Duck-Mobile (Team 18)

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ABSTRACT

Duck-Mobile is an innovative project that combines web technology with robotics to create a Wi-Fi-controlled remote car using the ESP8266 microcontroller. The car can be operated via a simple web interface, enabling users to send commands to move forward, backward, left, right, or stop. The project leverages the ESP8266 to host a local web server that processes HTTP requests. The car's movements are controlled by motor driver circuits connected to the ESP8266, which interprets the commands received from a web client. This setup allows for real-time control and responsiveness, making the user interface intuitive and efficient. The HTML interface provided by the web server features directional buttons styled with CSS to ensure a user-friendly experience. The layout employs flexbox to center and align the buttons, ensuring a clean and organized appearance. Each button press translates directly into motor actions, providing immediate feedback and control over the car's movements. Duck-Mobile serves as an excellent educational tool, demonstrating principles of embedded systems, web server programming, and wireless communication. It offers practical insights into how web technologies can be used to control physical devices, making it ideal for hobbyists, students, and those interested in IoT and robotics. This project exemplifies the fusion of software and hardware to create interactive and functional consumer electronics.

1 Introduction

In today's technologically advanced society, interactive and multifunctional devices have become integral to both entertainment and practical applications. However, there remains a significant gap in affordable, user-friendly robotics that can serve multiple purposes, from children's toys to household assistants. The challenge is to create a device that is not only engaging and fun but also practical and versatile enough to perform various tasks.

Developing a multifunctional robotic device addresses several important needs. Firstly, interactive toys that can engage children in both learning and play simultaneously are highly sought after. A device that entertains while teaching basic principles of robotics and programming can significantly benefit early childhood education. Secondly, the convenience in daily tasks is a crucial aspect. A small, agile robot that can transport items or assist in household chores can save time and effort, especially for individuals with mobility issues or busy schedules. Lastly, technological exploration is another key area. For enthusiasts and developers, a versatile robotic platform provides a rich field for experimentation, customization, and enhancement, fostering innovation and technical skills. By addressing these needs, the multifunctional robotic device can become an integral part of various aspects of everyday life, from education to practical assistance and technological development.

The Duck-Mobile is designed to bridge this gap by offering a versatile, engaging, and practical solution. It is an interactive toy, a handy item transporter, and an automated cleaning assistant all in one. By focusing on ease of use and multifunctionality, the Duck-Mobile aims to demonstrate the potential of affordable robotics in everyday life.

The Duck-Mobile can be controlled via a smartphone or tablet, allowing children to drive it around and perform tricks. Its whimsical duck design, complete with beak and webbed feet, makes it a delightful toy. By replacing the removable duck with a small basket, the Duck-Mobile can transport items such as snacks or remote controls around the house, controlled remotely via a web-based interface. With a broom or brush attachment, the Duck-Mobile can be used as a floor cleaning assistant, sweeping dust and debris as it navigates the room.

1.1 Objectives

The primary objective is to create a user-friendly, multifunctional robotic device that can cater to various needs. Firstly, it aims to entertain and educate children through interactive play, combining fun with fundamental lessons in robotics and programming. Secondly, it is designed to perform practical tasks such as item transportation, offering convenience and efficiency, particularly useful for individuals with mobility challenges or busy schedules. Lastly, the device will assist in household chores by functioning as an automated cleaner, helping maintain a tidy environment with minimal effort. By achieving these objectives, the robotic device will be a versatile tool that enhances both daily life and learning experiences.

By achieving these objectives, the Duck-Mobile will serve as a proof of concept for the broader application of affordable robotics in everyday life, demonstrating how a single device can seamlessly integrate into various aspects of daily living.
This project not only aims to deliver a multifunctional robotic device but also seeks to inspire future developments in interactive systems, broadening the scope of what is possible in the realm of affordable robotics.

2 Related Work

The development of WiFi-controlled RC cars has gained popularity among hobbyists and makers in recent years. Our duck-themed RC car project draws inspiration from several existing implementations while adapting them to our specific needs.

The DIY WiFi RC Car project using ESP8266 and Arduino IDE [1] demonstrates the fundamental concept of using WiFi for remote control. This project utilizes the ESP8266 module, which is similar to the WiFi module in our Arduino D1 Mini Lite. The use of Arduino IDE for programming is a common thread between this project and ours, highlighting the accessibility of these tools for hobbyist projects.

Another significant influence comes from the WiFi-controlled car using NodeMCU and Blynk app [2]. While our project opts for a locally hosted website instead of a mobile app, the core idea of using WiFi for communication remains the same. This project's step-by-step instructions provided valuable insights into the overall structure of a WiFi-controlled vehicle system.

An interesting, albeit more complex, implementation is the Pi-powered 1:35 scale Panther tank [3]. Although our project is simpler in scale and functionality, this tank project showcases the potential for adding more advanced features to RC vehicles, such as camera integration or more precise motor control.

In summary, our duck-themed RC car project utilizes the WiFi control concept from these related works, implementing it through a locally hosted website. We've adopted the use of a motor driver (L298N) to control four motors, enabling forward, backward, left, right movements, and stopping. The project combines elements from various sources, adapting them to create a unique, themed RC car controlled via a web interface.

3 Use Cases

Use Case 1: C[illegible] E[illegible] [illegible] T[illegible]
Scenario: The Duck-Mobile as a playful, interactive toy for children.

1. User places the Duck-Mobile on the ground.
2. User powers on the vehicle.
 2.1: A LED light will indicate the powered-on status.
 2.2: Create a Personal Hotspot with the name “Xe” and password “xenon99999”
3. User opens the controls for the car on the locally hosted webpabe
 3.1: The app displays controls for moving the Duck-Mobile forward, backward, left, and right.
 3.2: The app also provides access to other functionalities, such as stopping the vehicle.
4. User can drive the Duck-Mobile around, using the app to control its movements.
 4.2: The car can perform fun tricks like spinning keeping kids entertained and engaged.
6. Children can experiment with different tricks and movements.
 6.1: Kids can try out different combinations of controls to see how the Duck-Mobile reacts.
 6.2: The car's whimsical design, including a beak and webbed feet, adds to the fun.

Use Case 2: S[illegible] T[illegible]
Scenario: The Duck-Mobile as a handy tool for transporting small items around the house or office if you are feeling lazy.

1. User places the Duck-Mobile on the ground, replacing the removable duck with a small basket attached.
2. User powers on the vehicle.
 2.1: A LED light will indicate the powered-on status.
 2.2: Create a Personal Hotspot with the name “Xe” and password “xenon99999”
3. User places items, such as snacks or remote controls, into the basket.
4. User opens the control app on a smartphone or tablet.
 4.1: The app displays controls for moving the Duck-Mobile forward, backward, left, right and stop.
5. User directs the Duck-Mobile to the desired location.
6. The Duck-Mobile reaches the destination and the items are delivered.

Use Case 3: F[illegible] C[illegible] A[illegible]
Scenario: The Duck-Mobile as an innovative floor cleaning assistant.

1. User attaches a small broom or brush to the base of the Duck-Mobile.
2. User powers on the vehicle.
 2.1: A LED light will indicate the powered-on status.
 2.2: Create a Personal Hotspot with the name “Xe” and password “xenon99999”
3. User opens the control app on a smartphone or tablet.
 3.1: The app displays controls for moving the Duck-Mobile forward, backward, left, right and stop.
4. User starts a cleaning session by moving the car around.
5. The cleaning attachment can be easily maintained, changed or removed by the user.
 5.1: The broom or brush can be detached and cleaned after each session.

5.2: Parts can be replaced as needed.

4 Implementation

The Duck-Mobile project combines hardware, firmware, and user interface design to create an engaging and educational RC car. This implementation section details the key aspects of the project, from its whimsical duck-themed design to the technical considerations that power its functionality. The following subsections explore the design choices, technical challenges, hardware configuration, firmware development, and usage guidelines that bring this unique educational toy to life. Each component plays a crucial role in creating a device that's not only fun to use but also serves as an accessible introduction to robotics for children.

4.1 Design

The RC car was conceptualized as an educational toy for children, which inspired its playful duck theme. The bright yellow color scheme and duck-like appearance were chosen to make the device visually appealing and toy-like, catering to its young target audience.

One of the main design challenges was adapting the duck form to a functional RC car. While a realistic duck would have legs, this project cleverly incorporates wheels instead. This whimsical fusion of a duck body with car wheels creates a humorous and charming aesthetic, reminiscent of iconic vehicles like the Batmobile but with a child-friendly twist.

To achieve the distinctive duck appearance, a rubber ducky toy was incorporated into the design. This creative solution not only ensures the car is instantly recognizable as a duck but also adds a tactile, familiar element that children can relate to.

During the development process, an unexpected issue arose where one set of wheels would occasionally stop working, despite proper connections. This might be due to a faulty motor driver and represents an area for future improvement or troubleshooting.

Overall, the design successfully marries form and function, creating a unique, eye-catching RC car that serves its purpose as both an entertaining and educational toy for children.

4.2 Technical Considerations

Motor Control: A significant technical decision was whether to use one or two motor drivers. While two motor drivers would have offered more precise control and improved movement, the project ultimately opted for a single motor driver. This choice was made to prioritize simplicity and compactness, which are crucial factors in a toy designed for children.

Wireless Control: The decision to use WiFi for remote control was straightforward, leveraging the built-in capabilities of the D1 Mini Lite microcontroller. While Bluetooth could have potentially offered lower latency, it would have required an additional module, increasing complexity and cost. The WiFi solution provides a good balance of functionality and simplicity.

Power Management: An exposed AAA battery holder was implemented for power management, allowing for easy battery replacement. This design choice supports sustainability, as it enables the use of rechargeable batteries, eliminating electronic waste. The ability to quickly swap batteries also ensures continuous play without long downtimes for recharging.

Safety Considerations: Given that the target users are children, several safety measures were implemented:

1. All electronics were enclosed within an additional chassis layer, composed of cardboard and repurposed tin sheet from cans.
2. To mitigate the risk posed by sharp edges of the tin sheet, duct tape was used as a protective covering.
3. The final product has no exposed sharp edges or points, making it safe for children to handle.

These technical considerations reflect a balance between functionality, safety, and environmental responsibility, aligning with the project's goal of creating an educational and entertaining toy for children.

4.3 Hardware

The RC car's hardware configuration consists of the following main components:

1. Arduino D1 Mini Lite microcontroller
2. Four motors attached to wheels
3. L298N motor driver
4. Breadboard
5. Battery pack with four AAA batteries

Component Layout and Connections: The hardware layout is designed for efficient control and power distribution. The L298N motor driver serves as the central hub for motor control, with its outputs connected to the wheels in the following arrangement:

- Two outputs connected to the left side wheels
- Two outputs connected to the right side wheels

The motor driver is interfaced with the D1 Mini Lite microcontroller as follows:

- IN1 connected to D1
- IN2 connected to D2
- IN3 connected to D3
- IN4 connected to D4

Both the motor driver and the Arduino are powered by the same 5V battery pack, ensuring a unified power supply for the entire system.

Challenges and Troubleshooting: A persistent challenge encountered during the hardware implementation was intermittent functionality in one set of wheels. Specifically, the affected set would operate in one direction (e.g., forward) but fail to move in the opposite direction (e.g., backward). Despite thorough checks of physical connections and code verification, this issue recurred sporadically.

After extensive troubleshooting, including ensuring tight connections and validating the code, the problem persisted. This led to the hypothesis that the motor driver itself might be faulty. This issue highlights the importance of component quality and the potential need for redundancy or fault-tolerance in future iterations of the project.

This hardware configuration, while presenting some challenges, provides a functional foundation for the RC car, balancing simplicity with the necessary capabilities for an educational toy.

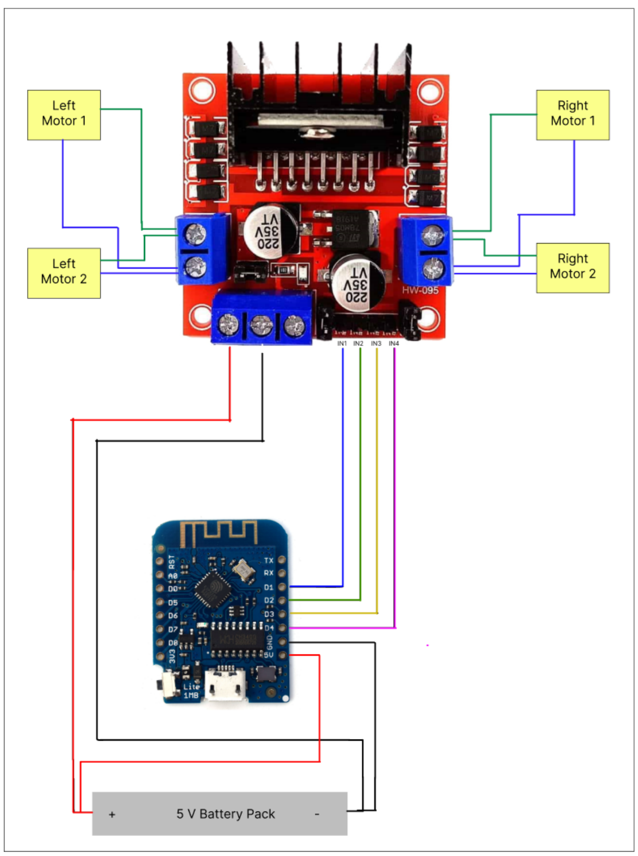

Figure 1: Hardware Arrangement

4.4 Firmware

The firmware for the Duck-Mobile RC car is designed to handle WiFi connectivity, remote control, and motor management. Here are the key aspects of the firmware implementation:

WiFi Connectivity and Remote Control: The project leverages the built-in WiFi capabilities of the D1 Mini Lite microcontroller to create a locally hosted remote control interface. This approach offers several advantages:

1. Ease of Implementation: The inbuilt WiFi module simplifies the connectivity setup.
2. Universal Access: Users can control the car from any device with a web browser, without needing to install a specific app.
3. Customizable Interface: The HTML-based control panel can be easily modified or styled to enhance user experience.

However, this method does introduce some latency, with a noticeable delay (around one second) between user input and the car's response. This latency is a trade-off for the simplicity and accessibility of the WiFi-based solution.

Motor Control Algorithm: The firmware employs a straightforward but effective algorithm for motor control. Each movement direction (forward, backward, left, right) is achieved by setting specific combinations of HIGH and LOW signals to the motor driver inputs.

Code Excerpt:

```
void moveForward() {
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, HIGH);
  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
}

void moveBackward() {
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, HIGH);
}

void turnLeft() {
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, HIGH);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, HIGH);
}

void turnRight() {
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
}

void stopCar() {
  digitalWrite(IN1, LOW);
```

```
    digitalWrite(IN2, LOW);
    digitalWrite(IN3, LOW);
    digitalWrite(IN4, LOW);
  }
```

This approach allows for precise control over the car's movements, enabling it to move forward, backward, turn left or right, and stop on command.

The firmware successfully integrates WiFi connectivity with motor control, creating a functional and accessible remote-controlled car. While there's room for optimization in terms of latency, the current implementation provides a solid foundation for the educational toy.

4.5 Usage

The Duck-Mobile RC car offers a unique and interactive user experience. Here's how users can operate and enjoy this educational toy:

Connecting to the Duck-Mobile:

1. Users must first create a personal WiFi hotspot with the following credentials:
   - SSID: "Xe"
   - Password: "xenon99999"
2. Once the hotspot is active, the Duck-Mobile will automatically connect to it.
3. Users need to enter the IP address of the D1 Mini Lite in their web browser to access the control interface. This IP address is displayed in the serial monitor when the Duck-Mobile connects to the WiFi network.

Control Interface: The locally hosted web interface provides intuitive controls for the Duck-Mobile. Users can issue commands through this interface to move the car in various directions.

Operation:

- The Duck-Mobile responds to one command at a time. For example, it can move forward, backward, left, or right, but cannot combine these movements simultaneously.
- While it can't move forward and turn at the same time, users can still achieve drifting effects by alternating between left and right controls.

Optimal Operating Environment: While the Duck-Mobile is designed to be versatile, it performs best on flat surfaces. However, thanks to its robust, large tires, it can also navigate rougher terrain, adding to its play value and educational potential.

Limitations and Precautions:

- Users should be aware that there's a slight latency between issuing a command and the car's response, typically around one second.
- The car's range is limited by the WiFi signal strength, so it's best operated within a reasonable distance from the controlling device.
- As with any electronic toy, users should avoid exposing the Duck-Mobile to water or extreme temperatures.

By following these guidelines, users can fully enjoy the Duck-Mobile's capabilities as both an entertaining RC car and an educational tool for introducing basic robotics concepts.

5 Pseudo-Evaluation and Results

The primary objectives of our evaluation for the Duck-Mobile project are to comprehensively assess its performance across key criteria. Our goal is to gauge how well Duck-Mobile meets user expectations and performs in real-world scenarios. By analyzing these aspects, we aim to identify strengths and potential areas for improvement, ensuring that Duck-Mobile delivers a seamless and satisfying user experience.

5.1 Study Design

In Milestone 2, we defined the key criteria for evaluating the Duck-Mobile project based on its intuitiveness and responsiveness. Functionality, appearance, and user interface were later added for a more comprehensive evaluation. These criteria were chosen to ensure a thorough assessment of the user experience and technical performance of the project.

Ratings for Each Criterion

We employed a rating scale of 1 to 5, where 1 indicates poor performance and 5 indicates excellent performance, to evaluate each criterion:

1. **Functionality**: Assessing the extent to which the Duck-Mobile meets functional requirements and performs expected tasks reliably.
2. **Intuitiveness**: Evaluating how easy and intuitive it is for users to navigate and use the Duck-Mobile.
3. **Responsiveness**: Measuring the speed and responsiveness of the application in processing user actions and providing feedback.
4. **Appearance**: Evaluating the physical design and aesthetic appeal of the Duck-Mobile.
5. **User Interface**: Assessing the overall usability of the interface, including layout, design consistency, and accessibility.

5.2 Results

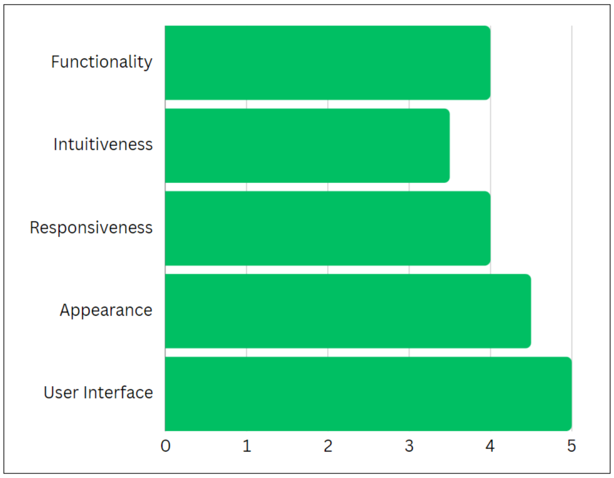

Figure 2: Study Evaluation Feedback

The chart above shows the average ratings received for these criteria from the 4 users who tested the Duck-Mobile. The project received generally high ratings across all evaluated criteria, indicating strong performance in functionality, appearance, and user interface design. The project received an overall positive response with an average total rating of 4.2 out of 5.

6 Conclusion

Duck-Mobile is a whimsical, wireless wonder that's part toy, part tiny transporter, and part tidy-upper. This little robot car introduces kids to robotics while doubling as a pint-sized delivery duck and a floor-cleaning friend. With its user-friendly interface, even the most tech-shy can send this feathered automaton waddling across rooms, ferrying small items, or sweeping up crumbs. The Duck-Bot's charm lies in its versatility – it's an educational toy that doesn't forget to be useful or fun. It proves that with a bit of creativity, even simple robotics can solve everyday problems and spark young imaginations.

ACKNOWLEDGMENTS

The Duck-Mobile project was primarily developed by myself, with minimal contributions from my team members. Initially, the project was intended to be a collaborative effort among three team members, including Sebastian Dewes and Rihanna Ikram Khalil. However, the actual development, coding, assembly, and documentation were solely handled by me.

Sebastian Dewes and Rihanna Ikram Khalil were involved in the initial phase, primarily in procuring the necessary components from the university. Sebastian provided me with the components but informed me that he might not be able to participate further because he couldn't register for the exam. Although I was offered the previous year's project by Sebastian, I chose not to use it because it had steering issues and used different parts.

Despite my efforts to engage and coordinate with my team, there was no response to my communications. Due to time constraints and the inability to switch teams, I proceeded independently with the Duck-Mobile project. As a result, I completed all key tasks and milestones, including planning, hardware assembly, software development, testing, and documentation.

The tasks I handled included:

Hardware Assembly: I assembled the Duck-Mobile hardware, ensuring correct installation and functionality of all components.
Software Development: I developed all the code, including control logic, Wi-Fi communication, and the web interface, utilizing the D1 Mini Lite microcontroller.

Testing: I conducted extensive testing to ensure that all components and the software were working as expected.

Documentation: I wrote detailed project reports, user guides, and technical documentation, covering all aspects of the project.

Final Troubleshooting: I debugged the code and refined hardware connections to resolve any issues, ensuring the Duck-Mobile operated reliably.

REFERENCES

[1] DIY WIFI RC Car With ESP8266 and Arduino IDE from https://www.instructables.com/DIY-WIFI-RC-Car-With-ESP8266-and-Arduino-IDE/

[2] How to make a WIFI controlled car using Nodemcu and Blynk app from https://srituhobby.com/how-to-make-a-wifi-controlled-car-using-nodemcu-and-blynk-app-step-by-step-instructions/

[3] Tom Nardi. 2007. Pi powered 1:35 scale panther tank. Retrieved July 10, 2023 from https://hackaday.com/2022/01/09/powering-up-a-135-scale-panther-tank/.