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Global Gesture-Controlled Car Using Arduino Nano BLE 33 Sense and MQTT Protocol

Abstract

This project explores the development of a Gesture-Controlled IoT Car, a significant advancement in remote interaction technology. The system leverages the capabilities of an Arduino Nano 33 BLE Sense [1] for gesture recognition and an Arduino Nano 33 IoT[2] for MQTT-based communication, with the two devices interconnected via I2C. The project's primary aim is to bridge geographical distances, allowing users to control a remote car from anywhere in the world using intuitive hand gestures.

This report provides a detailed account of the project's evolution, including its initial concept, design gap analysis, and the actual implementation. It discusses the hardware and software components used, the process of gesture recognition, and showcases the achieved milestones with relevant images and diagrams. Challenges encountered during development are addressed, and the influence of class readings and workshops on the project is reflected upon.

The project highlights the synergy between IoT and Machine Learning, with potential applications extending beyond remote control systems. It sets the stage for future research in gesture-based IoT applications, opening doors to new possibilities in human-machine interaction.

1 Introduction

In an era marked by the relentless pursuit of innovation and technology-driven solutions, this report presents the creation of a Gesture-Controlled IoT Car project. It explores the fusion of IoT and machine learning technologies to enable remote control of a car using hand gestures. The project's primary goal is to showcase the power of intuitive remote control, bridging geographical distances and redefining human-machine interaction. It also delves into the integration of MQTT for real-time communication and motor control logic to execute gesture commands.

2 Project Overview and Methodology

2.1 Objective

The primary objective of this project is to pioneer an intuitive, robust system facilitating the remote control of a vehicle through hand gestures. This endeavor aligns with the broader vision of enhancing human-machine interaction and revolutionizing remote operation capabilities. The system aims to offer a more natural and accessible method of controlling machines from a distance, moving beyond traditional remote controls or interfaces. Such advancements are not only technological milestones but also have significant implications for accessibility, efficiency, and safety in various fields.

2.2 Technological Components

This project integrates a diverse range of components to achieve gesture-controlled vehicle operation. The gesture recognition end employs two Arduino boards: the Nano 33 BLE Sense and the Nano 33 IoT, interconnected via the I2C protocol. The Nano 33 BLE Sense, with its advanced sensors, is responsible for gesture detection, while the Nano 33 IoT facilitates real-time communication using the MQTT protocol.

At the vehicle's end, the core control system is powered by the WeMos D1 R1 microcontroller[5], known for its robust performance and connectivity features. This microcontroller acts as the central processing unit, interpreting commands received from the gesture recognition system.

Driving the vehicle's motion are 2 L298N motor drivers [3], chosen for their efficiency in handling high current loads. These drivers control the 4 TT Motors/Gearbox Motors [4], which are responsible for the vehicle's movements. The TT Motors are selected for their reliability and power, ensuring responsive and precise maneuverability in accordance with the gesture commands.

Together, these components form a cohesive system. The Arduino boards at the gesture recognition end capture and process the gestures, while the WeMos D1 R1 microcontroller, along with the L298N motor drivers and TT Motors, translates these into the vehicle's controlled movements.

2.3 MQTT Integration

A vital component of this project is the integration of the MQTT (Message Queuing Telemetry Transport) protocol, which plays a crucial role in enabling real-time and reliable communication. The MQTT broker is hosted on an AWS EC2 instance, providing a robust and scalable platform for message handling. This setup ensures efficient management of the publish-subscribe messaging model intrinsic to MQTT.

The Nano 33 IoT, at the gesture recognition end, is configured to publish the recognized gesture data to this MQTT broker. Subsequently, the vehicle's control system, powered by the WeMos D1 R1 microcontroller, subscribes to the relevant MQTT topics to receive these gestures. By utilizing AWS for MQTT brokerage, the project benefits from enhanced stability and accessibility, ensuring that the gesture data is transmitted seamlessly from the sender to the receiver, irrespective of their geographical locations.

This MQTT integration is key to the project's success, as it provides a dependable conduit for the gesture commands to be communicated effectively to the vehicle's control system. It is instrumental in ensuring that the vehicle responds accurately and promptly to the hand gestures, thus providing an intuitive and smooth user experience.

2.4 Significance

The implications of this project extend significantly beyond its immediate use-case. It serves as a testament to the potential and versatility of gesture-based control systems, with applications that can span various domains. Particularly in environments where direct human intervention is impractical or perilous—such as handling robotic arms in hazardous areas or operating machinery in remote or disaster-stricken regions—the technology demonstrated in this project offers a promising gateway to innovative and safer solutions.

3 Methodology

3.1 System Design and Component Integration

The project's methodology encompasses a holistic system design, integrating both hardware and software components. Initially, the system was segmented into two primary units: the gesture recognition unit and the vehicle control unit.

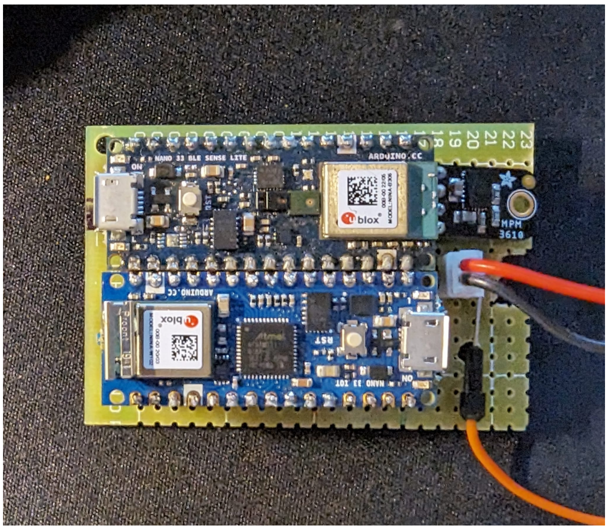


Figure 1: Gesture Recognition Unit

Gesture Recognition Unit: The gesture recognition unit involves setting up the Arduino Nano 33 BLE Sense to detect specific hand gestures. This setup required programming the board to capture and process sensor data, identifying gestures like forward, backward, left, right, and stop movements.

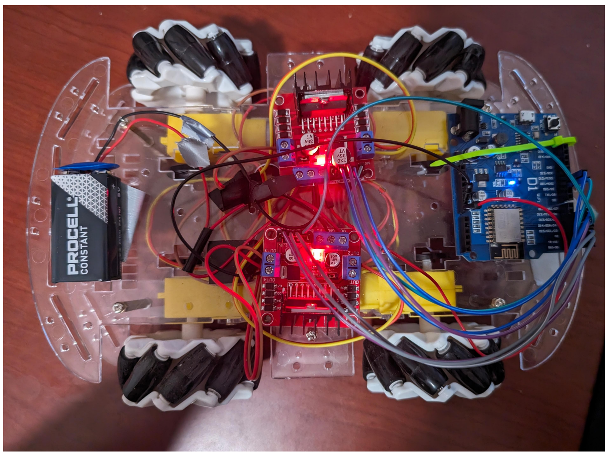


Figure 2: Vehicle Control Unit

Vehicle Control Unit: Concurrently, the vehicle control unit was assembled using the WeMos D1 R1 microcontroller as its core. This microcontroller was connected to 2 L298N motor drivers, which in turn were connected to 4 TT Motors/Gearbox Motors responsible for the vehicle's movements.

3.2 Implementation of MQTT for Communication

A critical step in the methodology was implementing the MQTT protocol for communication between the two units. An MQTT broker was configured on an AWS EC2 instance to manage the message queueing and delivery.

Publishing Gesture Data: Once the gesture recognition unit identifies a gesture, the Arduino Nano 33 IoT board publishes this data to the MQTT broker hosted on AWS EC2. This step involved setting up the Nano 33 IoT with the necessary network configurations to securely connect and communicate with the AWS-hosted MQTT broker.

Receiving and Processing Commands: On the vehicle control end, the WeMos D1 R1 microcontroller subscribes to the appropriate MQTT topics to receive gesture commands. This process involves programming the microcontroller to continuously listen for incoming MQTT messages and decode them into actionable commands for the motor drivers.

3.3 Execution of Vehicle Control Logic

Upon receiving gesture data, the WeMos D1 R1 microcontroller executes pre-defined control logic. This logic translates each gesture into specific motor movements, controlled via the L298N motor drivers, to maneuver the vehicle accordingly.

Testing and Calibration: The final phase involved rigorous testing and calibration to ensure the system's responsiveness and accuracy. This included real-time adjustments to the gesture recognition sensitivity and the motor control parameters, ensuring seamless integration and operation of the entire system.

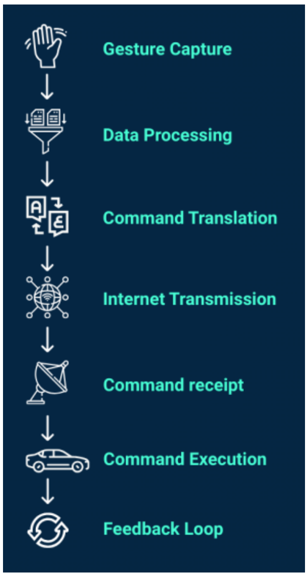
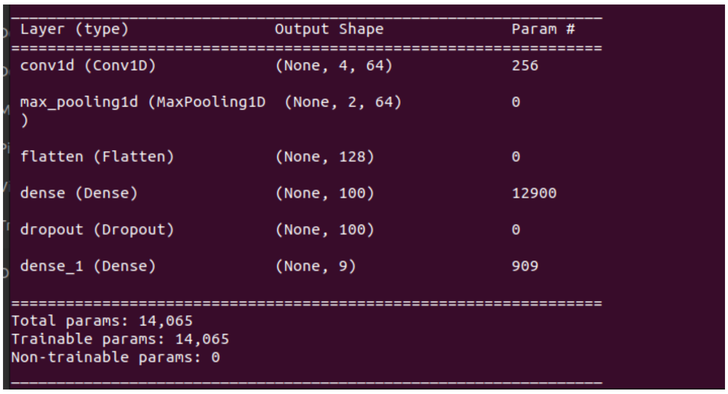


Figure 3: System Workflow and Methodology

4 Results

The implementation of the machine learning model on the Arduino Nano 33 BLE Sense yielded high performance, with training accuracy at 97.63



```
Layer (type)                 Output Shape              Param #
=================================================================
conv1d (Conv1D)              (None, 4, 64)             256

max_pooling1d (MaxPooling1D  (None, 2, 64)             0
)

flatten (Flatten)            (None, 128)               0

dense (Dense)                (None, 100)               12900

dropout (Dropout)            (None, 100)               0

dense_1 (Dense)              (None, 9)                 909

=================================================================
Total params: 14,065
Trainable params: 14,065
Non-trainable params: 0
```

Figure 4: Summary of the Convolutional Neural Network model used for gesture recognition.

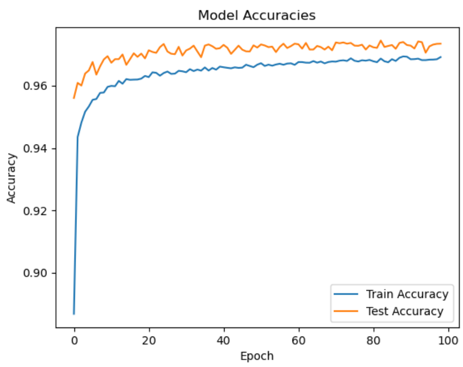


Figure 5: Training and test accuracy of the model over epochs.

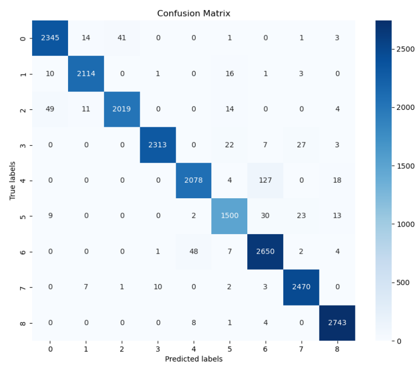


Figure 6: Confusion matrix demonstrating the model's classification performance across different gestures.

Field tests of the gesture-controlled car corroborate the model's efficacy, with the vehicle responding accurately to the recognized gestures. The car exhibits robust real-world performance, navigating smoothly and executing commands with precision. This practical success, indicative of the seamless integration of IoT and machine learning technologies, is captured in a video demonstration of the system in action.

Note: A supplementary video file demonstrates the responsive and precise maneuverability of the vehicle in a real-world setting, further validating the model's practical application.

5 Conclusion

The Global Gesture-Controlled Car project stands as a testament to the innovative integration of IoT with real-world applications. The course's focus on IoT principles and network communications has been pivotal in developing a system that responds to human gestures with high accuracy and reliability. The vehicle demonstrates excellent mobility, responding to commands with precision, which marks a notable achievement in IoT-enabled control systems.

While the course did not delve into machine learning, the project independently incorporated these techniques, demonstrating the interdisciplinary nature of technological innovation. Looking ahead, the plan is to refine the vehicle's autonomy further, exploring possibilities such as obstacle avoidance and path planning. The project's success has laid a promising groundwork for future research, with aspirations to delve deeper into intelligent AIoT systems and their vast potential applications.

References

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