

WHITE BOARD ASSISTANT ROBOT PROJECT PROPOSAL

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1. Introduction

1.1 Problem

Whiteboards are widely used in classrooms, laboratories, and meeting spaces, but writing information on them still requires a person to physically stand at the board and add the content by hand. This can disrupt the presentations and discussions, since the presenter may need to turn away from the audience to write or copy the information. It can also be inefficient if the same material already exists in a digital format and must be rewritten manually. Additionally, large vertical whiteboards may be difficult to use for individuals who cannot comfortably reach or write across the entire surface. To address these challenges, our goal is to develop a portable robot that can attach to a whiteboard and automatically write or erase content provided by the user. This would allow information to be displayed on the whiteboard without requiring someone to physically write it themselves.

1.2 Solution

The project is centered on creating a robot capable of automatically writing on and erasing a whiteboard based on content supplied by the user. Users would be able to enter the desired information either by typing it or through voice commands. The robot would be secured to the whiteboard with magnets and varying the speed and direction of these wheels, the robot could move horizontally, vertically, or diagonally across the whiteboard. To ensure reliable writing, a spring-loaded marker holder would maintain the steady contact between the marker and the whiteboard, providing consistent pressure as the robot moves.

1.3 Visual Aid

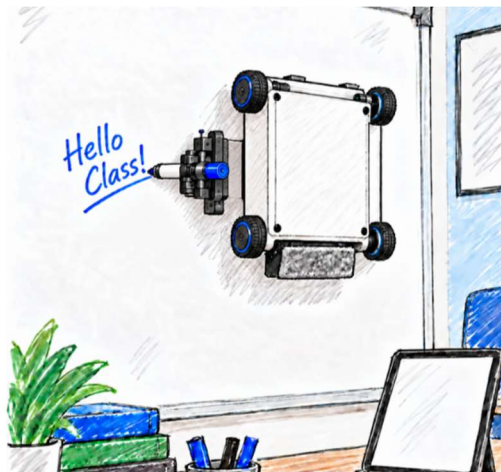


Figure 1: Conceptual design and intended operation of the White Board Assistant Robot.

1.4 High-level requirements

- The robot should attach to and move across a magnetic whiteboard in horizontal, vertical, and diagonal directions without external support.
- The robot should receive the user-provided text wirelessly and convert the text into motion paths representing recognizable characters.
- The robot should automatically control a spring-loaded marker mechanism to write recognizable characters while preventing unintended markings between strokes.
- The robot shall automatically erase written content from the whiteboard after writing is complete.

2. Design

2.1 Block Diagram

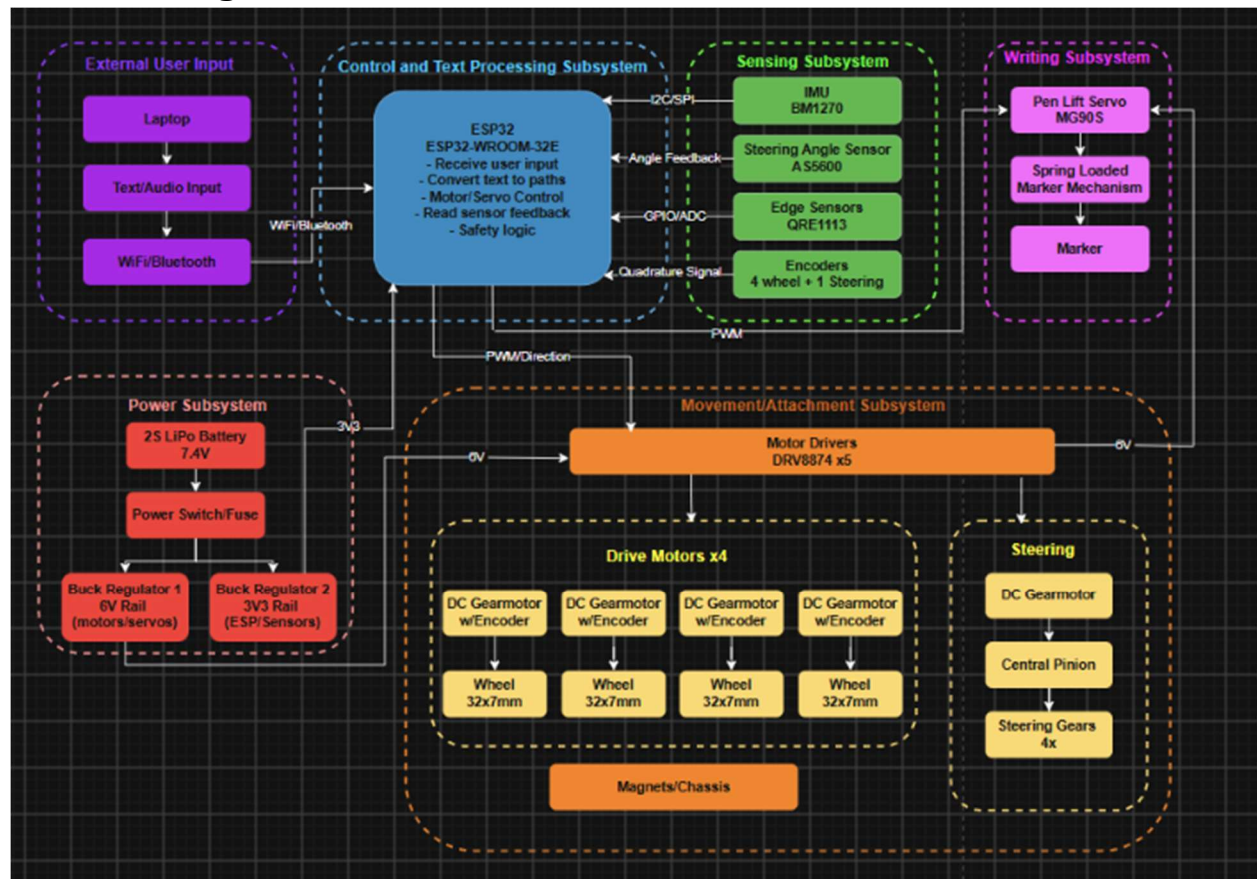


Figure 2: Overall system architecture and subsystem interconnections of the White Board Assistant Robot.

2.2 Subsystem overview

Movement and Attachment: The movement and attachment subsystem is responsible for keeping the robot securely attached to the whiteboard while allowing it to move across the board in different directions. Magnets will be used to provide the holding force needed to keep the robot on the vertical surface. The wheels and motors will control the robot's movement, while the wheel encoders will measure the distance travelled [1]. A steering angle sensor will monitor the direction of the wheels, and an IMU will help determine the robot's orientation and detect slipping or unexpected rotation [2]. Edge sensors will also be used to detect the boundaries of the whiteboard and prevent the robot from moving off the board [3].

Writing and Erasing: The writing and erasing subsystem is responsible for controlling the marker and eraser during operation. A spring-loaded marker holder will maintain consistent pressure between the marker tip and the whiteboard, allowing the robot to write clearly even if the surface is slightly uneven. A microservo [4] will raise and lower the marker depending on whether the robot is writing or repositioning. This will prevent unwanted lines from being drawn between letters or separate strokes. An eraser mechanism will also be included so that the robot can remove previously written content from the board.

Control and Text Processing: The control and text-processing subsystem is responsible for receiving user input, processing the requested text, and coordinating the robot's movement. The ESP32 will receive information wirelessly through [5] Wi-Fi or Bluetooth from a computer or other compatible device. The text received will be converted into predefined paths using a simplified vector or single-line font. The controller will then convert these paths into motor, steering, and marker commands. Sensor information will be used as feedback to help the robot follow the required paths accurately.

Power System: The power subsystem is responsible for supplying the electrical power required by all components of the robot. A 2-cell LiPo battery will provide the main power source, allowing the robot to operate without an external power connection. Voltage regulators will convert the battery voltage to the voltage levels required by the ESP32, sensors, motors, motor drivers, and servo. The power system must also provide enough current for the motors and electronics to operate simultaneously without causing unstable voltage levels or controller resets.

2.3 Subsystem requirements

Movement and Attachment

- The magnetic attachment system shall support the full weight of the robot on a vertical magnetic whiteboard while the robot is stationary.
- The robot shall remain attached to the whiteboard during normal horizontal, vertical, and diagonal motion without external support.
- The four drive motors shall receive a regulated 6.0 V supply from the power subsystem [1].
- Each drive motor shall receive independent PWM and direction control signals from the ESP32 through its motor driver [6].
- Each of the four drive motors shall provide encoder feedback to the ESP32 [1] so that commanded and measured wheel rotation can be compared.
- The controller shall be capable of determining wheel displacement with sufficient resolution to maintain approximately ± 5 mm positional accuracy over a 300 mm commanded movement.
- The steering motor shall rotate all four steering modules simultaneously through the central gear system so that all four wheels remain parallel.
- The AS5600 steering-angle sensor shall report the wheel steering angle to the ESP32 with a resolution of at least 1 degree.
- The steering system shall position the wheels within approximately ± 2 degrees of the commanded steering angle before translation motion begins.
- The robot shall be capable of commanding wheel orientations that produce horizontal, vertical, and diagonal movements.
- The IMU shall communicate robot orientation information to the ESP32 [2] and shall be used to identify unexpected chassis rotation during movement.
- The edge sensors shall detect loss of the whiteboard surface before a wheel passes beyond the board boundary [3].
- Detection of a board edge or invalid edge-sensor condition shall cause the ESP32 to command the drive motors to stop.
- Wheel slip shall be minimized such that the robot can complete a 300 mm movement without more than 5 mm of accumulated position error under normal operating conditions.

Writing and Erasing

- The pen-lift servo shall operate from the regulated 6 V power rail.
- The ESP32 shall control the pen-lift servo [4] using a PWM control signal.
- The mechanism shall provide at least two distinct positions of up and down.
- In the disengaged position, the marker tip shall maintain at least approximately 5 mm of clearance from the whiteboard to prevent unintended markings while repositioning.
- In the engaged position, the marker shall remain in continuous contact with the whiteboard throughout a commanded stroke.
- The spring-loaded holder shall provide compliance of at least several millimeters so that small variations in the whiteboard surface do not cause the marker to lose contact.

- The marker mechanism shall raise the marker between disconnected strokes or separate characters.
- The marker shall not produce unintended connecting marks longer than approximately 2 mm during pen-up motion.
- The mechanism shall be capable of producing recognizable alphabetic characters using the paths generated by the control subsystem.
- The eraser mechanism shall be capable of contacting the whiteboard and removing the majority of visible dry-erase markings within the commanded erase region.

Power System

- The robot shall use an onboard 2S LiPo battery with a nominal voltage of 7.4 V.
- The battery shall power all robot electronics without an external power connection during normal operation.
- A dedicated regulator shall provide a 3.3 V logic rail for the ESP32 and low-voltage sensors [5].
- The 3.3 V rail shall remain within approximately $3.3 \text{ V} \pm 0.1 \text{ V}$ during normal robot operation.
- The 3.3 V rail shall be capable of supplying at least 500 mA continuously to the ESP32 and sensor electronics.
- A separate regulator shall provide a nominal 6.0 V motor/servo rail.
- The 6 V rail shall remain within approximately $6.0 \text{ V} \pm 0.3 \text{ V}$ during normal operation.
- The 6 V rail shall support at least approximately 3 A peak current for simultaneous motor and servo operation.
- Motor startup or rapid changes in motor load shall not cause the ESP32 supply to fall outside its acceptable operating range or cause the controller to reset.
- The battery output shall pass through a master power switch and fuse before reaching the voltage regulators.
- The power subsystem shall provide a common electrical ground between the ESP32, sensors, motor drivers, and servos.

Control and Text Processing

- The ESP32 shall operate from a regulated 3.3 V supply [5].
- The controller shall receive user commands wirelessly through Wi-Fi or Bluetooth [5] without requiring a wired data connection during normal operation.
- The system shall accept text input from an external laptop or other compatible device.
- Voice input, if decided to implement, shall be converted to text by the external device before or during transmission to the robot.
- The controller shall represent supported characters using predefined single-line or vector paths.
- The controller shall support at minimum the 26 alphabetic characters A-Z or a-z.
- The ESP32 shall convert each path into drive distance, drive direction, steering-angle, and pen-up/pen-down commands.

- The ESP32 shall provide PWM/direction commands to four drive motor drivers and one steering motor driver.
- The ESP32 shall provide a PWM command to the pen-lift servo.
- The controller shall read encoder feedback from five motor encoders: four drive motors and one steering motor.
- The controller shall receive steering-angle feedback from the AS5600 sensor.
- The controller shall receive orientation information from the IMU and edge-detection information from the QRE1113 sensors.
- The controller shall compare commanded wheel displacement with encoder-measured displacement and adjust motor commands when an error is detected.
- The controller shall verify the commanded steering direction before executing a writing movement.
- When detecting the edge, the robot shall override the normal writing command and cause motor motion to stop.
- After receiving a valid writing command, the robot shall be able to complete the path without continuous user control.

2.4 Tolerance Analysis

The main tolerances affecting the robot are wheel size, steering angle, wheel slip, and marker contact pressure. Since the robot estimates displacement using wheel encoder counts, small differences in the effective wheel diameter can accumulate into position error over longer movements. For example, with a nominal 32 mm wheel [7], a ± 0.5 mm variation corresponds to roughly a $\pm 1.6\%$ distance error, which could produce about 5 mm of error over a 300 mm movement. Similarly, a steering-angle error of 1 degree could create about 5.2 mm of lateral error over the same distance. To reduce these effects, the wheel encoders and AS5600 steering angle sensors will provide feedback to the ESP32 so that measured motion can be compared with the path and corrected when necessary. Smaller wheels also help reduce the effect of errors, as a smaller wheel has a smaller circumference, making angular slips less impactful when translated to linear movement. The spring-loaded marker holder also provides mechanical tolerance by allowing small variations in the whiteboard surface while maintaining consistent marker contact. These feedback and compliance mechanisms will help prevent mechanical tolerances from significantly affecting writing accuracy.

3. Costs

Table 1: Bill of Materials and Estimated Project Cost

Part	Manufacturer	Retail Cost (\$)	Quantity	Actual Cost
DFRobot FIT0485 6V 75 RPM w/ Encoder	DFR Robot	11.90	5	\$59.50
32×7 mm Wheel Pair	Pololu	4.45/pair	3	13.35
Encoder Cable	Pololu	3.00	5	15.00
Motor Bracket Pair	Pololu	4.95/pair	2	9.90
Steering Gear Set	Makerspace	0.00	1	0.00
AS5600 Steering Angle Sensor	Amazon	5.00	2	10.00
Flexible Silicone Wire	Amazon	6.00	1	6.00
Neodymium Magnets	Amazon	0.73	24	17.52
MG90S Pen-Lift Servo	Amazon	5.50	2	11.00
Compression Spring Assortment	Amazon	7.00	1	7.00
2S 7.4 V LiPo Battery	Amazon	14.00	2	28.00

4. Ethics, Safety, and Societal Impact

Our project introduces several ethical and safety concerns because the robot uses an onboard LiPo battery, moving motors and gears, strong magnets, and moves while unsupported on a vertical whiteboard. According to the IEEE Code of Ethics [8], which requires engineers to prioritize public safety and to disclose potential risks and limitations, we will design and test the robot so that we can avoid foreseeable dangers to both users and property. The primary physical risk is the robot falling from the board (whether the magnet is too weak or it drives off), and LiPo battery overheating, short circuit, or fire. To reduce these risks, we will use edge sensors and software movement boundaries to prevent the robot from leaving the whiteboard, use a safety tether during development, and have a easily accessible power switch and fuse.

We will follow UIUC's Division of Research Safety's charging recommendations and requirements to prevent physical and electrical damage to Li-ion/LiPo batteries [9]. Furthermore, we will be using batteries that meet recognized standards such as UL 1642 [10] or IEC 61960 [11]. UIUC policy also requires students conducting university work to comply with applicable Illinois Department of Labor,

OSHA, and other safety requirements. Intentional misuse could include having the robot to write inappropriate or unauthorized material, so wireless access needs to be limited to an authorized connected device, and the user needs to be able to stop operation at any time.

From a societal perspective, the robot could improve accessibility and reduce the need to manually reproduce digital material on whiteboards. Economically, because it is small, and doesn't require prior setups to the whiteboards, should make this product available. Environmentally, rechargeable batteries and replaceable components can reduce waste, although damaged batteries and electronics must be disposed appropriately [12].

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