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Autonomous Navigation Bot

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Abstract: *This article presents an innovative concept for an autonomous vehicle that operates and navigates without human intervention. The proposal involves constructing a 1/10 scale RC car that utilizes an array of sophisticated software and hardware components, including a Convolutional Neural Network (CNN), an Arduino UNO Board, an NVIDIA Jetson Nano board, a camera, an ultrasonic sensor, a gyroscope, an accelerometer, an Electronic Speed Controller (ESC), a BLDC motor, and a servo motor.The camera and ultrasonic sensor are integrated with the Arduino UNO board to provide input data for the CNN running on the Jetson Nano. This enables the vehicle to detect and classify objects in real-time and make informed navigation decisions. The ultrasonic sensor, located at the front of the vehicle, plays a crucial role in collision avoidance by halting the vehicle before reaching a certain distance from an obstacle. The Jetson board sends a signal to the BLDC motor to stop the vehicle when required. To achieve real-time object detection and obstacle avoidance, the vehicle employs a highly advanced system that utilizes both the camera and ultrasonic sensor.*

Keywords: autonomous, real-time object detect, Convolutional Neural Network, YOLOv7, obstacle avoidance. BLDC motor, ESC

I. INTRODUCTION

Given the rapid advancements in the field of robotics, it is now an opportune time to focus on developing an autonomous vehicle capable of navigating its environment with precision. Currently available autonomous navigation systems are prohibitively expensive, while affordable systems lack the requisite level of precision for many applications. Our objective is to construct a practical and efficient autonomous navigation system which can have broad applications, such as crop monitoring, environmental monitoring, or access to locations that are risky for humans. Our approach involves modeling the system on a 1/10 scale RC car, which will utilize a combination of camera and ultrasonic sensor inputs to sense its environment. The vehicle's sensor data will be streamed from the Arduino UNO board to the Jetson Nano board, where we will process the images using a Convolutional Neural Network (CNN) for object detection. Additionally, the sensor data will be processed to prevent front-end collisions by applying the braking mechanism and steering mechanism, which will stop the vehicle at a safe distance from obstacles and steer it to avoid the obstacle. The vehicle will detect the edges of obstacles and use its steering to avoid collisions. This innovative approach represents a efficient solution to the challenge of developing a cost-effective autonomous navigation system. By leveraging cutting-edge technologies such as CNN, we aim to deliver a highly reliable and precise autonomous vehicle that has the potential applications in wide range of industries.

II. PROBLEM STATEMENT

Navigation is a complex task that relies on developing an internal representation of space, grounded by recognizable landmarks and robust visual processing, that can simultaneously support continuous self-localization and a representation of the goal. Recent advancements in Artificial Intelligence (AI), Computer Vision (CV) and related technologies can make this achievable. As autonomous vehicles have the potential to automate a wide array of labor-intensive tasks in the factory environment and improve output and it can navigate to places where humans cannot or simply has to put human life at risk.

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We aim to design a fully autonomous vehicle that would be capable of moving anywhere without any human intervention. Overall, the primary objectives of the vehicle are to be able to navigate to a given location, capable of detecting the hurdles and obstacles coming along the way.

III. SYSTEM ARCHITECTURE

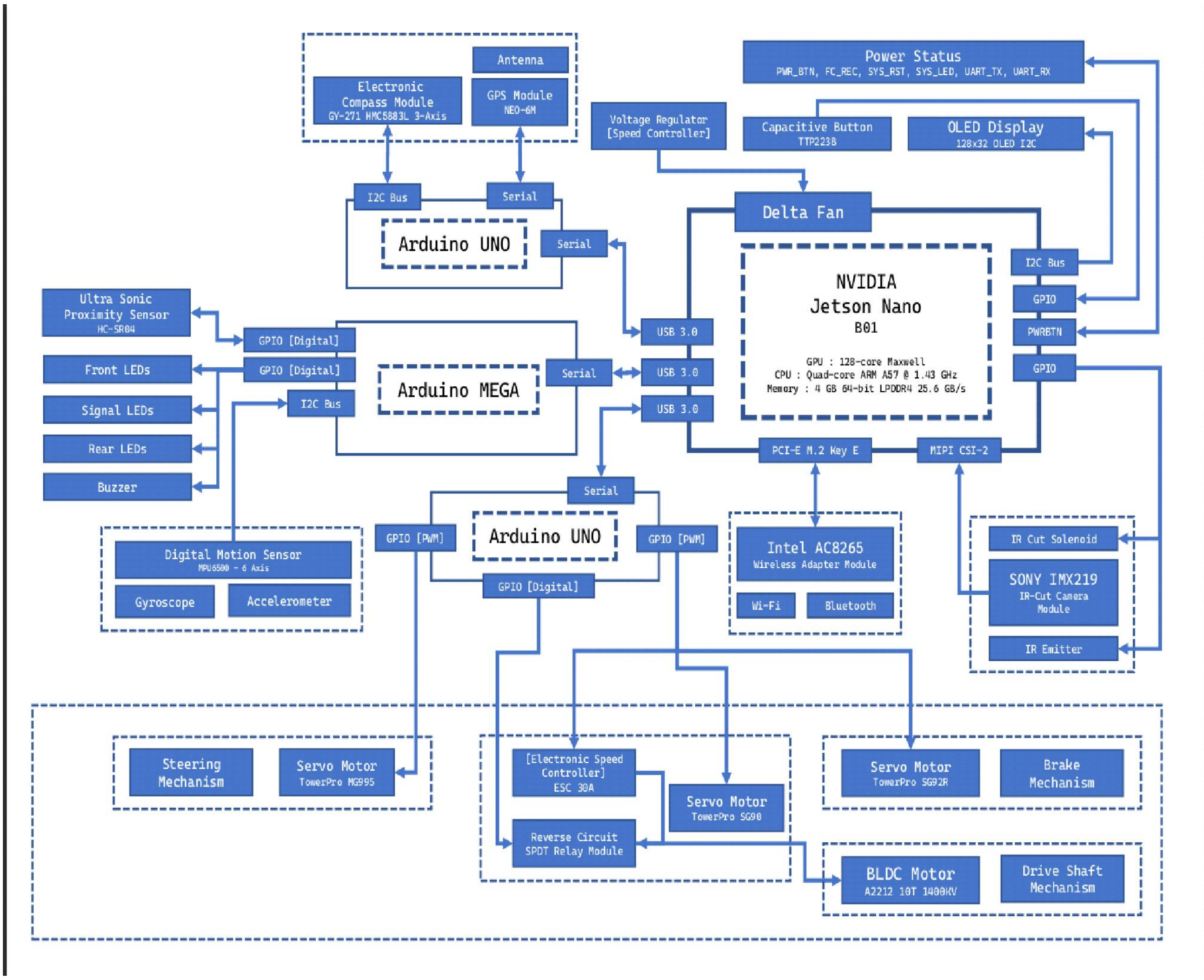

Figure 1. Autonomous Navigation Bot System Architecture

3.1 Detection of obstacle using ultrasonic sensor and sending it to Arduino Mega

Ultrasonic proximity sensors work by sending out high-frequency sound waves and then measuring the time it takes for the sound waves to bounce back after hitting an object.The sensor sends out a high-frequency sound wave from a transmitter, and this sound wave then travels through the air until it hits an object. When the sound wave hits the object, it bounces back to the sensor and is detected by a receiver. The sensor then measures the time it took for the sound wave to travel to the object and back, which can be used to calculate the distance between the sensor and the object.The Arduino Mega can be programmed to turn on an LED or activate/deactivate a motor.

3.2 Sending Gyroscope and accelerometer data to Arduino Mega

To send data to an Arduino Mega, both the gyroscope and accelerometer would typically use a communication protocol such as I2C or SPI. The gyroscope and accelerometer would be connected to the Arduino via their respective communication lines, and the Arduino would read data from them using the appropriate libraries and functions. Once

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the Arduino has received data from the gyroscope and accelerometer, it use that data to perform a variety of tasks such as to control the movement of a Vehicle or to stabilize the orientation of an Vehicle.

3.3 Avoiding Obstacles using Servo Motor

Once an object is detected by a vehicle using an IMX219 camera, the Jetson Nano can use its processing power to analyze the camera feed and detect the object's position and distance. The Jetson Nano can then send signals to the Arduino Mega micro-controller, which is connected to the servo motor. These signals can be sent via serial communication, where the Jetson Nano sends data to the Arduino over a serial port. The Arduino can then interpret the data and use it to control the servo motor's direction and movement.

3.4 Controlling a BLDC motor using Arduino UNO through ESC

Once the ESC is connected to the motor and micro-controller, you can control the motor speed by sending PWM signals to the ESC. The ESC will then convert these signals into a high-frequency signal that controls the motor speed by adjusting the voltage and current supplied to the motor. The ESC works by switching the power to the three phases of the motor in sequence, using the pulse-width modulation (PWM) technique. The ESC adjusts the PWM duty cycle to regulate the amount of current that flows to the motor. By changing the PWM duty cycle, the ESC can control the motor's speed.

IV. HARDWARE

4.1 Arduino UNO:

Figure 2. Arduino UNO

The board interfaces with the camera and ultrasonic sensor to collect input data, which is then processed by the Convolutional Neural Network running on the NVIDIA Jetson Nano board. The Arduino UNO board plays a crucial role in streaming the collected data to the Jetson Nano board, which runs the neural network responsible for detecting obstacles and processing the sensor data to avoid front collision. Through the Arduino UNO board, we were able to integrate different hardware and software components, thereby enabling the vehicle to perform its functions autonomously.

4.2 Arduino Mega:

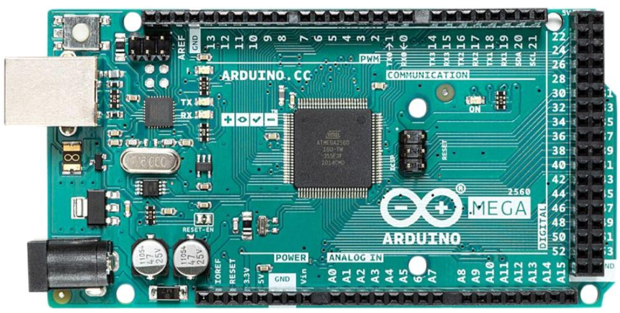

Figure 3. Arduino Mega

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The Arduino Mega can communicate with the Jetson Nano board through several communication protocols, including Serial communication and I2C (Inter-Integrated Circuit) communication. For Serial communication, the Arduino Mega and Jetson Nano are connected via USB cable. The Jetson Nano board can send commands or receive data from the Arduino Mega through the Serial port using the appropriate Serial communication libraries. Arduino Mega is connected to the Jetson Nano board to transmit sensor data from the ultrasonic sensor and camera to the Jetson Nano board.

4.3 Jetson Nano

Figure 4. Jetson Nano

Jetson Nano is used to process the data collected by the vehicle's camera and ultrasonic sensor. The data is streamed from the Arduino UNO board to the Jetson Nano board, where a Convolutional Neural Network (CNN) is used to process the images and detect obstacles. The Jetson board also sends a signal to the BLDC motor to stop the vehicle when necessary, based on the data collected by the ultrasonic sensor. In this way, the Jetson Nano plays a critical role in enabling real-time object detection and obstacle avoidance for the autonomous vehicle.

4.4 Ultrasonic Sensor:

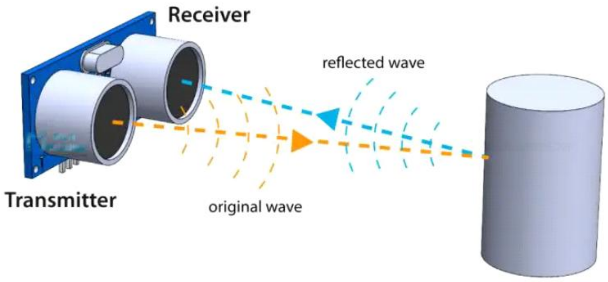

Figure 5. Ultrasonic Sensor

An ultrasonic sensor works by emitting high-frequency sound waves and then detecting the time it takes for the sound waves to bounce back to the sensor. This information is then used to determine the distance between the sensor and an object in front of it. In a system such as the one described in the previous paragraph, an ultrasonic sensor is connected to an Arduino Mega, which is in turn connected to a Jetson Nano board. The ultrasonic sensor provides distance information to the Arduino, which then sends this data to the Jetson Nano.

4.5 BLDC Motor

Figure 6. BLDC Motor

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Brushless Direct Current (BLDC) motor is used as the main engine. This type of motor offers several advantages over traditional brushed motors, including higher efficiency, longer lifespan, and higher torque-to-weight ratio we have used 1400KV motor. The BLDC motor is controlled by the Jetson Nano board, which sends signals to the Electronic Speed Controller (ESC) that controls the speed and direction of the motor. The ESC takes the input signal from the Jetson Nano and sends the appropriate signals to the BLDC motor to maintain the desired speed and direction.

4.6 TowerPro Mg995

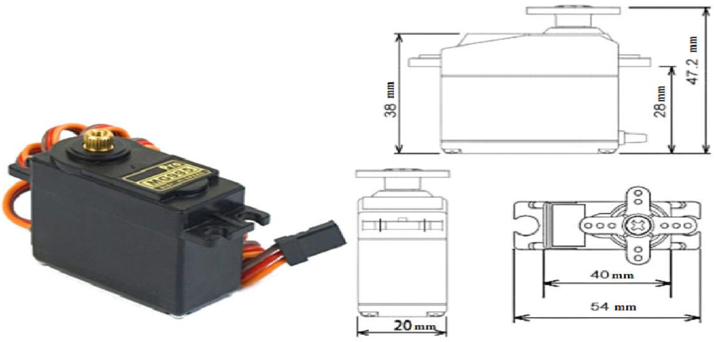

Figure 7. Servo Towerpro Mg995

The MG995 servo motor is used to control the turning of the vehicle. The servo motor is connected to the steering mechanism of the vehicle and can be programmed to turn the vehicle left or right based on the input received from the sensors and the neural network running on the Jetson Nano board. When the neural network detects an obstacle, it sends a signal to the Arduino Mega board, which in turn sends a signal to the servo motor to turn the vehicle in a direction away from the obstacle. This allows the vehicle to avoid collisions and navigate around obstacles in its path. The MG995 servo motor is a high-torque servo motor that is capable of precise movements and can be controlled with great accuracy.

4.7 Electronic Speed Controller

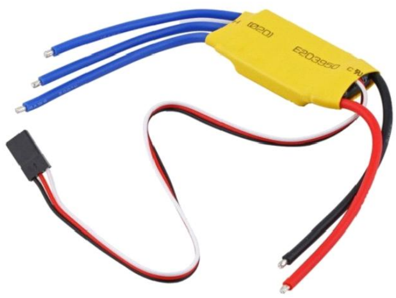

Figure 8. Electronic Speed Controller

The ESC is responsible for controlling the speed of the BLDC motor which is the main engine of the vehicle. The ESC works by receiving signals from the Jetson Nano board which determines the speed at which the BLDC motor should run. The Jetson Nano board runs a neural network algorithm that processes data from the camera and ultrasonic sensor to determine the speed at which the vehicle should move.The ESC then regulates the power supplied to the BLDC motor to achieve the desired speed. The ESC uses Pulse Width Modulation (PWM) technique to vary the voltage supplied to the motor. This allows the motor to run at different speeds as required by the neural network algorithm.

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4.8 SONY IMX 219 Camera

Figure 9. SONY IMX 219

The camera is connected to the Jetson Nano board, which is responsible for processing the input images collected by the camera. The camera provides high-resolution images to the Jetson Nano, which are used for object detection and navigation.

The use of the Sony IMX 219 camera connected to the Jetson Nano allows for accurate and reliable object detection and navigation, making the proposed autonomous vehicle a viable solution for various applications, such as environmental monitoring, crop inspection, and exploration in hazardous or remote locations.

4.9 MPU6500 – 6 Axis

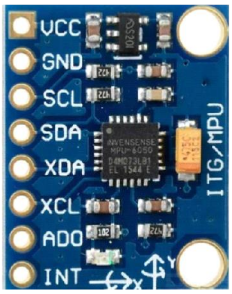


Figure 10. MPU6500-6 Axis

MPU6500 is a 6-axis MotionTracking device that combines a 3-axis gyroscope and a 3-axis accelerometer in a small package. It can be connected to a micro-controller such as the Arduino Mega to obtain measurements of rotational and linear motion, which can then be used in various applications such as robotics, gaming, and navigation systems. The gyroscope can detect angular velocity, while the accelerometer can detect linear acceleration, allowing for accurate measurement of the device's orientation and motion.

V. METHODOLOGY

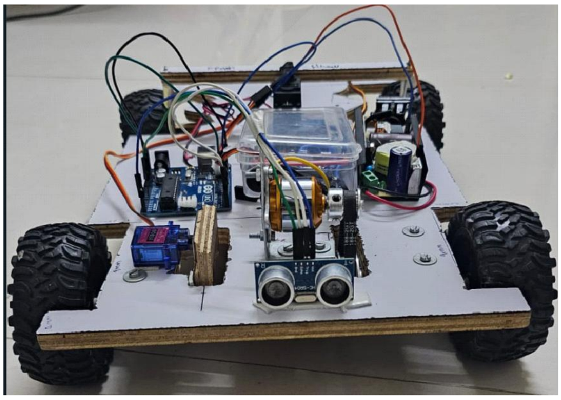
The system is a fully autonomous vehicle that uses various software and hardware components to navigate and avoid obstacles without human guidance. The vehicle is modeled on a 1/10 scale remote-controlled car and comprises an Arduino UNO board, an NVIDIA Jetson Nano board, a camera, an ultrasonic sensor, a gyroscope, an accelerometer, an Electronic Speed Controller (ESC), a BLDC motor, and a servo motor.

The camera and ultrasonic sensor are attached to the Arduino UNO board, which collects input images for the Convolutional Neural Network (CNN) running on the Jetson Nano. The CNN processes the images to detect obstacles and sends signals to the BLDC motor to stop the vehicle when necessary. The ultrasonic sensor located at the front of the vehicle helps to avoid collisions by stopping the vehicle before reaching a certain distance from an obstacle.

The MPU6500 – 6 Axis attached to the Arduino Mega board provides the vehicle's orientation data, which is used by the Jetson Nano to calculate the vehicle's position and orientation in real-time. The servo motor is used to control the steering mechanism of the vehicle, and the Electronic Speed Controller (ESC) is used to control the speed of the BLDC motor.

The Sony IMX219 camera connected to the Jetson Nano provides high-quality image data for real-time object detection, and PyTorch is used for running the CNN model on the Jetson Nano. The vehicle's software and hardware components work together to enable autonomous navigation and obstacle avoidance.

VI. RESULTS



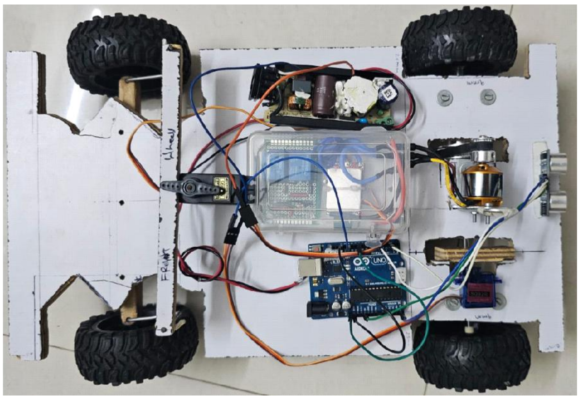


Figure 11. The car prototype for the Real-Time Object Detection implementation(Rear View)

Figure 12. The car prototype for the Real-Time Object Detection implementation(Top View)

The performance metrics of the autonomous navigation vehicle can vary depending on several factors such as the hardware configuration, the software used, and the type of tasks it is performing

1. Object Detection: The camera and ultrasonic sensor enable it to detect objects and navigate accordingly. The Convolutional Neural Network (CNN) running on the Jetson Nano can detect objects in real-time, allowing the vehicle to avoid obstacles in an efficient and effective manner.

2. Latency: The vehicle is designed to minimize latency and provide fast response times. This is achieved by optimizing the software and hardware components, such as the use of the Jetson Nano board and the ESC.

3. Power Efficiency: The vehicle is designed to be power-efficient, allowing it to run for long periods of time on a single battery charge

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