust. While solutions exist for automatically erasing a whiteboard most of them use two rails mounted to the board with a big eraser that slides back and forth across the board. Our proposed solution would magnetically attach to the board allowing for greater flexibility and an easier setup while still erasing the board efficiently.

1.3 High-Level Requirements

- The robot must be able to erase a 6’ by 4’ board in two and a half minutes or less.
- The robot must be able to work with both magnetic whiteboards as well as magnetic blackboards.
- The robot must be able to clean the whiteboard or blackboard effectively and return to its starting position upon completion.

2 Design

The robot has three main systems necessary for the design to work: a power supply, a control unit, and a physical component. The power supply will power the motors, sensors, and the microcontroller. The power supply unit will also feature a USB charging module. The control unit will consist of an accelerometer, IR sensors, motor controller, and microcontroller and will be responsible for ensuring the car erases the board properly and stays on track. The control unit will work with the IR lighthouses which will aid the robot in ensuring it has erased the whole board and that it will return to its proper starting point. The physical component consists of a chassis that will hold the PCB, motors, eraser, and magnets. Several components must be selected carefully to ensure that the robot can erase the board in time and do it effectively. The magnetic properties of the robot and lighthouses will make the design easily transportable to a different board and a simple switch of erasers will allow be used on either a whiteboard or blackboard.

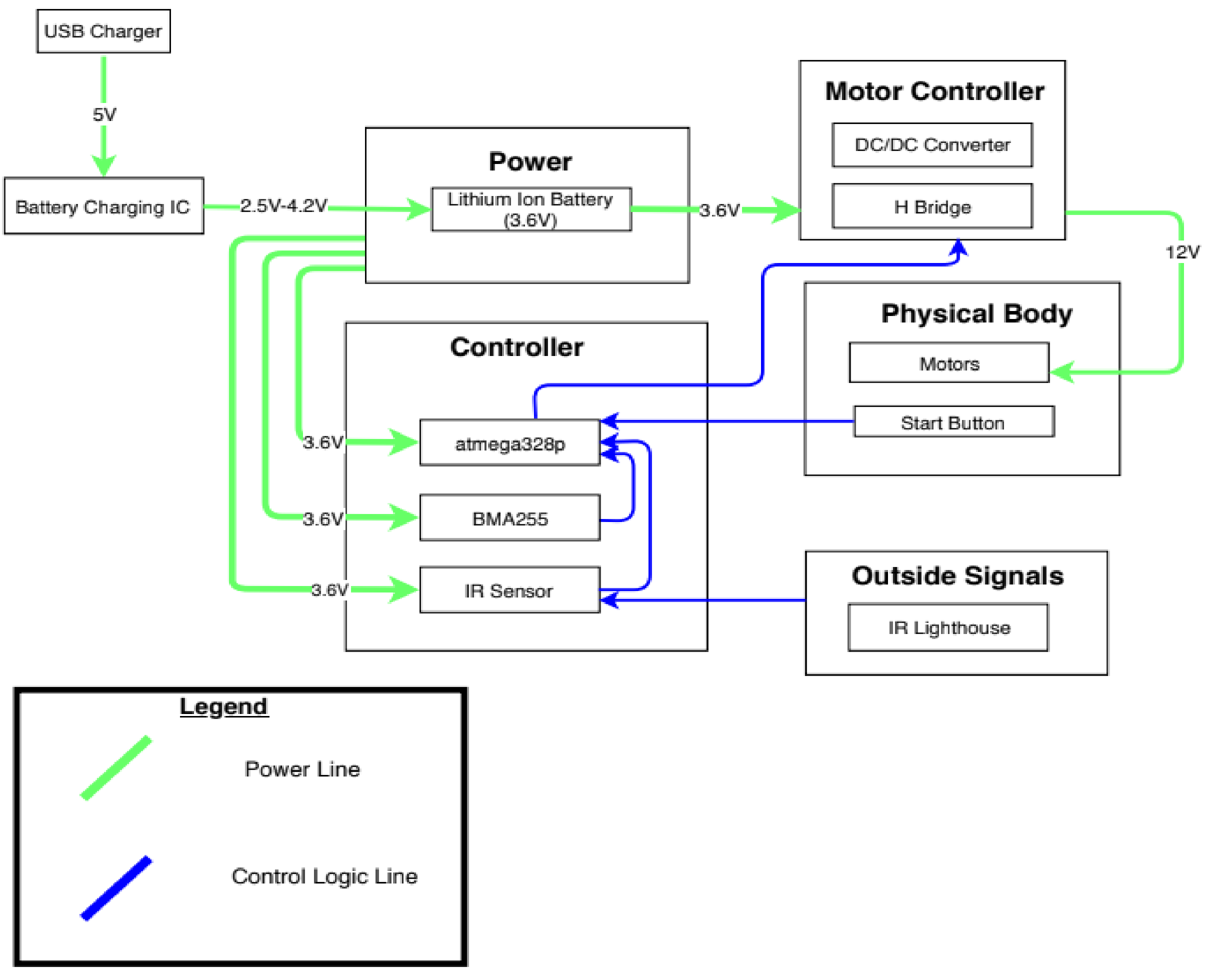

Figure 1. Block Diagram

The physical layout (shown in Figure 2) of the design consists of two wheels located in the rear with the eraser located at the front providing the swivel point for the car. There will be four bar magnets located underneath as well to provide the attaching mechanism to the board. The battery and PCB will most likely be mounted on top of the chassis or in the remaining space in the middle underneath the chassis. The start button would be located on the top of the chassis to allow for easy user interface with the car. The exact number and placements for the magnets and erasers may be subject to change as we test out which combinations yield the best grip and erasing results.

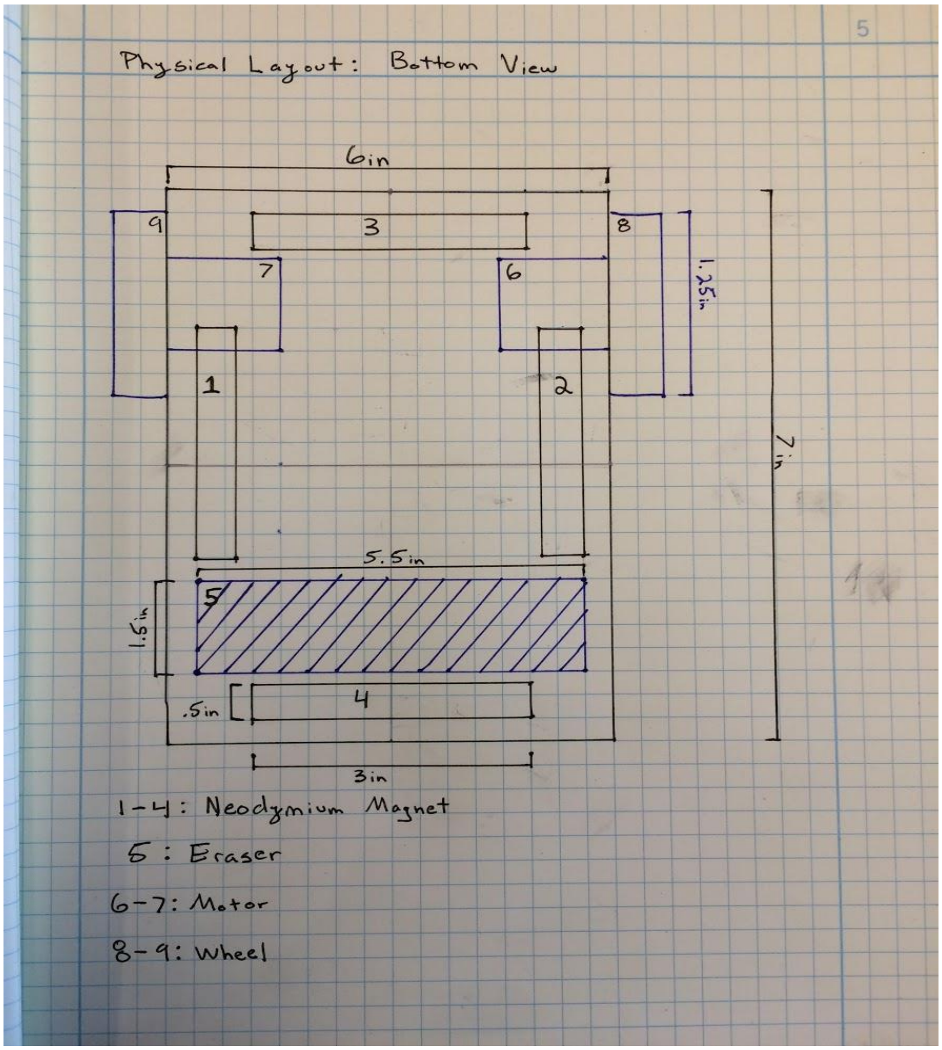

Figure 2. Physical Body Diagram

2.1 Power Supply

The power supply will consist of lithium ion battery and a charging circuit. This will allow for the robot to be continuously operational and easily recharged once the battery is depleted.

2.1.1 Lithium Ion Battery

We will use the LGDBHE418625 lithium ion battery to power the motors and circuitry. The battery must be able to power the car with about two hours of continuous use. It will also have a resting life time of over a month. The battery is rated to 2500 mAh, we believe this will be enough for our desired run time. In testing, if we realize this is not enough power, we can add another battery.

Requirement 1: The battery must be able to put out 250mA ranging from 2.8 V– 4.2 V.
Requirement 2: The battery must be able to provide around 2 hours of run time usage.

2.1.2 USB Charger

The USB charger will be able to work with any device with USB ports. The charging cable will have a standard USB port on one side and a micro USB on the other side. The charger will be passes into the battery charging IC via the micro USB port.

Requirement 1: The USB charger must work with any device with USB ports.

2.1.3 Battery Charging IC

For this we will use the Sparkfun PRT-10217. It will take the USB-C from the USB charger as an input and will charge the lithium ion battery. The IC will have a positive and negative terminal output that connects with the housing of the battery when charging. The battery charges based on a constant voltage and constant current scheme which is what the IC will provide to the battery.

Requirements: This IC must act as the interconnect between the USB charger and battery

2.2 Controller

The controller is responsible for taking in all the sensory input and then processing this data in order to send output signals to the motor controller.

2.2.1 Atmega328p

This is the microcontroller that will monitor and respond to the input from the sensors. The accelerometer, IR sensor, and start button will be all the inputs into the microcontroller. The accelerometer will communicate by a SPI link while the IR sensor and push buttons will be active high signals. The microcontroller will drive the motor controller which then controls the wheels.

Requirement 1: The microcontroller must be able to respond to all inputs quickly.
Requirement 2: The microcontroller and accelerometer will be on a closed loop system.

2.2.2 BMA255

This is the Bosch accelerometer that will constantly be monitoring the x and y axis orientation of the car so that the car will always be able to drive in straight lines. It will also have some crash detection logic to notify us if we hit anything. This chip is only connected to the microcontroller through a SPI link.

Requirements 1: This chip must detect if the car has moved to far of an axis.
Requirement 2: This chip must give the car a sense of orientation so that it can find its way back to the starting location.
Requirement 3: This chip must give us axis orientation accuracies to the tenths place.

2.2.3 IR Receiver

The robot will have an array of four TSOP38238 receiver diodes. These receivers will be placed around the robot, so the robot will be able to pick up any of the signals from the IR lighthouse. When a receiver picks up the signal, the robot will know that it has reached the edge of the board so that it can turn around. The receiver will be connected directly to an I/O pin on the microcontroller. We are still considering different frequencies.

Requirement 1: The receiver must register all light house signals from all possible directions.
Requirement 2: The receiver must be supplied with 2.5 V – 4.2 V.

2.3 Motor Controller

The motor controller is responsible for receiving data from the controller and the it will then drive the motors to control the robot's traversal

2.3.1 H Bridge

For the first part of the motor controller, we will use the TB6612FNG H Bridge chip. This chip will oversee controlling the direction of movement of each wheel. There will be two chips because we will have two motors. The control signals to drive this chip will come from the microcontroller. This chip will pass the output of the DC to DC converter to the motors in a controller manner.

Requirement 1: This chip must be able to precisely control the motors.
Requirement 2: This chip must route the 12 V output of the DC/DC converter to the motors

2.3.2 DC to DC converter

The DC to DC converter will be inserted between the battery and the motors. It will take in the 3.6 V from the battery and increase it to 12 V with a loss of current. The converter is tunable, so we will test a range of values to find the best performance for our design. The output of the converter will be given to the H-Bridge where it will be used to power the motors.

Requirement 1: The converter must be able to increase the voltage from 3.6 V to anywhere ranging from 9.5 V – 12 V.

2.4 Physical Body

The physical body is the housing for all the components and will consist of the magnets that hold the chassis to the board

2.4.1 Start Button

This is the start button that will rest on the top of the car. When this button is pushed, the car will begin its cleaning sequence. For the button, we will use a standard push button. The push button will be routed to the microcontroller which will control the start logic.

Requirement 1: The button must be easy to reach and use.
Requirement 2: The push of the bottom turns on the robot and starts the cleaning sequence.

2.4.2 Motor

These are the motors that drive the car. There are many motors we are considering for this project, so we are unsure on the exact product now. We are considering different RPM's as well as torques. The motors will get their power from the H bridge and use it to spin the wheels.

Requirement 1: The motors must consume around 200mA during 2 minutes of use.
Requirement 2: The motors must be strong enough to overcome the friction of the wheels on the board as well as the magnetic force that holds the car to the board.

2.4.3 Magnets

The magnets will be used to hold the chassis to the board. The exact magnets have not been determined but will most likely be neodymium bar magnets.

Requirement 1: The magnets must be able to hold the car to the board without dramatically impeding its driving capability

2.4.4 Eraser

The eraser will be mounted under the chassis and will be the main method for erasing the board.

Requirement 1: The quality of the eraser should be good enough to erase markings within no more than two passes
Requirement 2: The method of which the eraser is attached should be easily interchangeable to allow for replacement erasers and the ability to switch between whiteboard and chalkboard erasers.

2.5 Outside Signal

2.5.1 IR Lighthouse

To help sense the edge of the board, we will have four IR lighthouses. These lighthouses emit an IR wave which the robot will receive. Each lighthouse will be individually attached to the board magnetically. Each light house will also have its own power supply. The lighthouses will require a onetime set up when the robot is applied to a new board.

Requirement 1: The IR wave length must be something not commonly found in an academic setting.
Requirement 2: The lighthouse battery must be able to last over an extended period.

2.6 Risk Analysis

This project has two major risk factors that must be tackled for the project to work. The first is ensuring the car will stay attached to the board and once attached have enough power to drive around the whiteboard. This risk is significant because if this cannot be achieved then the project will not be a success. This risk also imposes many constraints onto the design: the car must be lightweight, the motors must be able to overcome the friction of the eraser and the force of the magnets, and the car must have enough friction to keep it from sliding down the board. If the robot is unable to satisfy these constraints, then it would be more of an inconvenience than the professor simply erasing the board on their own.

Once this risk is overcome another major risk crucial to the project arises: being able to detect the edge of the whiteboard. Overcoming this risk is essential because even if the robot can successfully drive on the board if it cannot detect the edge of the board it would simply drive off and need to be placed back on the board every time rendering the robot useless. This risk poses problems because the solution must be something that can be applied to any magnetic board. Simple collision detection with the edge may not be the best solution since every board is different. Using the accelerometer to just track distance traveled would allow for some inaccuracies depending on the precision of the device and would also pose a new issue of dealing with boards of different sizes. The IR lighthouses should be able to solve most of these issues by creating a precise barrier and be able to easily attach to the board.

3 Ethics and Safety

This project contains a few potential safety hazards. The first of these being the use of Lithium ion battery. Lithium ion batteries can explode especially if they experience thermal runaway. The more energy the cell has stored the more energetic the resulting thermal runaway. The most severe thermal runaway results when the cell is at full electrical capacity or more if overcharged [3]. Our design will prevent this because the USB charging IC has built in regulators to ensure the battery does not get overcharged. The output side of the battery will also be regulated by the DC to DC converter that will assist with controlling any odd voltage and current outputs the battery may have.

Another safety hazard could be skin damaging effects caused by IR light exposure; however, it has also been found that low energy exposer to near infrared light can be beneficial to humans and in general is not harmful until prolonged exposure [1]. Our design will alleviate any potential issues since the IR emitters being used would be low power and in the near infrared range (approximately 940nm). None of the emitters will be pointed in the direction of people, but instead will be forming a square around the board. The IR emitters and detectors will be very similar to ones used for things like wireless remotes and other everyday applications.

The final potential safety concern follows the ninth code in the IEEE Code of Ethics: “to avoid injuring others, their property, reputation, or employment by false or malicious action” [2]. This project could possibly injure others in a couple scenarios. If the robot loses traction to the board and falls to the ground potentially injuring the users foot and since it is a moving object it could perhaps collide into the user’s hand if they are writing on the board. These injury concerns are easily avoided since the robot must be lightweight to stick to the board it would not be heavy enough to cause sufficient injury to the user. In addition, since the robot is lightweight and will not be moving that fast, the momentum it possesses will not be enough to injure a hand. In fact, it is more likely that the robot will be stopped by the hand and simply remain in place as it attempts move forward.

References

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[2] “IEEE Code of Ethics.” *IEEE - Advancing Technology for Humanity*, Ieee, www.ieee.org/about/corporate/governance/p7-8.html.

[3] Long, Thomas R., and Michael Kahn. “Lithium-Ion Battery Hazards .” *Effectiveness and Reliability of Fire Protection Systems - SFPE*, SFPE, www.sfpe.org/page/2012_Q4_2/Lithium-Ion-Battery-Hazards.htm