Triangle Sign Deployer Car

ECE 445 Design Document - Spring 2024

Team #51

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Section I. Introduction

1.1 Problem

The urgency of efficiently alerting oncoming traffic in the event of a traffic emergency cannot be overstated. Effective communication of hazards ahead is crucial for preventing accidents and ensuring the safety of all road users. The required distance for these warning signs can vary by jurisdiction. In some cases, regulations specify that warning signs be placed up to 100 meters away from the emergency site to provide ample warning to oncoming drivers, thereby significantly reducing the likelihood of further incidents. Given the critical importance of adequate reaction times and stopping distances in high-speed traffic conditions, the Federal Highway Administration provides comprehensive guidelines to ensure safety. These guidelines emphasize the necessity of sufficient stopping sight distances along roadways, factoring in a driver's perception-reaction time of 2.5 seconds, to mitigate the risks associated with increased speeds [1].

However, the manual deployment of these signs poses significant safety risks, particularly in conditions of high traffic volume or on roads with high-speed limits. The act of walking against incoming traffic to position a warning sign is dangerous, exposing individuals to the risk of serious injury or death. Research from the Road Safety Foundation indicates that manual sign placement in high-traffic conditions significantly increases the risk to emergency responders and roadside workers [2].

This situation highlights a critical gap in current traffic management practices, underscoring the need for a safer, more efficient, and practical solution for deploying warning signs without compromising human safety.

1.2 Solution

Our proposed solution is the development of a deployable, remotely controlled electric vehicle (referred to later as “car”) designed specifically for the task of carrying and deploying triangle warning signs at the required distance from a traffic emergency site. This vehicle, released at the emergency site, would be capable of traveling distances ranging from 10 to 100 meters, in accordance with the range suggested in various regulations, to deploy the warning sign accurately and safely. Our design prioritizes low power consumption, ease of storage, a manual control system, and a backup autonomous navigation system. This approach not only mitigates the risks associated with manual sign placement but also enhances the rapid deployment of essential warnings, thereby contributing to road safety and the prevention of further incidents.

1.3 Visual Aid

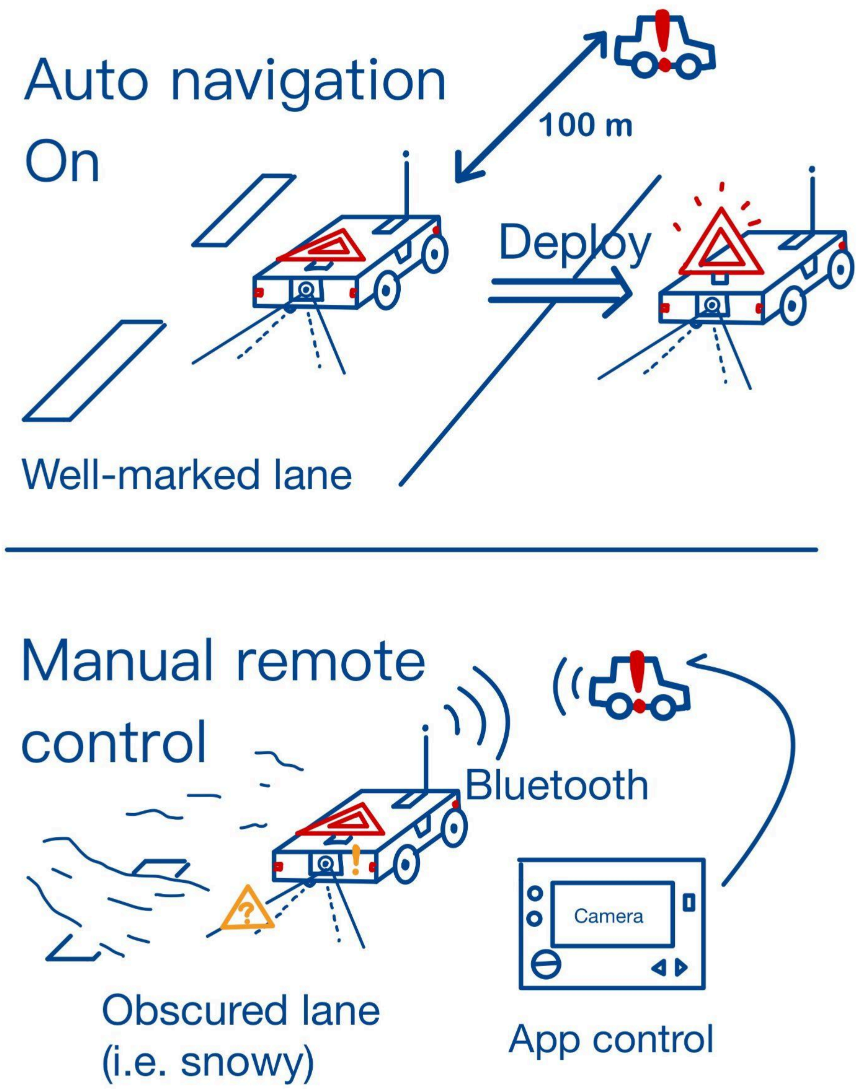


Fig 1. Visual Aid of the Operation Modes

To maximize safety and control, the system defaults to manual operation at the release site, crucial in environments where Auto Navigation System (ANS) may lack sufficient data due to inadequate road markings. Users remotely manage vehicle navigation and warning sign deployment via a dedicated app.

The ANS, reserved as a secondary measure, activates only during wireless communication failures, utilizing camera data to maintain a course within the current lane and execute sign placement at the 100-meter mark. Manual activation of the ANS is also an option post-release.

1.4 High-Level Requirements

To deem our project a success, the following criteria must be met by our system:

1. **Operational Range:** The car must be capable of traveling up to 100 meters away from the user, ensuring effective remote operation over a significant distance.
2. **Controller Communication:** The phone controller must be able to send commands within the operational range and maintain a stable camera feed, ensuring the user has full control and visibility of the car's environment.
3. **Automatic Signage and Prop Deployment:** Upon receiving a command from the user or the Auto-Navigation System, the car must be capable of automatically raising signage and deploying props, enhancing its functionality and interaction capabilities.
4. **Auto-Navigation System Performance:** The Auto-Navigation System should function accurately in conditions where traffic is minimal and road markings are clear. It should autonomously navigate to its predetermined destination under such conditions, even in the event of a connection loss, ensuring reliability and safety.

These requirements establish a framework for evaluating the functionality, control, and autonomous capabilities of our remote-controlled car, guiding the development process toward achieving a successful outcome.

Section II. Design

2.1 High-Level Block Diagram

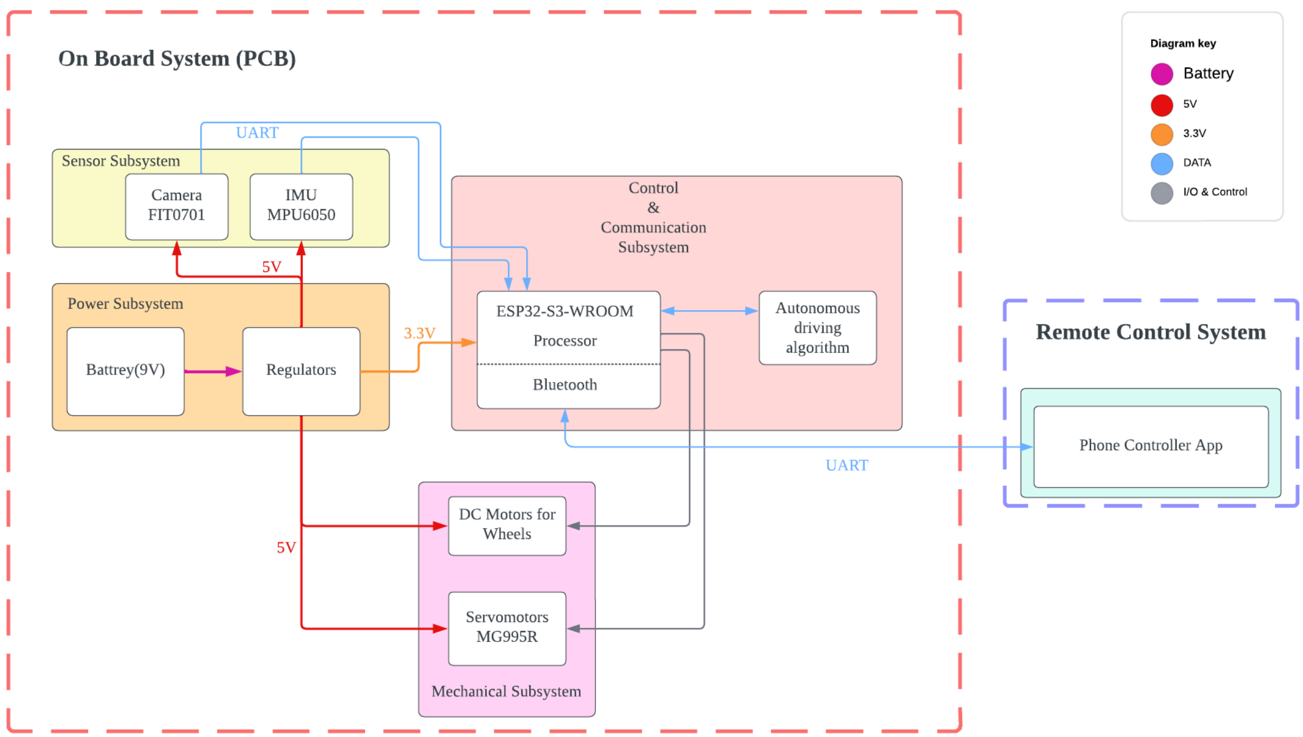


Fig. Block Diagram of Whole System

2.2 Physical Specifications

Car parameters:

Size: 10*29*30cm

Weight: 1.3 - 2.0kg

Wheel parameters:

Inner diameter: 8mm

Outer wheel diameter: 89mm

Thickness: 37mm (without couplings)

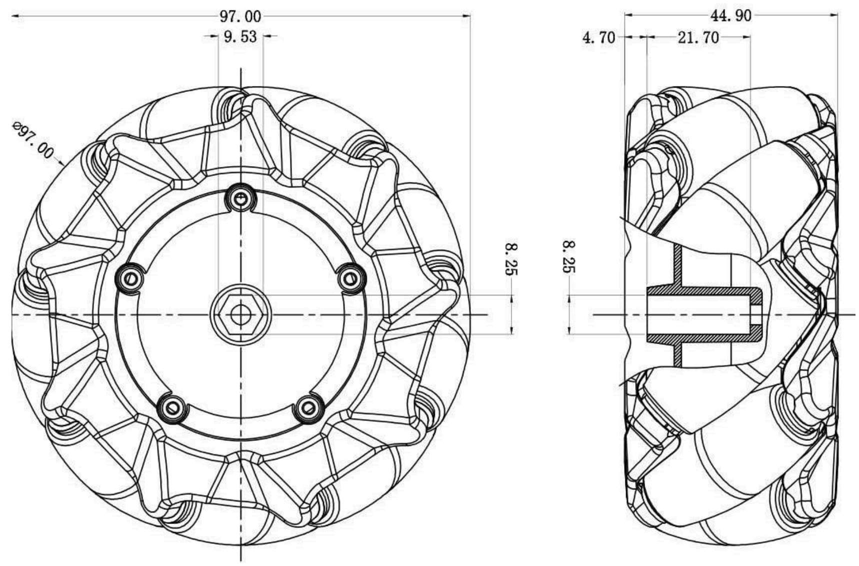


Fig 2. Image of Mecanum Wheel

Fig 3. Example Picture of Electric Car Chassis (wheels may be different)

2.3 Subsystems

2.3.1 Subsystem 1: Control

This subsystem is the central processing unit of the entire design, taking in data from sensors and delivering control signals to motors. It consists of an ESP32-S3-WROOM processor microchip.

Data from the camera and the IMU are fed to two different groups of microchip pins using SCCB(serial camera control bus) and I2C protocol. Then, the frame data from the camera and displacement vector computed from gyrometer and accelerometer values are directly sent to the internal Bluetooth antenna and transmitted over the air into the user's phone.

Certain variants of ESP32 chips have external antenna connectors and that makes using narrow-angle antennas possible. Narrow angle antennas have higher directivity than wide angle ones and are more capable of retaining amplitude over distance. If the wide angle antenna within S3-WROOM type chips cannot reliably transmit at long distances, these variant chips will remain options to be considered.

Requirements	Verification
The chip can start up.	Before powering the chip, perform a visual inspection to ensure there are no visible damages. Ensure that the power supply to the ESP32 is correct and stable. The ESP32 typically operates at 3.3V. Connect a USB-to-serial adapter to the ESP32's U0TXD and U0RXD pins. Open a serial monitor tool, such as Arduino IDE's. Reset the ESP32 by toggling the EN (Enable) pin. To further verify, flash a simple program or a Blink LED example onto the ESP32.
The chip can call the Bluetooth peripheral.	Verify that the Bluetooth peripheral you intend to communicate with is compatible with the Bluetooth version supported by the ESP32. Use Arduino IDE, and include the BluetoothSerial.h library for Classic Bluetooth or BLEDevice.h for BLE in your sketch to start programming the ESP32 for Bluetooth communication. Use a smartphone or computer to find and pair with the ESP32. Once paired, confirm that a serial Bluetooth terminal app on your smartphone or computer can send and receive data from the ESP32.

2.3.2 Subsystem 2: Power

This subsystem supplies power to all other subsystems. It consists of the battery and a set of voltage regulators.

As for the current revision, four different voltages are needed across the entire platform: 3.3V and 5V for most components and 1.2V and 2.8V for two of the OV2640 camera pins. Due to the ease of obtaining them, we chose AZ1117I-3.3, -5.0, and -1.2 fixed voltage regulators. However, the AZ1117I does not have a 2.8V fixed voltage output. Therefore, we’ve decided to create a 2.8V voltage output using -ADJ(adjustable) packages.

To adjust the output voltage, a voltage divider is set up according to the following schematic:

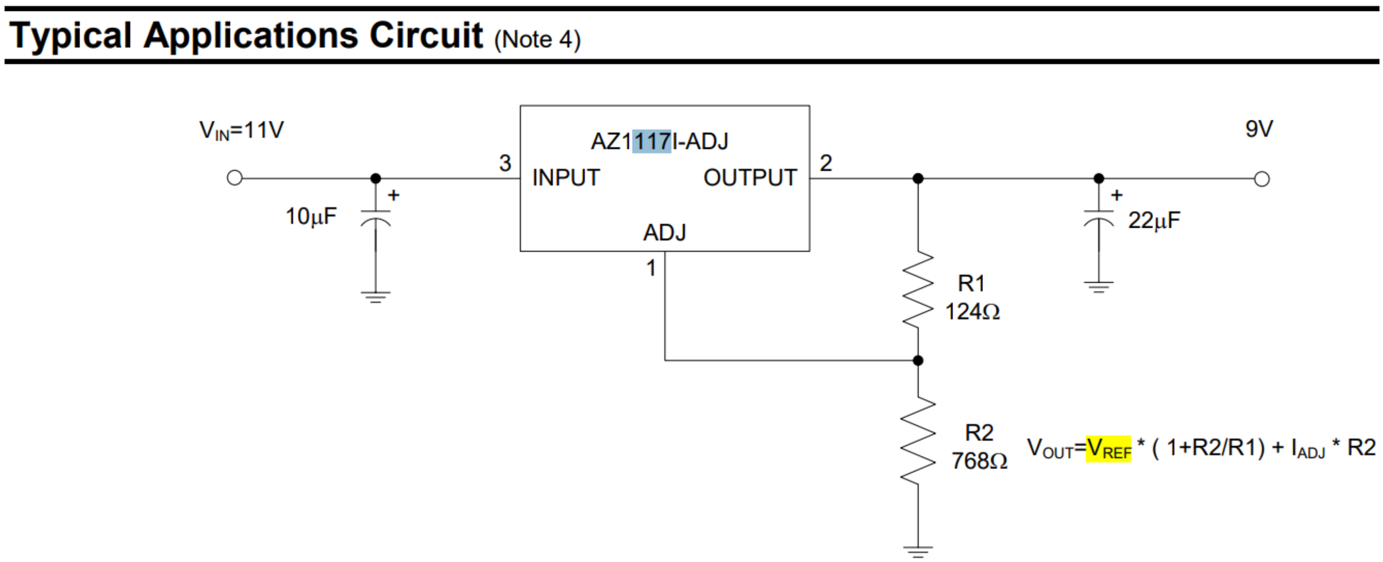


Fig. 2.3.1. Typical application circuit, provided by AZ1117 family datasheet. Vref is a fixed voltage of 1.25V with Δ1%. Vout is 9V in this example, and we adopted R2=1.24kohm and R1=1kohm to yield Vout=2.8V. These two values of resistors are picked because they are easy to obtain.

There are current rating implications of these regulators that might be exceeded by power-hungry modules such as motors. More computation in regard to this concern is included in the Tolerance Analysis section.

A 9V battery is more than capable of supplying the aforementioned voltage regulators. LiPo batteries are not considered due to safety and storage concerns. Since this entire project is expected to be put in use once or twice in a lifetime, it is certainly less desirable to pair it with a battery that requires frequent maintenance.

<table>
<tr><th>Requirements</th><th>Verification</th></tr>
<tr><td>Fixed regulators output Δ1% within base voltage ratings</td><td rowspan="2">Place the regulator is put under working condition (input voltage and ground), probe Vout checkpoint with a multimeter to see if value falls within range.</td></tr>
<tr><td>Adjustable regulator outputs 2.8V Δ5%, under 9V Vin</td></tr>
</table>

2.3.3 Subsystem 3: Sensors

This subsystem feeds data to assist deployment, whether human-controlled or autonomous, into the ESP32 microchip. It consists of a camera module and an IMU(inertial measurement unit) module.

The OV2640 camera directly interfaces with the ESP32 chip through designated pins. We selected this type because we were able to find reference projects that pair this camera with another version of the ESP32 chip [3]. It comes with an 8-bit or 10-bit selectable transmission mode, and the latter takes up two more pins from the already scarce available pins, therefore we pick the former.

A typical IMU module consists of three measurements: the gyrometer measures angular displacements, the accelerometer measures acceleration by force, and the magnetometer measures magnetic field change. We plan to only use the former two, as the typical application scenario doesn't guarantee a stable magnetic field distribution. Given this, we then chose a cheap and widely adopted variant, the MPU6050 series.

Data from this module is fed via I2C protocol to the ESP32 chip. Based on previous development experience, the input data per clock tick consists of data from all three modules, comes in a format that requires driver packages to decode and needs to be parsed to discard magnetometer data and retain other data.

Requirements	Verification
The camera module interfaces with ESP32 properly.	Insert a properly grounded LED at one of the camera data pins; Use call functions in camera driver libraries; Move the camera around, and that LED changes in intensity(indicating a different on/off ratio and thus implying camera data 1/0 ratio is changing).
The camera maintains resolution and frame rate at far distances.	(Can only be verified after core app functionalities are set up) Move the car to 100m away from the user; Visually compare with the camera feed when in proximity to the car.
The IMU module interfaces with ESP32 properly.	Probe SCL/SDA pin. The oscilloscope should show a typical SCL/SDA pattern; Insert test code in ESP32 IDE to read gyroscope and accelerometer data.
The IMU module has a 5% delta in total displacement.	(Can only be verified after core app functionalities are set up) With a scale on the ground, drive precisely 100m away from the user. Read total displacement data as reported on the app.

2.3.4 Subsystem 4: Mechanicals

This subsystem performs all the movement. It consists of wheel motors, their controllers, and a servo.

The servo with large torque is used to lift the sign up, and is directly controlled via PWM signals delivered through ESP32 GPIO pins. Two normal servo motors are designed to prop up the support legs after the car reaches its destination. Both motors are on the side of the car.

Considering the fact that regular triangle signs have a weight that can easily exceed the maximum torque, we've decided to forfeit the idea of using any randomly purchased triangle sign on the market and instead customize the triangle sign by applying reflective foils over a thin, lightweight plastic board to reduce torque.

Electrical motors are pivotal in converting electrical energy into mechanical energy. In our design, we deem that every second is essential in a traffic emergency, and therefore would like the car to spend as short as possible in reaching its destination.

With such regards, and concerns to power consumption and mechanical stability, we estimate that 3m/s is an appropriate speed. Therefore, two JGA25-370 motors with a gear ratio of 1:9.6 and an output of 646 RMP(Revolutions Per Minute) at 6V are used in our design. With a gear ratio of 1:9.6, the electric motor operates efficiently to increase its output torque(1.5kg*cm) while reducing speed, making it particularly useful in applications requiring significant force at lower speeds.

$$646\,RPM = 10.7\,RPS\,;\,equivalent\ velocity = 10.7RPS * \pi * D \approx 3m/s;\ D \approx 8.9cm$$

According to our calculation, four wheels with a diameter of 8.9cm can support our requirement, which can run at 3m/s to finish its task. By leveraging the gear reduction, this motor setup can deliver precise, controlled motion, making it an indispensable component in mechanical systems that demand high torque at lower speeds.

Additionally, we need several reflective strips on the surface of the electric car. Reflective strips on cars play a crucial role in enhancing vehicle visibility and safety, especially under low-light conditions such as at night or during adverse weather.

Requirements	Verification
The wheel motors must achieve their Stall current at 5-6V (900mA) within a tolerance of ±5% of the designed current value.	Connect the motor to the power supply. Ensure all connections are secure and correct according to the motor's wiring diagram. Configure the multimeter to measure current and ensure it's in series with the motor circuit to measure the stall current accurately. Safely secure the rotor or apply a load that prevents the motor from turning. Turn on the power supply to apply the rated voltage to the motor. Then, record the data on the multimeter. Confirm the actual current of the motor is within a tolerance of ±5% of the designed current value.
The wheel motors must achieve their Stall torque at 5-6V (1.5kg*cm) within a tolerance of ±5% of the designed torque value.	Mount the motor on a rigid fixture to prevent movement. Wire the motor to the power supply according to its specifications, ensuring all connections are safe and secure. Then, connect the torque wrench to the motor shaft. The connection should be direct and firm to measure the torque accurately. Apply power to the motor and read the torque value. Confirm the actual torque of the motor is within a tolerance of ±5% of the designed max torque value.
The servo motor must reach the designed operating angle (80 degrees) within a tolerance of ±5% of the designed value.	Before deploying the servo in an application, it is crucial to carry out calibration procedures. This ensures that the servo accurately aligns with the commanded position when directed to move to a certain angle. Execute the program., Then, calibrate the feedback system or use a protractor to check the angle at which the servo has stopped manually. Confirm the actual current of the motor is within a tolerance of ±5% of the designed value.

Requirements	Verification
The motor can receive a PWM signal to turn forward or backward.	Connect your motor to the motor driver. Connect the PWM output pins of your controller to the motor driver's PWM input. Connect the power supply to the motor driver, ensuring it's suitable for the motor's voltage and current requirements. Write or obtain a simple program that generates PWM signals. In the program, include functionality to change the PWM duty cycle (to control speed) and the ability to reverse the polarity (to control direction). Run the program with a command to set the motor direction forward or backward and a moderate PWM duty cycle. Observe if the motor turns in the expected direction.

2.3.5 Subsystem 5: Communication

This subsystem transmits data to and receives control inputs from the user. A fully autonomous car in an application scenario that has highly varying traffic conditions is too time-consuming and can grow cost intensive, thus we mainly rely on human control, and since the purpose of the overall system is to replace the need for walking, some method of telecommunication is a must. It consists of a Bluetooth module integrated into the ESP32 microchip. A signal amplifier module may be incorporated separately in future PCB revisions if we find the signals can't cover distances as long as 100m.

Requirements	Verification
The Communication subsystem shall ensure the reliable transmission of data to and from the user within a range of 100 meters to facilitate effective human control. Data transmission distance should be within a tolerance of ±20% of the designed value.	Choose a location that is flat and open, free of obstructions and interference that could affect the remote control signal. Ensure the RC car is fully charged or has fresh batteries. Position the RC car at your starting point and try to drive the car to its maximum control distance (car disconnected from the remote control). Use GPS-based apps on smartphones or smartwatches to measure the traveling distance of the car from the starting point.
The image transmitted back from the camera should not have a lot of noise. The image should be clear to see.	Integrate a camera module with ESP32 and set up a basic video streaming function over Bluetooth. Conduct initial tests to measure the baseline video quality, bandwidth, and latency at short distances where Bluetooth performance is optimal. Gradually increase the distance between the car and the receiving device, monitoring the video quality, latency, and connection stability. Record the distances at which the video quality begins to degrade significantly.

2.3.6 Subsystem 6: Auto Navigation Algorithm

This subsystem is entirely algorithmic and software-based, and is flashed into the ESP32 microchip. In the rare case of a connection loss, the car must still at least be able to deploy its warning sign and optionally move to its destination autonomously.

The planned algorithm is rather simple:

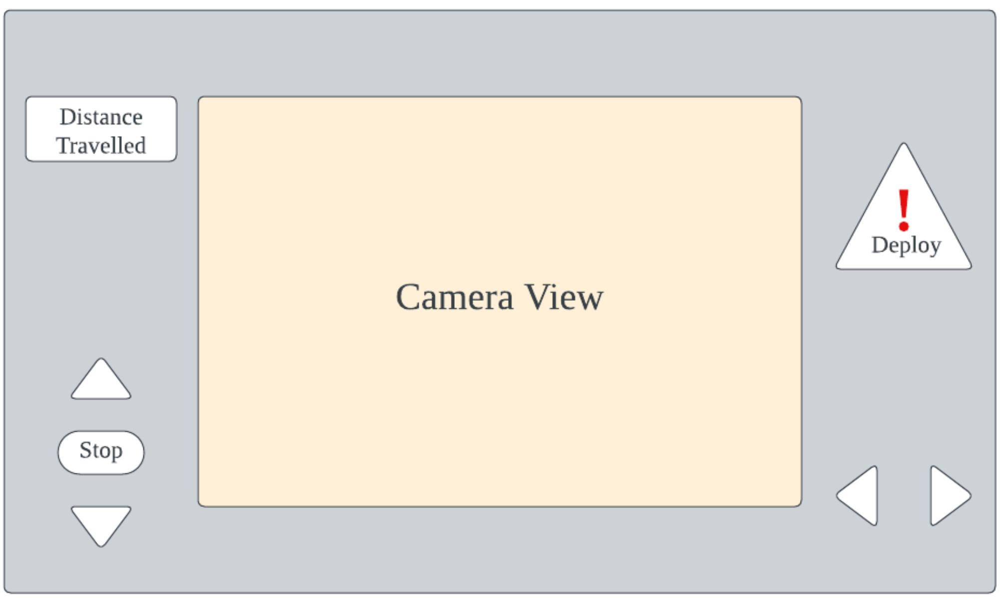
1. Calculate the displacement vector and extend it to a magnitude of 100m. This is based on the assumption that at a distance far enough to cause a connection loss, the car has already traveled in a direction very close to its intended direction. Therefore, it is safe to keep traveling in that direction to target distance and deploy the car.
2. Deploy the sign. It should function identically to pressing the “deploy” button on the app. Autonomous retraction is NOT expected since the reclamation of the car is deemed unnecessary.

Previous developments with inertial measurement units suggest that the measurements can be fairly inaccurate at less-than-a-meter scales. This subsystem will be developed with a focus on flexibility and real-time responsiveness.

Requirements	Verification
The Auto Navigation System will disengage when the IMU sensor’s movement vector reaches 100m within a tolerance of ±5m in the front direction.	Place the vehicle at a known starting point of a well marked 100m track. Align the front of the vehicle towards the marking, and activate the Auto Navigation System. Continuously monitor the ANS output and the IMU data. Verify the point at which the ANS disengages, noting the distance traveled as per the IMU sensor's movement vector. The system should disengage as the vehicle's IMU sensor reports a movement vector that reaches 100m within the predefined tolerance.
The Auto Navigation System will disengage when the IMU sensor loses connection for 0.5s with a tolerance of 5%	Prepare a timestamp logging software. Ensure the Auto Navigation System and the IMU sensor are operational and connected. Prepare the mechanism for simulating the loss of IMU connection. Begin the test by simulating the loss of connection from the IMU sensor while the system is engaged. Monitor the system's response to detect the moment of disengagement. Record the time taken from the moment the IMU connection is lost to when the system officially disengages and compare with predefined value and tolerance. Note any additional system responses or states initiated by this event.
The vehicle’s motor power will be cut off when the disengage signal from the Auto Navigation System is sent in 0.5s with a tolerance of 5%	Prepare a Digital Oscilloscope and a timestamp logging software. Initiate the software controlled disengage signal from the Auto Navigation System with timestamp recording. Simultaneously start the oscilloscope to capture the timeline of the disengage signal and the moment motor power is cut off.

Requirements	Verification
	Measure the time interval between the disengage signal and the motor power cut-off. Compare the interval's length with the value and tolerance specified. Repetition: Perform the test multiple times (at least 5-10 iterations) to ensure consistency and reliability in the results.
Servos can autonomously extend after the Auto Navigation System disengages in 1s with a tolerance of ±0.1s	Prepare a timestamp logging software. Connect the Auto Navigation System to the test bench, ensuring servos are in their initial position and ready to extend. Set up the data logging software to capture the disengagement timestamp and the servo extension initiation timestamp. Trigger the Auto Navigation System disengagement manually or through a predefined condition. Use the data logging software to record the exact timestamps of disengagement and the beginning of servo extension. Conduct the test multiple times. Calculate the time difference between these two events, and compare with the value and tolerance specified.

2.3.7 Subsystem 7: Remote User Interface



This subsystem serves as the primary control method of the car. Auto navigation algorithms may be prone to varying traffic conditions, and in addition to that, robust algorithms might not fit into a standalone microchip. Thus human control is almost always preferable.

The primary interface for human control will be through a custom-developed Android application, which will serve as the command center for the vehicle's operation. The application will communicate with the vehicle's systems via Bluetooth, utilizing efficient and reliable data packets for transmitting control signals and receiving the camera feed before some error reduction method will be incorporated into calculating the distance vector.

Requirements	Verification
Car moves forward when pressing the “Up” arrow button, moves backward when pressing “Down” in 0.5s with tolerance of ±0.1s.	Place the vehicle in manual remote control. Prepare a precise stopwatch. Press the respective button on the app and observe the movement of the vehicle. Time the interval between button press and beginning of desired movement. Compare with desired value and tolerance.
Car generates a speed difference in two driving wheels, causing it to turn when pressing “Left”/”Right” arrow buttons in 0.5s with tolerance of ±0.1s.	Place the vehicle in manual remote control. Prepare a precise stopwatch. Press the respective button on the app and observe the movement of the vehicle. Time the interval between button press and beginning of desired movement. Compare with desired value and tolerance.
Wheel motors halt upon pressing the “Stop” button in 0.5s with tolerance of ±0.1s	Place the vehicle in manual remote control. Prepare a precise stopwatch. Press the “Stop” button on the app and observe the movement of the vehicle. Time the interval between button press and beginning of desired movement. Compare with desired value and tolerance.
Servo motor turns the sign upon pressing the “Deploy” button in 1s with tolerance of ±0.5s	Place the vehicle in manual remote control. Prepare a precise stopwatch. Press the “Deploy” button on the app and observe the movement of the servo motor. Time the interval between button press and beginning of desired movement. Compare with desired value and tolerance.

Section III. Tolerance Analysis, Cost Planning & Work Distribution

3.1 Tolerance Analysis

3.1.1 Current Ratings

The AZ1117I family linear voltage regulators have a current rating of 1.35A. To ensure all subsystems remain functional during operation, at any moment of time the current load on 5V supply must never exceed this limit. All the modules that use a non-5V supply voltage draw significantly less current.

According to manufacturer specifications, the wheel motors have a stall current of 900mA at nominal voltage 6V, and have an operating range from 3 to 9V. Given that two motors are needed to drive the car, the combined current draw when stalled at our supplied voltage(which is 5V) will be approximately twice that of 900mA. Due to the nonlinear nature of motor electrical characteristics, we have yet to test out their current draw at non-nominal supply voltage.

Proceeding with the assumption that stall current will not significantly drop at 5V, it can be seen that to guarantee current supply to other modules, the maximum current ratings of these motors must be limited. Preliminary estimates suggest that we can reserve around 300mA of current for other subsystems, resulting in approximately 500mA of current limit to the motors. More measurements of electrical characteristics of these motors are required as part of our future work. Alternatively, it is possible to add two different voltage regulators to evenly distribute current load; whether this approach is better is up to future inspections.

3.1.2 Bluetooth Communication Range

To calculate the effective transmission distance of the mounted bluetooth antenna, we use the Friis transmission equation, which takes into account the transmit power, receiver sensitivity, frequency, and path loss:

$$Pr = Pt + Gt + Gr - L$$

Where Pr is the received power at the receiver (in dBm), Pt is the transmitted power at the transmitter (in dBm), Gt is the gain of the transmitter antenna (in dB), Gr is the gain of the receiver antenna (in dB), and L is the path loss (in dB).

The equation for path loss is:

$$L = 20\log10(d) + 20\log10(f) + 20\log10(4\pi/c)$$

Where d is transmission distance, f is operating frequency, and the last term is a constant.

Receiver sensitivity can be amplified without consequences, however transmitter sensitivity is limited to its sensitivity labeled in the datasheet. In the datasheet provided by Espressif Systems(manufacturer), the antenna can send a signal with a maximum of +20dBm power [3]. This value is the combined effect of Pt, Gt, and 20log10(f)+20log10(4π/c) terms of the Friis equation. The only term left is the distance-related term, which attenuates signals by -40dB at receiver end. This results in a

-20dBm power at the receiver end, which is a lot higher than typical receiver sensitivity(~-80dB). Therefore, transmission of bluetooth signals at ~100m is theoretically possible.

Undoubtedly many additional constraints will apply in reality. We have yet to test this on an ESP32 evaluation kit.

Table 23: Transmitter Characteristics - Bluetooth LE 2 Mbps

Parameter	Description	Min	Typ	Max	Unit
RF transmit power	RF power control range	–24.00	0	20.00	dBm
	Gain control step	—	3.00	—	dB
Carrier frequency offset and drift	Max $\|f_n\|_{n=0,\ 1,\ 2,\ ..k}$	—	2.50	—	kHz
	Max $\|f_0 - f_n\|$	—	2.00	—	kHz
	Max $\|f_n - f_{n-5}\|$	—	1.40	—	kHz
	$\|f_1 - f_0\|$	—	1.00	—	kHz
Modulation characteristics	$\Delta\ f1_{avg}$	—	499.00	—	kHz
	Min $\Delta\ f2_{max}$ (for at least 99.9% of all $\Delta\ f2_{max}$)	—	416.00	—	kHz
	$\Delta\ f2_{avg}/\Delta\ f1_{avg}$	—	0.89	—	—
In-band spurious emissions	±4 MHz offset	—	–42.00	—	dBm
	±5 MHz offset	—	–44.00	—	dBm
	>±5 MHz offset	—	–47.00	—	dBm

Fig3.1.1. Transmitter characteristics at 2Mbps, as given by the datasheet.

3.2 Cost Analysis

Below is the estimated total cost beyond items obtainable at the Supply Center & covered by PCBway orders.

Description	Manufacturer	Quantity	Price
ESP32-S3-WROOM-1-N16 / RF TXRX MODULE BT PCB TRACE SMD	Espressif Systems	1	$3.48
AZ1117-3.3 / IC REG LINEAR 3.3V 1A SOT223	Diodes Incorporated	1	$0.38
AZ1117-5.0 / IC REG LINEAR 5V 1A SOT223	Diodes Incorporated	1	$0.38
AZ1117-1.2 / IC REG LINEAR 1.2V 1A SOT223	Diodes Incorporated	1	$0.38
AZ1117-ADJ / IC REG LINEAR POS ADJ 1A SOT223	Diodes Incorporated	1	$0.38
MPU6050 / IMU ACCEL/GYRO 3-AXIS I2C 24QFN	TDK InvenSense	3	$9.00
JGA25-370 / DC Gearmotor with Encoder	PrUva	2	$35.76
CH340N / USB to TTL Serial Port Converter Module	Generic	1	$3.43
OV2640 / 2 million pixels camera (24pin)	OmniVision	1	$9.42

A4950 / DMOS Full-Bridge Motor Driver IC	Allegro MicroSystems	2	$ 5.72
Servomoter 1142 / Servo Motor RC 5V High Torque	Adafruit Industries LLC	1	$19.95
Car Chassis	SZDoit	1	$30.00
			Total Cost = $118.28

It is within the $50 per person budget.

3.3 Scheduling

Below is our current planning of work distribution. Due to uncertainty in PCB functionality and software development span, the schedule and work distribution after spring break will be subject to change.

Week	Task	Person
Feb 19th - Feb 25th	**Finish Design Document, Revise Proposal**	**Everyone**
	Determine Component Specs, Place Orders	
	First Draft PCB Schematic Design	Yue, Yuanfeng
Feb 26th - Mar 3rd	Android App Skeleton & UI Layout	Chaoyang
	Prototype Bluetooth Transceiver Design	Chaoyang,Yuanfeng
	Validate Mechanicals, Contact Machine Shop	Yuanfeng
	PCB Layout Design, Pass Audit	Yue, Yuanfeng
	Design Review	**Everyone**
Mar 4th - Mar 10th	Integrate Android App with I/O	Chaoyang
	Test and Revise Transceiver Design	Yue, Yuanfeng
	First Draft Control System and Auto Navigation Design	Everyone
	First Draft IMU & Camera I/O Design	Chaoyang, Yue
	1st Round PCB Order	**Everyone**
Mar 11th - March 17th	Revise Control System Design	Yuanfeng
	Sensor & Auto Navigation Integration	Chaoyang, Yue
	Revise Transceiver Design	Chaoyang, Yuanfeng
	Chassis & Mechanical Testing	Yue, Yuanfeng
Mar 17th - March 24th	Finalize Android App framework	Chaoyang, Yue
	Remote Control & Auto Navigation Testing	Yue, Yuanfeng

	Pass Audit, Revise PCB Design	Everyone
	2nd Round PCB Order	**Everyone**
Mar 25th - Mar 31st	Auto Navigation Fine Tuning	Chaoyang, Yue
	Revise Remote Control and Transceiving	Yuanfeng
	Individual Progress Report	Everyone
	Pass Audit, Revise PCB Design	Everyone
	3rd Round PCB Order	**Everyone**
Apr 1st - Apr 7th	Revise Auto Navigation System	Chaoyang, Yue
	Revise Remote Control and Transceiving	Yue, Yuanfeng
	Finalize Chassis and Mechanicals Design	Chaoyang, Yuanfeng
	Pass Audit, Revise PCB Design	Everyone
	4th Round PCB Order	**Everyone**
Apr 8th - Apr 14th	Finalize Auto Navigation System	Everyone
	Finalize Remote Control System	Yue, Yuanfeng
	Test and Revise Transceiving, Optimize integration	Chaoyang, Yue
	Pass Audit, Make final design testing	Everyone
	5th Round PCB Order	**Everyone**
Apr 15th - Apr 21st	Final QoL Improvements & Extendables	Everyone
	Finalize Transceiving and App, Final Assemble	Everyone
	Integration Tests	Chaoyang, Yuanfeng
	Mock Demo	**Everyone**
Apr 22nd - Apr 25th	**Final Demo**	**Everyone**

Section IV. Ethics and Safety

In the development of the Triangle Sign Deployer Car, our team is deeply committed to enhancing safety and upholding ethical standards in line with the IEEE and ACM Code of Ethics. This commitment guides our approach of bringing an autonomous or semi-autonomous vehicle into public spaces, particularly on highways, where the potential for impact on human lives and traffic flow is significant.

4.1 Ethical Considerations:

Public Safety and Responsibility: Central to our project is the imperative to "hold paramount the safety, health, and welfare of the public" as per IEEE's Code of Ethics Section I.1 [4]. Our system is designed with the foremost goal of not endangering human lives or causing unnecessary disruptions in traffic flow. Rigorous testing and validation will be conducted in diverse settings to minimize the hazard of the vehicle's unsafe or unreliable operation. However, it is important to acknowledge that while we strive to mitigate as many risks as possible, not all risks can be completely eliminated. Continuous user caution will be required at all times during operation to ensure the highest level of safety.

Privacy Respect and Data Security: In accordance with ethical standards, our design respects individual privacy and is committed to not collecting or transmitting sensitive information without explicit consent. This commitment to privacy and data security aligns closely with the ACM Code of Ethics, which emphasizes "the importance of privacy and confidentiality in technological advancements." Specifically, the ACM Code of Ethics states, "Design and implement systems that are robustly and usably secure, ensuring the privacy and proper use of personal information obtained in the course of their work" [5]. In line with this principle, our vehicle not only employs strict access controls to protect operational and communication data but also ensures that sensitive sensor data is erased after each operation. This approach minimizes any risk of unauthorized access or misuse of information, adhering to the highest standards of data privacy and security.

4.2 Safety Measures:

No-Trouble Protocols: To mitigate risks associated with a potential loss of communication, our system is equipped with fail-safe mechanisms that bring the vehicle to a complete stop if it loses connection with the controller while Auto Navigation is unavailable. This safety protocol ensures that the vehicle does not proceed unguided, reducing the risk of accidents.

Visibility Measures: Our system features a reliable hybrid visibility improvement installation to ensure safe introduction into traffic systems. It features high-visibility markers and lighting to ensure that it is easily seen by other drivers, particularly in adverse weather conditions.

By addressing these ethical considerations and implementing comprehensive safety measures, the Triangle Sign Deployer Car project aims not only to innovate but also to contribute positively to the societal understanding and implications of emerging technologies in public spaces. This approach underscores our commitment to ethical responsibility and the safety of all road users, aligning with our goal to improve public safety through technological advancement.

References

[1] Federal Highway Administration, "*Speed Concepts: Informational Guide,*" U.S. Department of Transportation, FHWA-SA-12-004, 2012. Available: https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa12004/. [Accessed: Feb. 22, 2024].

[2] Road Safety Foundation. (2023, December 13). *Road safety performance and investment opportunities.* Road Safety Foundation. https://roadsafetyfoundation.org/road-safety-performance-and-investment-opportunities/

[3] Espressif Systems. (2023). *"ESP32-S3-WROOM-1 & ESP32-S3-WROOM-1U Datasheet."* [Online]. Available: https://www.espressif.com/sites/default/files/documentation/esp32-s3-wroom-1_wroom-1u_datasheet_en.pdf

[4] IEEE. (2023). *"IEEE Code of Ethics."* [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html

[5] Association for Computing Machinery (ACM). (2023). *"ACM Code of Ethics and Professional Conduct."* [Online]. Available: https://www.acm.org/code-of-ethics