WRO
WORLD ROBOT OLYMPIAD ™

THE INNOVATION STORY

TEAM PARADUCKS

FUTURE ENGINEERS

TABLE OF CONTENT

WHO ARE WE?

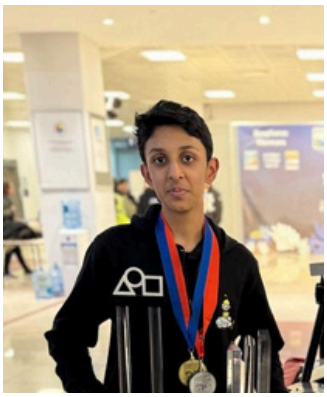
Team Name: Paraducks

Category: Future Engineers

School: Grade 10, Bombay International School

MEMBERS

Neel



Dev

Tara

FUTURE ENGINEERS

MOBILITY MANAGEMENT

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MOBILITY MANAGEMENT

Motors

We are following the motor limit and are using one Servo motor and one DC motor

Servo Motor

We used a servo to turn the front axle, controlling robot steering, while the wheels remained uncontrolled to move with the rear axle. The robot dimensions allow a maximum turning range of 90°. The axle is a disjoint shaft to prevent the wheels from slipping.

DC Motor

We connected our DC motor to a bevel gear to power the entire rear axle with the singular motor, powered by the motor driver in turn directly sourcing power from the battery.

Differential gearbox: Allows wheels to rotate at different speeds

12V brushed DC motor: Affordable, simple, reliable, power efficient, consistent torque and speed, adequate to move entire robot at moderate speeds

RKI-1203 digital servo: Adequate torque for robot weight and accurate, fast turning, space and power efficient.

Cytron MD10C R3 Motor Driver: High continuous current supply.

MOBILITY MANAGEMENT

Engineering Factor

The design needed to be **agile** and have a **very small radius of turn.** This was achieved by using a smaller wheelbase and a stacked CNC made Polycarbonate sheets design to accommodate displaced electronic components.

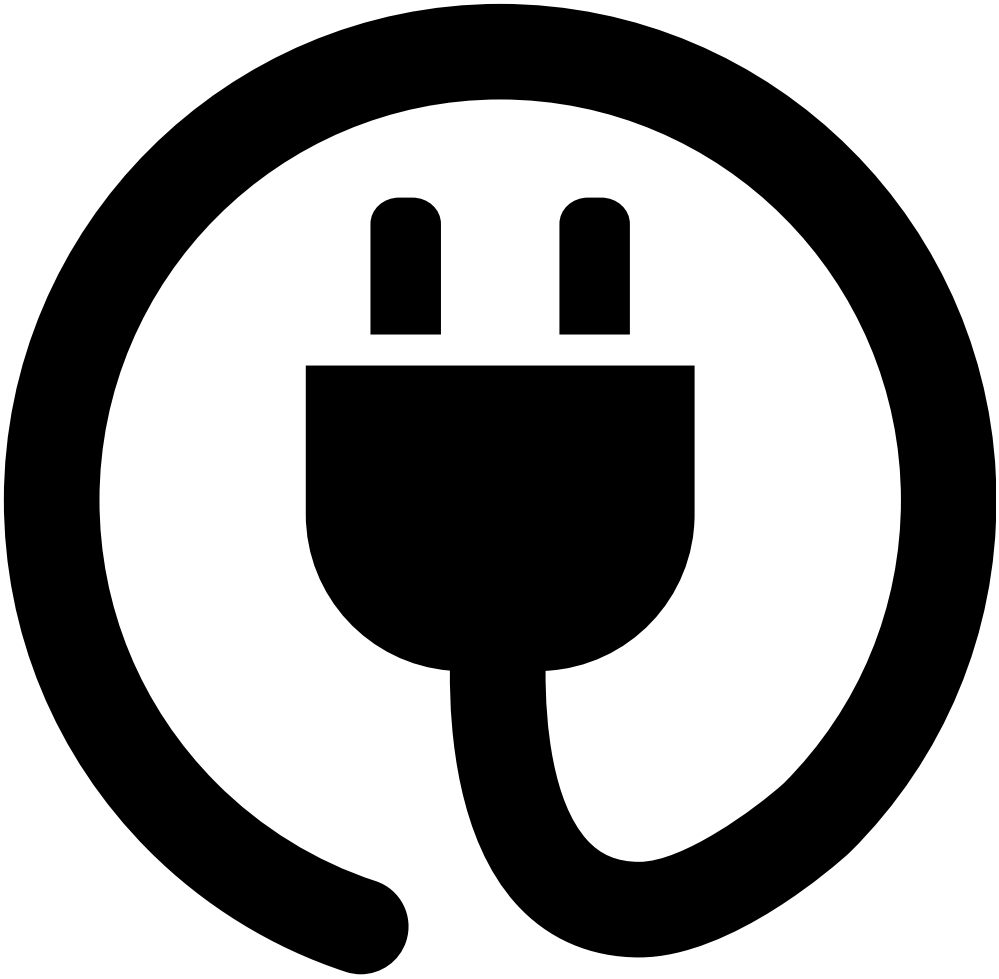
A metal differential is used to couple the rear disjoint shaft together, for better power delivery to both the rear wheels. This leads to close to no slippage while turning.

The motor is mounted vertically with the shaft **facing down**. The stability of the bot was another priority, taken care by **very low Centre of gravity** due to the battery being placed below the deck.

The camera is mounted on a very **high position** which gives us a very large POV for detection of blocks.

The C1 Lidar placed in front helped to get a better view of the block surrounding at all times, which allows for quick turning around blocks. The lidar also acts as an ddditional sensor for circumventing around the blocks. This paired with the TF-minis we have on the left, right, and front ensures we are able to manipulate the servo to turn **efficiently** every time.

POWER AND SENSE MANAGEMENT



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COMPONENTS

Rp Lidar c1

Hikvision camera

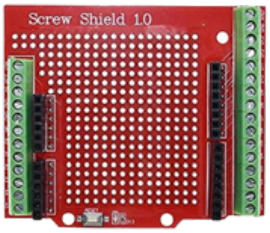
Google Coral

Tfmini lidar

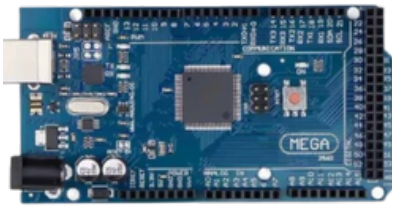
Raspi 4b

Buck converter REES52

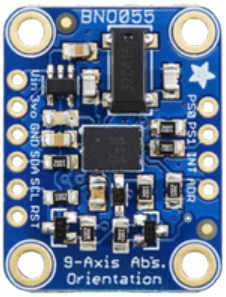
Switch



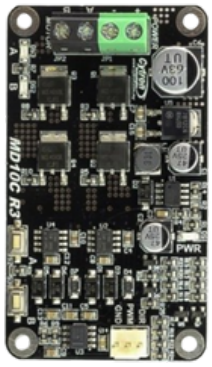
Screw Shield



Arduino Mega



BNO085 IMU



MD10C motor driver

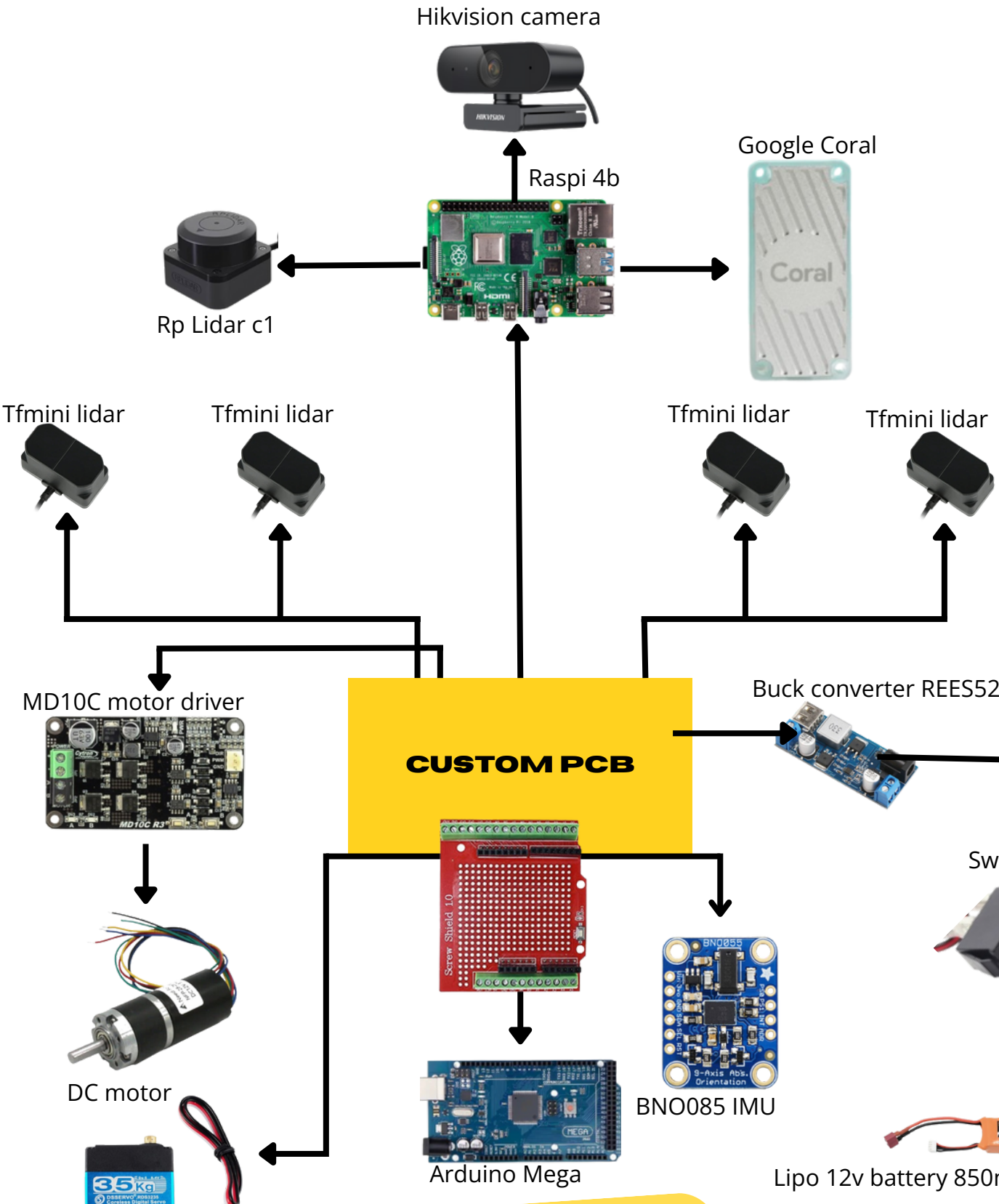
35kg servo blue rds3235

DC motor

Lipo 12v battery 850mah

FUTURE ENGINEERS

CIRCUIT



FUTURE ENGINEERS

POWER

Power Supply: Range LiPo 11.1 V 1300mah 3 cell battery

The motor driver is **directly** connected and powered by the battery, which in turn powers the motor.

We use a **12V -> 5V buck converter module** to step down voltage which is distributed by our custom PCB to all sensors and the following methods for the remaining components:

Raspberry Pi 4B: Connected and powered by the USB-A port in the buck converter to its USB-C power port

Arduino MEGA: Connected and powered from the RPi's USB-A port to its USB-B power port. Same connection used for serial communication between the two.

MICROCONTROLLERS

We initially began prototyping with an Arduino UNO, but found many flaws in it, primarily its image processing with a HuskyLens.

We now use combination of :

Raspberry Pi 4B: Primary microprocessor, where programs are stored and programmed in Python. Far better image processing and multiprocessing due it its multiple cores, GPIO ports are easy to use, display also attaches easily. Problems with serial communication.

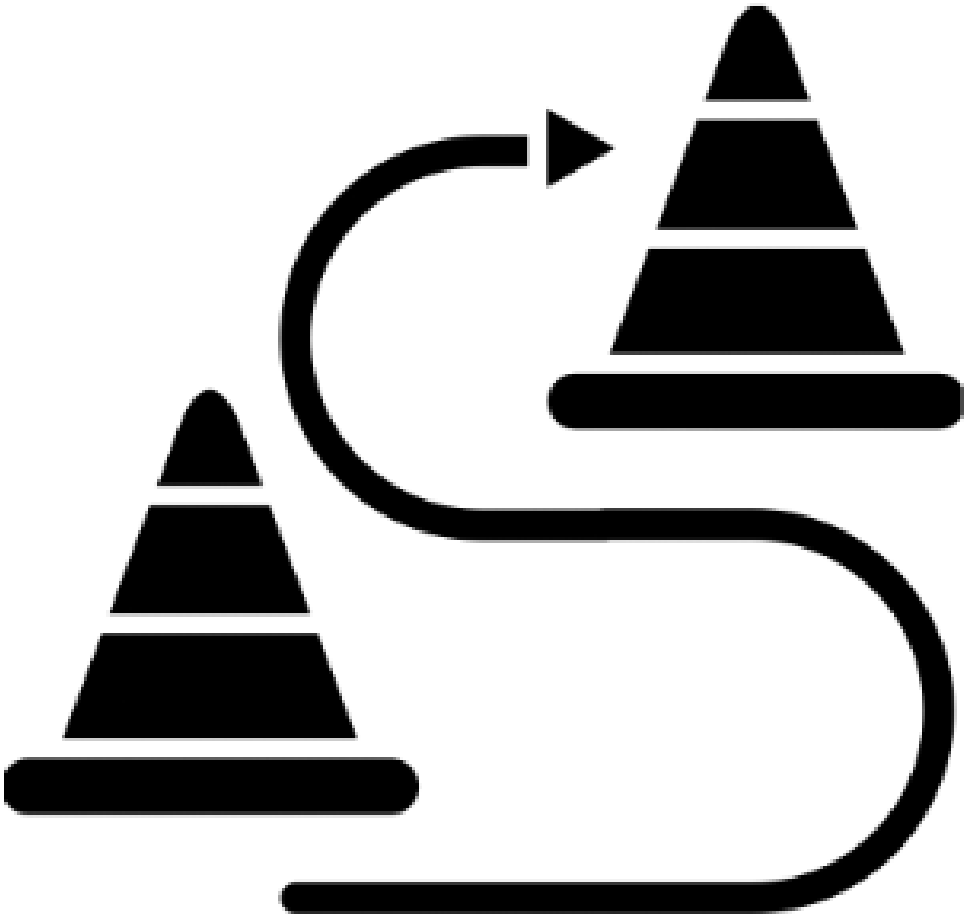
Arduino MEGA 2560 Rev3: Secondary microcontroller. Used for its superior compatibility and libraries for serial communication with sensors: colour sensor and IMU.

Note: We also used an ESP32 DevKit for a while, but compatibility and connectivity issues forced us to replace it with the Arduino MEGA.

SENSORS

Name	Description	Use
C1 LiDAR	Compact laser sensor, measures distance with high precision, wide field of view	Mapping surroundings and obstacle avoidance
Hikvision Camera	High-resolution color camera, supports video recording and streaming	Object and colour detection, visual navigation
TF-mini LiDAR	Small and cost-effective LiDAR, up to 12 meters range	Detecting nearby objects, simple distance sensing
Motor Encoder	Rotary encoder, counts wheel or shaft rotations	Monitoring robot movement and controlling speed
IMU	Contains gyroscope and accelerometer for motion tracking	Tracking orientation, measuring acceleration

OBSTACLE MANAGEMENT



AI DETECTION

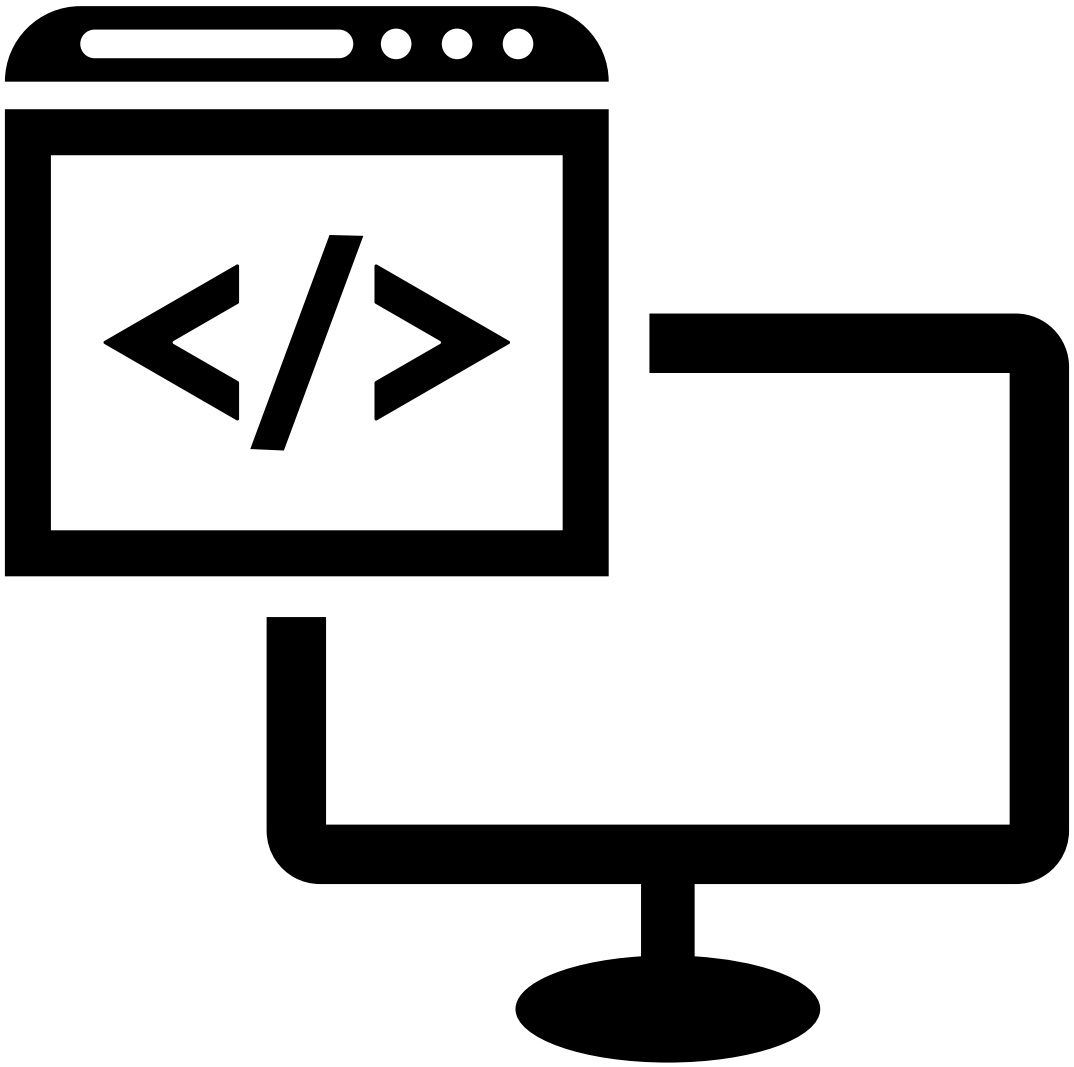
AI Model

MobileNet SSD v2 is an efficient, lightweight deep learning model designed for real-time object detection on mobile and embedded devices. It combines the MobileNet V2 architecture, which extracts important features from images using advanced convolution techniques,

Why we are using this:

- **Efficiency on Low-Power Devices:** MobileNet SSD v2 is highly optimised for mobile and embedded hardware. It can deliver accurate object and colour detection at fast speeds even on resource-constrained devices like Raspberry Pi and microcontrollers—something traditional models or manual colour sensors cannot do reliably.
- **Real-Time Detection and Versatility**: This model detects blocks and classifies their colors in a single pass, giving rapid, real-time feedback that's ideal for robotics tasks. It is robust against varied lighting, camera angles, and backgrounds compared to simpler methods like color sensors or thresholding, which often require manual calibration.
- **Easy Customization and Wider AI Support**: MobileNet SSD v2 is compatible with popular AI frameworks and can be custom-trained for your specific block colors and environments, unlike traditional threshold-based pipelines or hardware color sensors that are harder to adapt.

PROGRAMMING



FUTURE ENGINEERS

PROGRAMMING

Key Functions:

TFMini Data: Calculates checksum of 9-bit data packages sent by TFMini, accepts value if correct and converts to cm.

Set Angle: Uses PWM (pulse-width modulation) to set angle, converts degree input to pulse-width

Button Toggle: Compares previous and current state of the button (on/off) to see if it is pressed to start or stop the robot.

Running Encoder: Establishes UART communication with Arduino MEGA; reads, decodes and strips lines of data received

PID controller: Used to decrease error between desired and servo position

Programming Language:

Python

Turning Logic

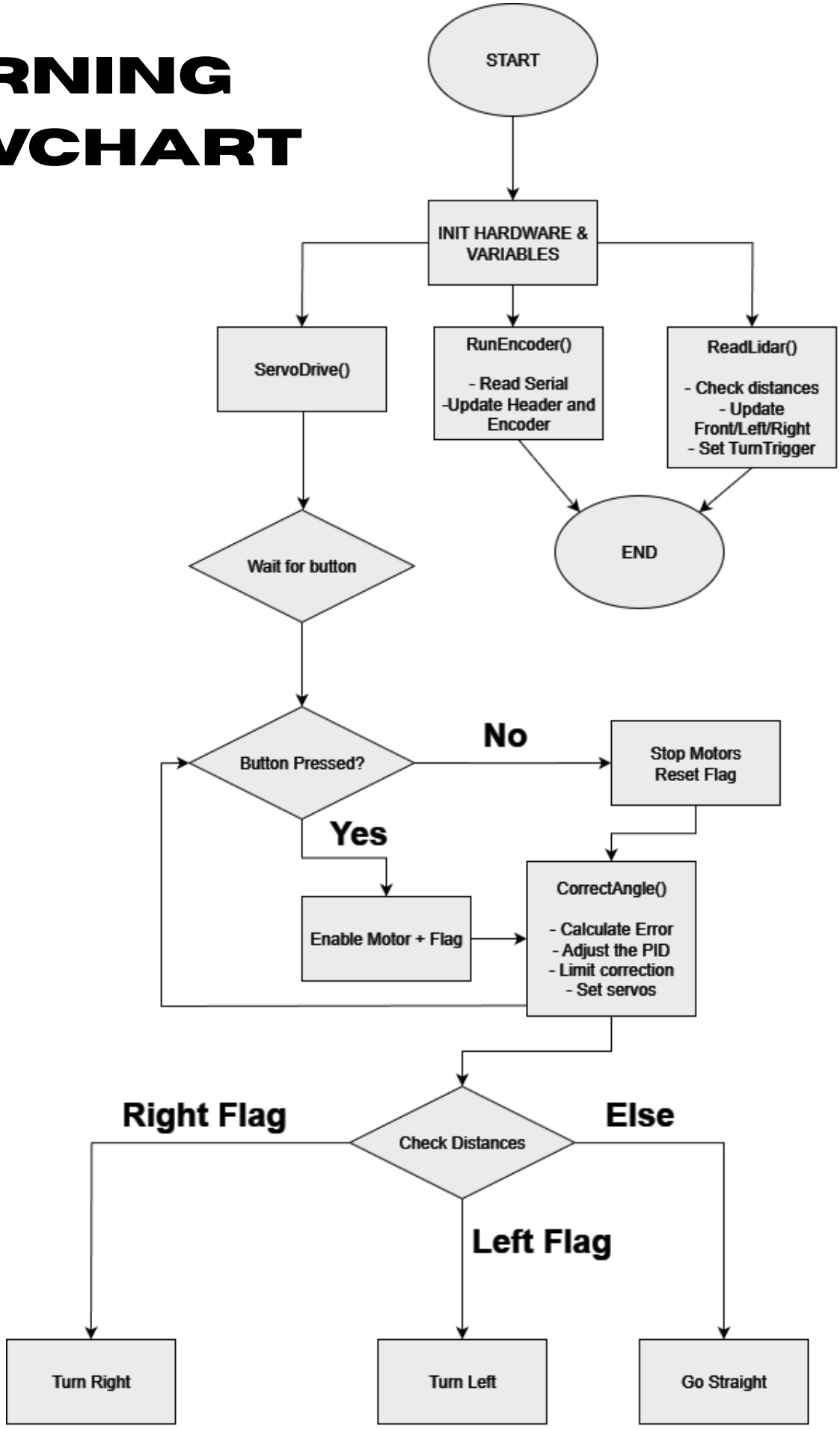
The turning logic is based on LIDAR sensor readings and special direction flags:
If there is an obstacle close in front (lidar_front<900lidar_front<900), and space to the right (lidar_right>1500lidar_right>1500), and the right flag is set (right_f.value) but not the left flag, the robot triggers a right turn (turn_trigger.value = True).
If there is an obstacle close in front, and space to the left (lidar_left>1500lidar_left>1500), and the left flag is set (left_f.value) but not the right flag, the robot triggers a left turn.
If neither condition is met, the robot does not trigger a turn (turn_trigger.value = False).

PSEUDOCODE

TURN

```
IF sp_angle > 180 THEN
 sp_angle ← sp_angle - 360
ENDIF
IF previous_angle ≠ angle THEN
 IF prev_sp ≠ sp_angle THEN
 sp_angle ← 360 - sp_angle
 ENDIF
 prev_sp ← sp_angle

 WHILE (angle - previous_angle) > 1 DO
 lidar_angle ← (previous_angle + 1) MOD 360
 lidar_distance ← previous_distance
 previous_angle ← lidar_angle

  IF lidar_angle = ((0 + imu_r + sp_angle) MOD 360) THEN
 lidar_front ← lidar_distance
 lidar_f ← lidar_front
 ENDIF

IF lidar_angle = ((90 + imu_r + sp_angle) MOD 360) THEN
 lidar_left ← lidar_distance
 ENDIF

 IF lidar_angle = ((270 + imu_r + sp_angle) MOD 360) THEN
 lidar_right ← lidar_distance
 ENDIF

 # Turning decision based on lidar readings and flags
 IF (lidar_front < 900 AND lidar_right > 1500) AND right_flag = TRUE AND left_flag = FALSE THEN
 turn_trigger ← TRUE
 ELSE IF (lidar_front < 900 AND lidar_left > 1500) AND left_flag = TRUE AND right_flag = FALSE THEN
 turn_trigger ← TRUE
 ELSE
 turn_trigger ← FALSE
 ENDIF

 # Print current status (for debugging)
 PRINT "turn_trigger: ", turn_trigger, " lidar_front: ", lidar_front, ", lidar_left: ", lidar_left, ", lidar_right: ", lidar_right, " sp_angle: ", sp_angle, " head: ", head
 ENDWHILE
ENDIF
```

TURNING FLOWCHART



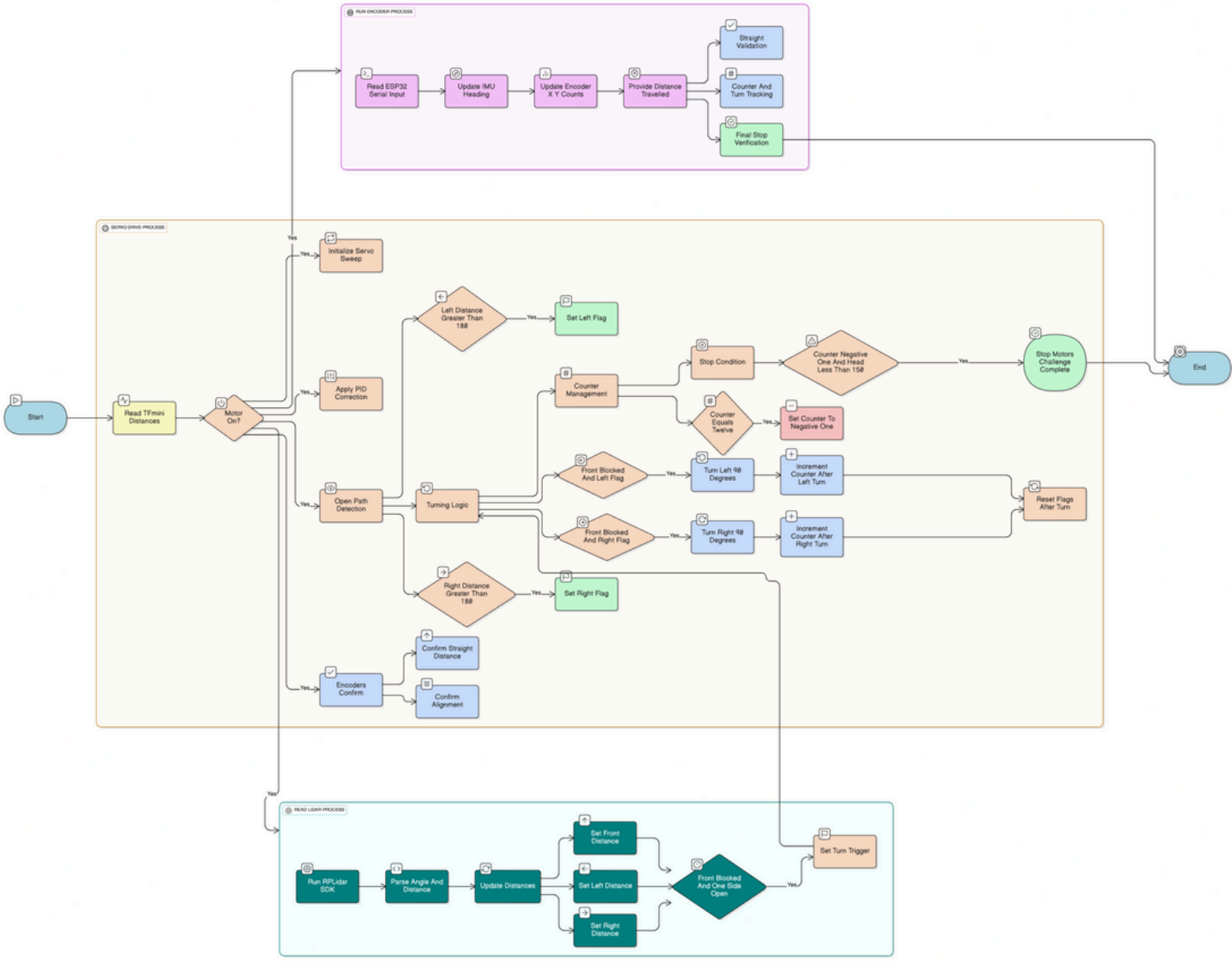
PSEUDOCODE

OPEN CHALLENGE

```
BEGIN PROGRAM

INIT hardware, reset Arduino, open serial, set variables

PROCEDURE CorrectAngle(Target, Heading, L, R)
  error ← Heading - Target
  IF error > 180 THEN
    error ← error - 360
  ENDIF
  correction ← kp*error + kd*(error-prevError) + ki*
(totalError+error)

  IF L < 15 THEN
    correction ← correction - 20
  ELSE IF
    R < 15 THEN correction ← correction + 20
  ENDIF

  LIMIT correction TO -30..30
  SetServo(90 - correction)
ENDPROCEDURE

PROCEDURE ServoDrive()
  WAIT button
  LOOP
    READ front, left, right
    IF button pressed THEN
      ENABLE motor
      IF no flags THEN
        IF right > 180 THEN
          RightFlag ← TRUE
        ELSE IF left > 180 THEN
          LeftFlag ← TRUE
        ENDIF
      ENDIF
    CALL CorrectAngle(Target, Heading, left, right)
    IF RightFlag AND right > 130 AND front < 75 AND NOT
Trigger THEN
      counter ← counter+1
      Target ← (90*counter) MOD 360
      Trigger ← TRUE
    ELSE IF LeftFlag AND left > 130 AND front < 75 AND NOT
    Trigger THEN
      counter ← counter+1
      Target ← -(90*counter) MOD 360
      Trigger ← TRUE
    ELSE IF (right < 85 OR left < 85) AND front > 75
THEN
      Trigger ← FALSE
    ENDIF
  ELSE
    STOP motor, RESET flags
    CALL CorrectAngle(0, Heading, left, right)
  ENDIF
  ENDLOOP
ENDPROCEDURE

PROCEDURE RunEncoder()
  LOOP READ serial → update Heading,
EncoderCounts
  ENDLOOP
ENDPROCEDURE

PROCEDURE ReadLidar()
  LOOP
    READ angle, dist → update Front, Left, Right
    IF Front < 900 AND (Right > 1500 OR Left > 1500)
THEN
      TurnTrigger ← TRUE
    ELSE
      TurnTrigger ← FALSE
    ENDIF
  ENDLOOP
ENDPROCEDURE

RUN ServoDrive, RunEncoder, ReadLidar IN
PARALLEL

END PROGRAM
```

FLOWCHART

OPEN CHALLENGE



FUTURE ENGINEERS

PSEUDOCODE

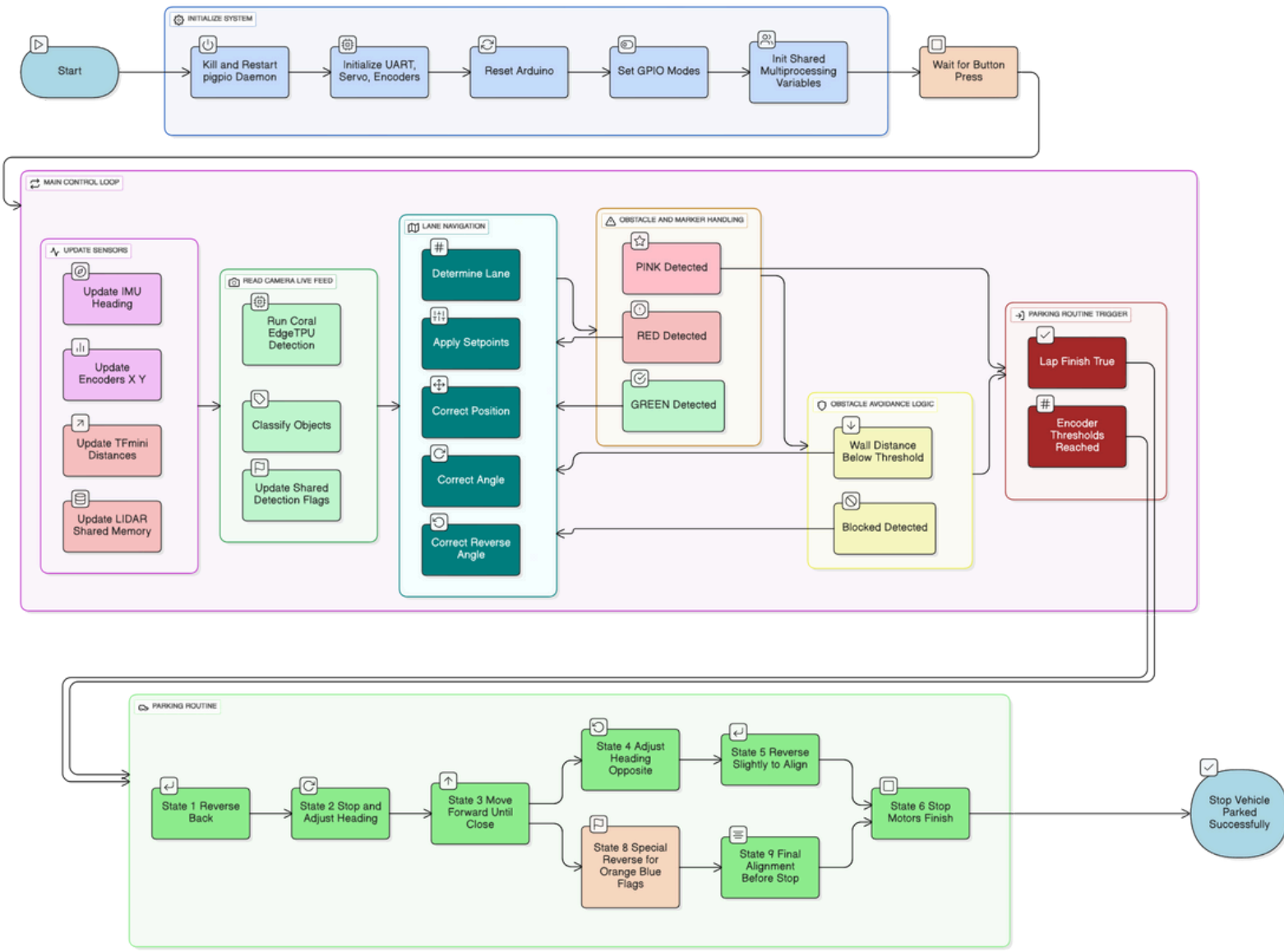
OBSTACLE CHALLENGE

```
PROCEDURE Main
    INITIALISE all pins and devices
    RESET Arduino
    CREATE Servo using servo_pin
    CREATE TFmini using RX_Head, RX_Left, RX_Right, RX_Back
    CREATE EncoderCounter
    inParkingAtStart ← FALSE
    lap_finish ← FALSE
    continue_parking ← FALSE
    blue_flag ← FALSE
    orange_flag ← FALSE
    parking_flag ← FALSE
    counter ← 0
    WHILE TRUE
        IF ButtonIsPressed() THEN
            DriveRoutine()
        ELSE
            StopMotors()
            heading_angle ← 0
            counter ← 0
            CALL CorrectAngle(heading_angle, CurrentHeadValue())
        ENDIF
    ENDWHILE
ENDPROCEDURE
PROCEDURE DriveRoutine
    WHILE ButtonIsPressed()
        CALL UpdateSensors()  'Get all necessary sensor data

        IF lap_finish = FALSE THEN
            IF ParkingDetected() THEN
                inParkingAtStart ← TRUE
                IF TF_Left < 20 AND TF_Head < 200 THEN
                    RightParking()
                ELSEIF TF_Right < 20 AND TF_Head < 200 THEN
                    LeftParking()
                ENDIF
            ENDIF
            CALL DriveLogic()
        ELSE
            CALL ParkingLogic()
        ENDIF
    ENDWHILE
ENDPROCEDURE
```

```
PROCEDURE CorrectAngle(setPoint_gyro, heading)
    error_gyro ← heading - setPoint_gyro
    IF error_gyro > 180 THEN
        error_gyro ← error_gyro - 360
    ENDIF
    correction ← kp * error_gyro + kd * (error_gyro - prevErrorGyro)
+ ki * totalErrorGyro
    IF correction > 30 THEN
        correction ← 30
    ELSEIF correction < -30 THEN
        correction ← -30
    ENDIF
    prevErrorGyro ← error_gyro
    SET_SERVO_ANGLE(90 - correction)
ENDPROCEDURE

PROCEDURE UpdateMotors(power)
    SET_PWM_DUTYCYCLE(pwm_pin, power)
    SET_DIRECTION(direction_pin, 1)
ENDPROCEDURE

PROCEDURE StopMotors()
    SET_PWM_DUTYCYCLE(pwm_pin, 0)
    SET_DIRECTION(direction_pin, 0)
ENDPROCEDURE
PROCEDURE DriveLogic
    IF DetectGreenBlock() THEN
        power ← 70
        CALL CorrectPosition(setPointL, heading_angle, x, y, counter, blue_flag,
orange_flag, ...)
    ELSEIF DetectRedBlock() THEN
        power ← 70
        CALL CorrectPosition(setPointR, heading_angle, x, y, counter, blue_flag,
orange_flag, ...)
    ELSEIF DetectPinkBlock() THEN
        IF blue_flag THEN
            IF TF_Left < 30 THEN
                CALL CorrectAngle(heading_angle + 10, CurrentHeadValue())
            ELSE
                CALL CorrectAngle(heading_angle, CurrentHeadValue())
            ENDIF
        ELSEIF orange_flag THEN
            IF TF_Right < 30 THEN
                CALL CorrectAngle(heading_angle - 10, CurrentHeadValue())
            ELSE
                CALL CorrectAngle(heading_angle, CurrentHeadValue())
            ENDIF
        ENDIF
    ELSE
        power ← 85
        CALL CorrectPosition(setPointC, heading_angle, x, y, counter, blue_flag,
orange_flag, ...)
    ENDIF
    CALL UpdateMotors(power)
ENDPROCEDURE
```

FLOWCHART

OBSTACLE CHALLENGE



OBJECT DETECTION MODEL

Create a Roboflow dataset with 5193 annotated and augmented images.

Download the dataset as a ZIP file in TensorFlow TFRecord format.

Unzip and extract test, train, and validation images on a Linux system.

Install Ultralytics and set up a virtual environment compatible with EdgeTPU.

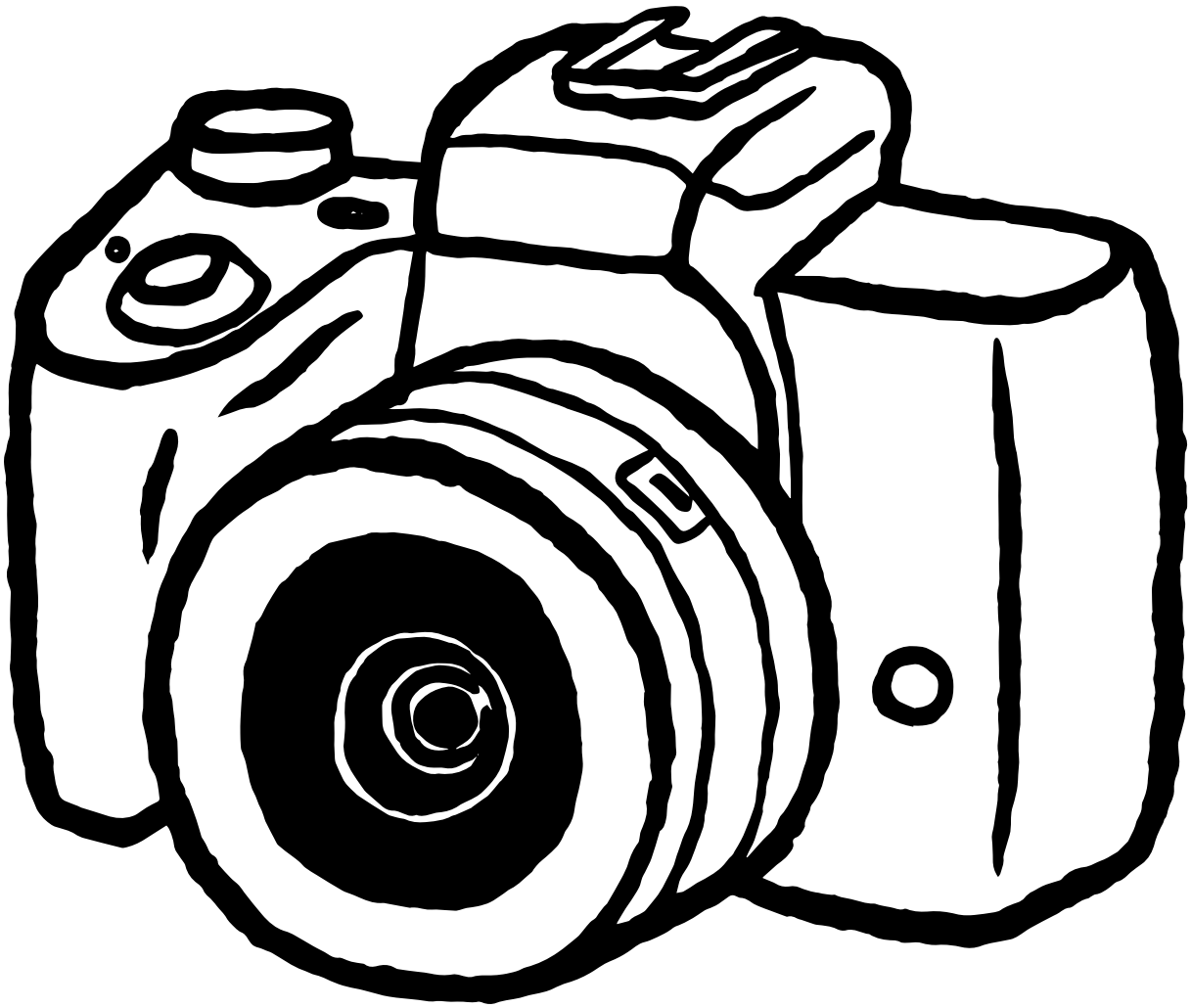
Start model training after confirming that there are no import errors.

After training, compile the MobileNet SSD v2 model file using the EdgeTPU compiler with all quantisations (full integer, float-32, etc.).

Import the compiled, quantised model file into the code directory.

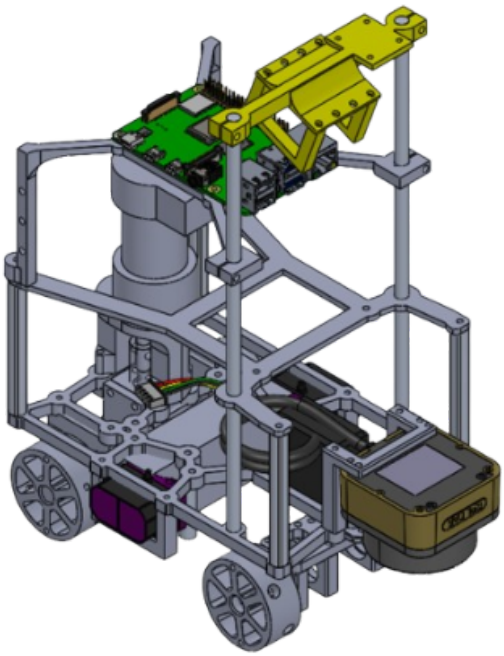
Copy the model path and test performance by printing FPS with both CPU and Google Coral; also, check the bounding box outputs.

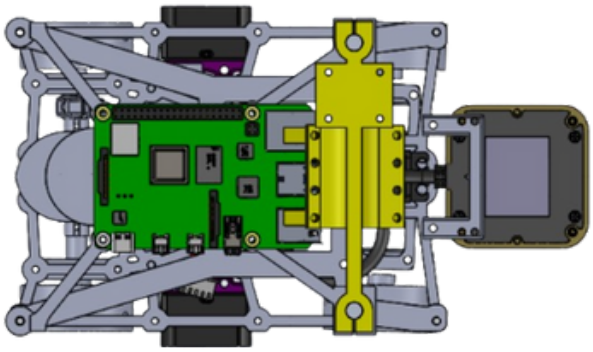
GALLERY

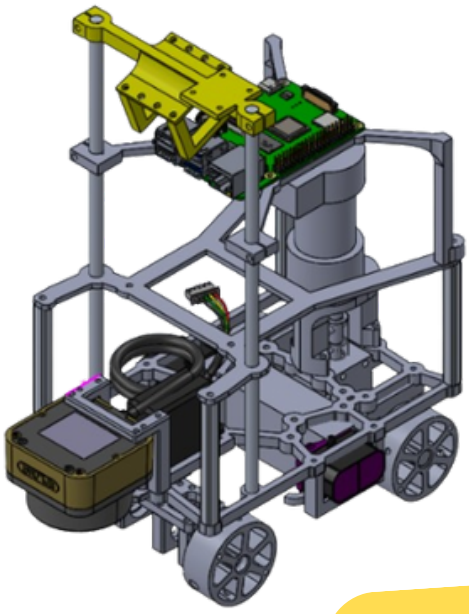


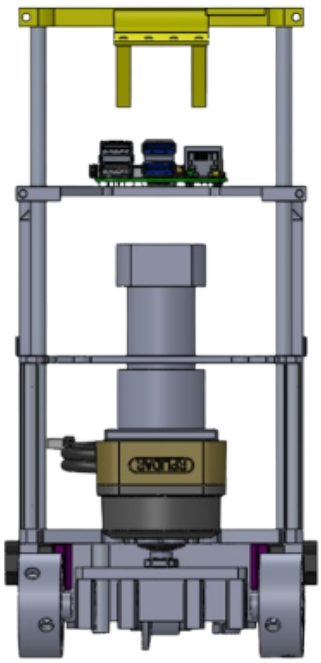
CAD IMAGE

We designed our robot's online model using Solidworks as our software for computer aided design (CAD) which helped in a very high accuracy for sizing of components and creation of custom 3D printed mounts, helping us stay within the stipulated robot limitations.

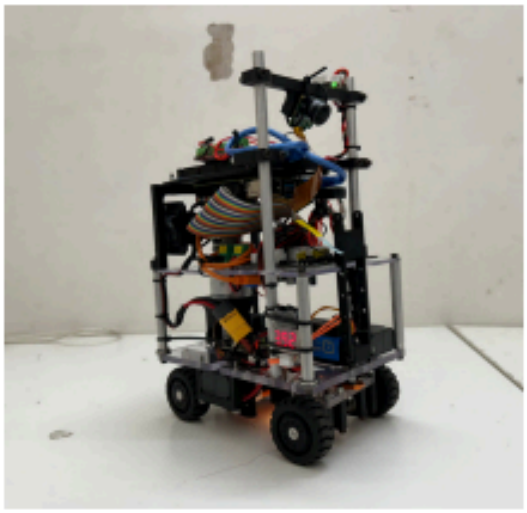
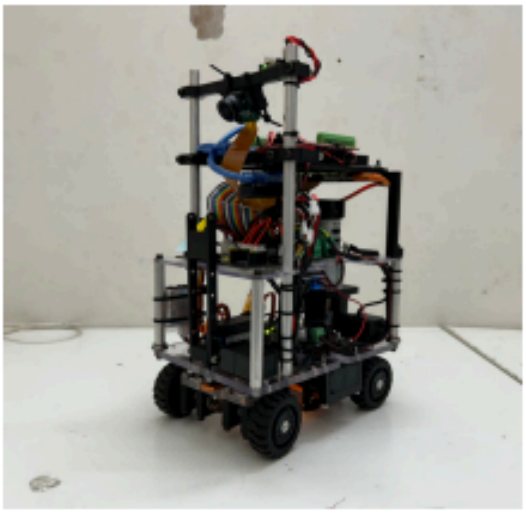
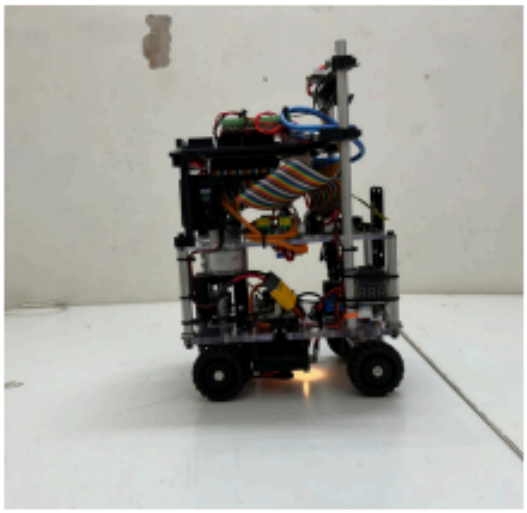
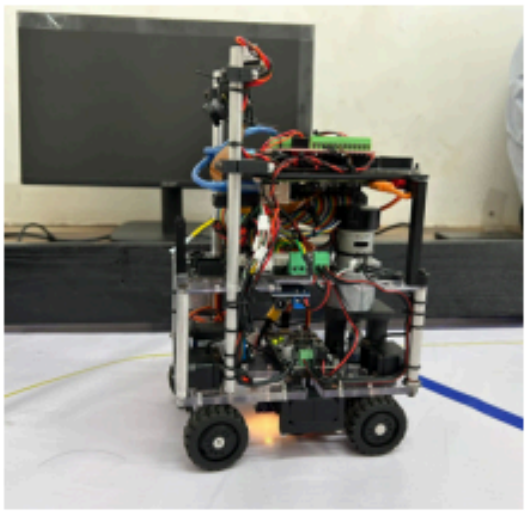
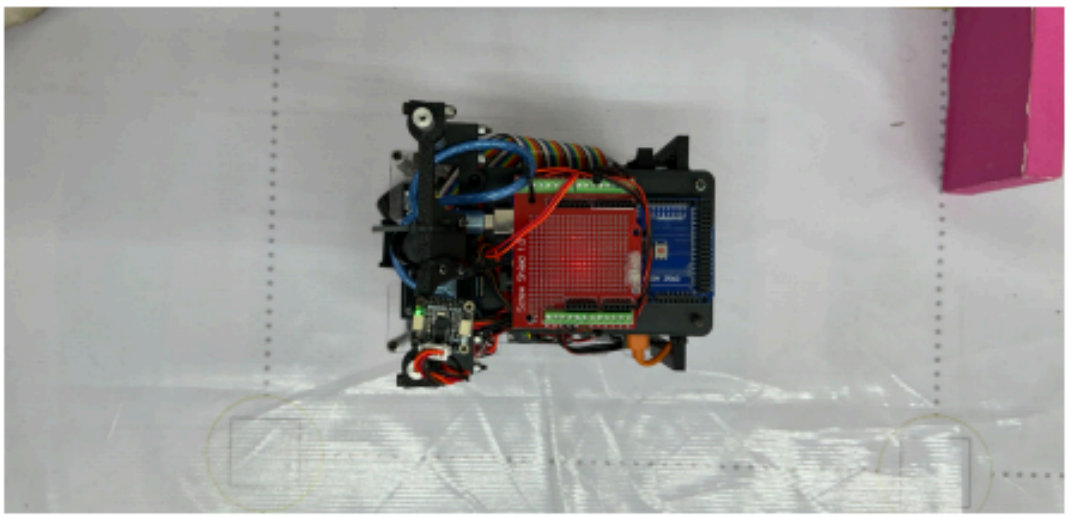








IRL IMAGES

FUTURE ENGINEERS

GITHUB

FUTURE ENGINEERS