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Gesturon: Gesture-controlled robot

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Abstract

The Gesturon project focuses on developing a gesture-controlled robotic vehicle powered by the PIC16F877A microcontroller. The system integrates two control modes: Bluetooth-based manual operation and gesture-based autonomous control, utilizing an accelerometer sensor. This report provides an in-depth analysis of the design, implementation, challenges, and successes, showcasing Gesturon's potential to revolutionize assistive mobility and enhance independence for users with physical disabilities. Testing confirmed reliable operation and intuitive user control, demonstrating the potential of this system to enhance independence and safety. Gesturon's implications extend to healthcare, industrial automation, and personal mobility, offering a significant step forward in assistive robotics.

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1 INTRODUCTION

The integration of robotics with assistive technology has opened new possibilities for enhancing mobility and independence for individuals with physical disabilities. Traditional mobility aids, such as wheelchairs, often lack the adaptability or intuitive controls needed for users with limited physical capabilities. Gesturon, a gesture-controlled robotic vehicle, addresses this gap by offering a hands-free, gesture-based control system that is both user-friendly and efficient.

Gesturon is designed to provide seamless operation using an accelerometer-equipped glove to detect hand gestures, enabling intuitive movement control. Powered by the versatile PIC16F877A microcontroller, the system also includes ultrasonic sensors for obstacle detection and a Bluetooth module for alternative manual control via smartphone. With two operational modes—gesture-based control for autonomous navigation and Bluetooth-based control for manual operation—Gesturon combines innovation with practicality.

1.1 THEORY

The foundation of the Gesturon project lies in the convergence of robotics, gesture recognition, and assistive technologies. Robotics has emerged as a transformative force in assistive technology, enabling innovative solutions for individuals with physical disabilities. By integrating advanced sensors, controllers, and actuators, robotics systems can bridge the gap between user intent and mobility. Assistive robotic vehicles, such as wheelchairs or autonomous navigation systems, often leverage user input through traditional interfaces like joysticks or buttons. However, these systems may not be practical for users with severe motor impairments, necessitating alternative control mechanisms like gesture recognition.

Gesture recognition is a method of interpreting human motions, particularly hand movements, into actionable commands for machines. This technology has gained traction in various fields, including gaming, virtual reality, and assistive robotics, due to its ability to provide intuitive and natural interaction.

In Gesturon, gesture recognition is achieved through an accelerometer sensor embedded in a glove. The accelerometer detects variations in hand orientation and movement, converting these signals into data that the microcontroller processes to determine the corresponding robotic actions. This approach ensures a hands-free and intuitive control mechanism, enhancing accessibility for users with physical disabilities.

1.2 OBJECTIVE

1. **Gesture-Based Autonomous Navigation:** Develop algorithms and control strategies to enable the robotic vehicle to navigate autonomously using hand gestures, with precise detection of accelerometer signals for smooth and intuitive operation.
2. **Obstacle Detection and Avoidance:** Implement ultrasonic sensors to detect obstacles in real-time and ensure safe navigation, preventing collisions and enhancing user safety.
3. **Dual-Control Integration:** Design and implement two operational modes:
    - **Gesture-Based Autonomous Control:** Utilizing an accelerometer-equipped glove for intuitive navigation.
    - **Bluetooth-Based Manual Control:** Enabling users to operate the vehicle via a smartphone for enhanced flexibility and control.
4. **Seamless Hardware Integration:** Ensure the robust integration of the PIC16F877A microcontroller, accelerometer, Bluetooth module, ultrasonic sensors, and actuators to create an efficient and reliable robotic system.
5. **Assistive Mobility Focus:** Provide a practical solution for individuals with physical disabilities by offering an assistive robotic vehicle that enhances independence and mobility.
6. **Versatility and Scalability:** Showcase the system's potential applications beyond personal mobility, including industrial automation, healthcare, and other assistive technology domains.

2 DESIGN

2.1 HARDWARE DESIGN

The hardware design of **Gesturon** integrates multiple components to enable smooth and efficient operation, focusing on gesture-based and manual control modes:

1. **Microcontroller (PIC16F877A):** Acts as the core controller, managing signals from sensors, actuators, and Bluetooth communication. Processes accelerometer data to control the robotic vehicle's movements and handles obstacle detection and feedback mechanisms.
2. **DC Motors and Two-Wheel System:** Powered by two 3.7V lithium-ion batteries, the DC motors drive the two-wheel system for navigation. Controlled via an H-bridge circuit, allowing PWM-based speed adjustments.
3. **Accelerometer (GY-61 DXL335):** Captures hand gestures by measuring acceleration along X and Y axes. Sends analog signals to the microcontroller to determine movement directions.
4. **Bluetooth Module (HC-06):** Facilitates wireless communication in serial mode, allowing the user to send commands such as "F" (Forward) and "R" (Right) from a smartphone.
5. **Ultrasonic Sensor:** Detects obstacles within 40 cm and lights up LEDs as a warning. Activates the glove's vibration motor for objects closer than 10 cm to alert the user.
6. **Infrared Sensor and Servo Motor:** The IR sensor triggers the servo motor to adjust the compartment angle between 0° and 90° for hands-free tasks.
7. **Power Supply:** Two 3.7V lithium-ion batteries provide stable power to all components.
8. **Switches:** Includes an on/off button and a reset switch for easy system control and reinitialization.

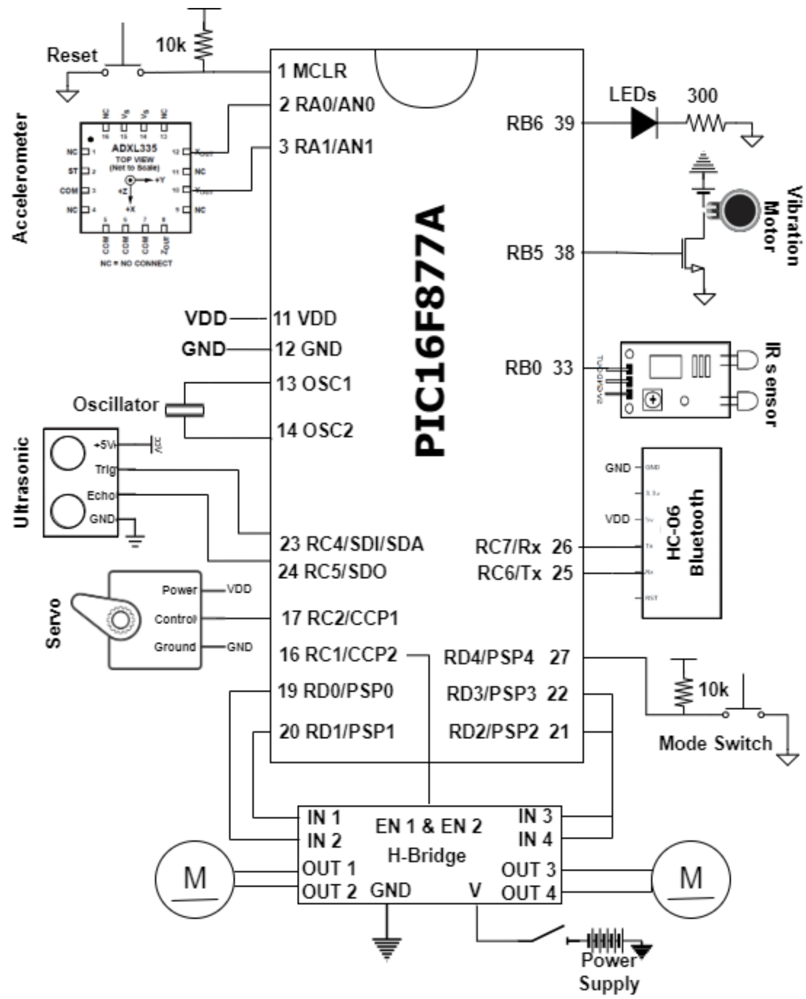

Figure 1 Gesturon's block diagram.

2.2 SOFTWARE DESIGN

The software design for **Gesturon** is centered on responsive and efficient control of its hardware components. A key feature is the implementation of PWM (Pulse Width Modulation) based on accelerometer input to control the speed of the DC motors. The accelerometer captures hand gestures by measuring acceleration along the X and Y axes, and these values are processed to adjust the PWM duty cycle dynamically, enabling smooth and precise motor speed adjustments. This ensures that movements such as forward, backward, left, and right are proportional to the intensity of the gestures, providing intuitive and user-friendly navigation. Additionally, the software integrates dual control modes—gesture-based and Bluetooth-based manual control—allowing users to seamlessly switch between autonomous and manual operation. Real-time responses are achieved through interrupt-based control for processing gestures, commands, and sensor data. The ultrasonic sensor enhances safety by triggering LEDs for obstacles within 40 cm and activating the glove's vibration motor for objects closer than 10 cm. Combined with servo motor control for compartment adjustments, initialization routines, and fail-safe mechanisms, the software ensures robust and adaptive operation of the robotic vehicle.

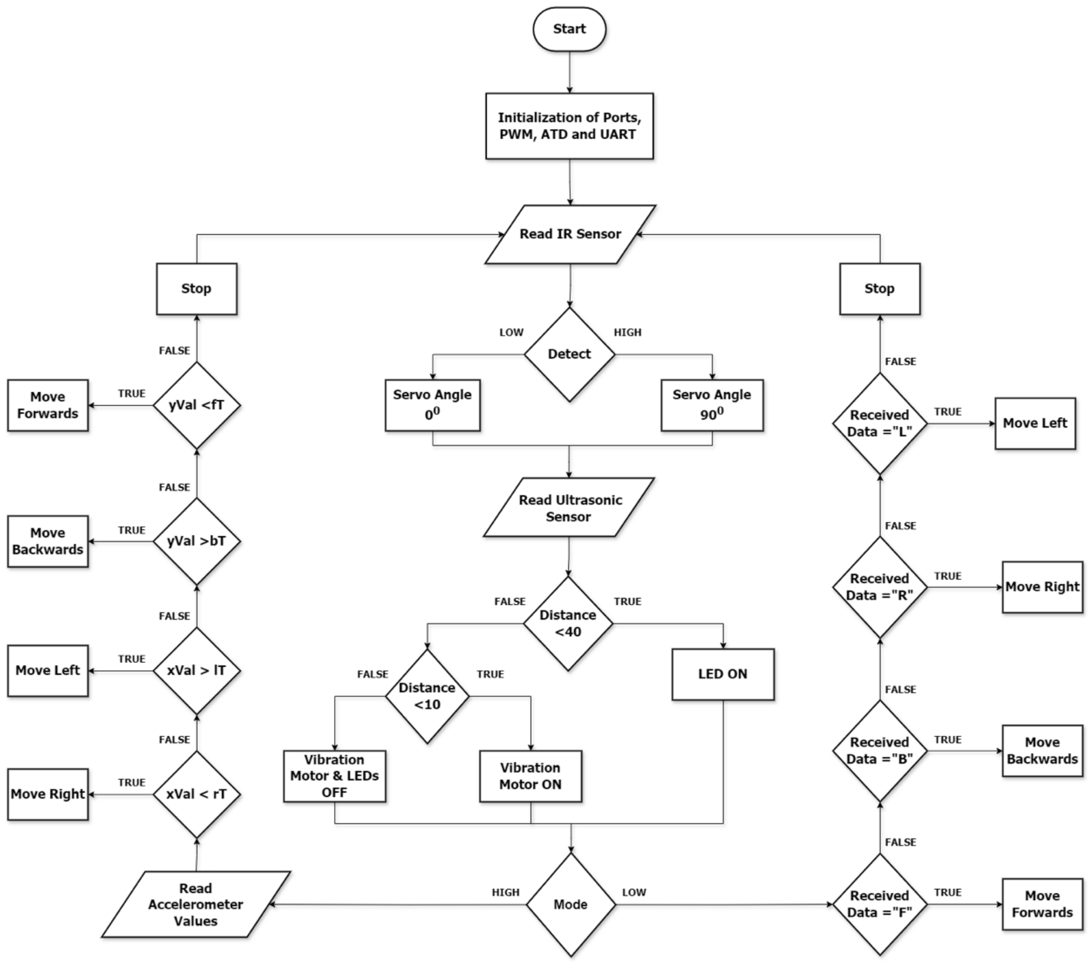

Figure 2 Gesturon's flow diagram.

3 RESULTS

Our **Gesturon** project delivered impressive results! We tested it in two modes: gesture-based autonomous control and Bluetooth-based manual control. In gesture mode, the accelerometer worked seamlessly, allowing smooth and proportional control of the robot's movements based on hand gestures, while the ultrasonic sensor effectively detected obstacles and provided feedback through LEDs and the glove's vibration motor. In Bluetooth mode, commands like "F" for forward or "R" for right were executed instantly, making manual control highly responsive. Gesturon's ability to navigate, avoid obstacles, and adapt to tasks like adjusting its compartment angle makes it a reliable and versatile solution for assistive mobility, and we're excited about its potential for future applications!

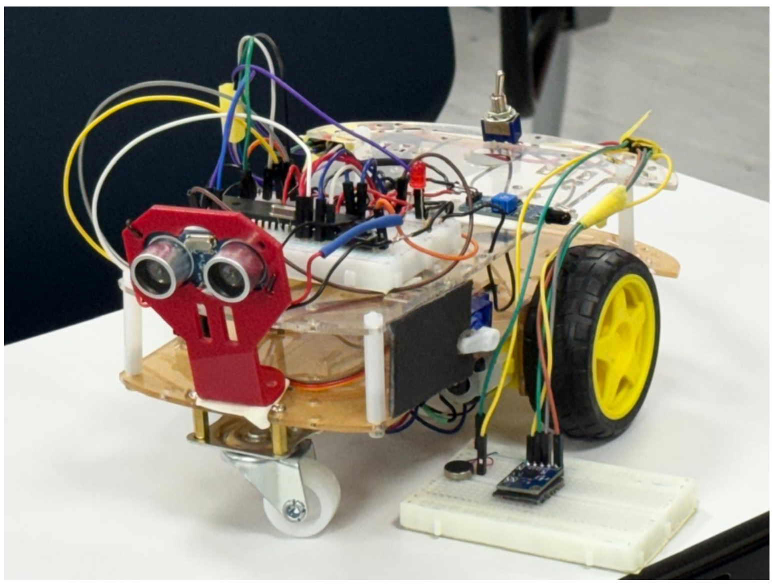

Figure 3Gesturon's Final Design

Youtube Video link: https://youtube.com/shorts/Dkxwo1M2TDk?feature=share

Github link: https://github.com/QabasAK/Gesturon

4 PROBLEMS AND RECOMMENDATIONS

1. **Bluetooth-to-Bluetooth Communication:**

   - **Issue:** Implementing Bluetooth-to-Bluetooth communication proved challenging due to the short timeframe, requiring a shift to dual-mode control with gesture-based and Bluetooth-based manual modes.
   - **Recommendation:** Utilize advanced Bluetooth modules or alternative communication protocols like Wi-Fi to simplify implementation and enhance reliability.

2. **Servo Motor and Ultrasonic Sensor Conflicts:**

   - **Issue:** Both components wrote to the same register, causing operational conflicts and malfunctions.
   - **Recommendation:** Use flags or a scheduling mechanism to ensure that only one component operates at a time, preventing register overwriting.

3. **Accelerometer Threshold Tuning:**

   - **Issue:** Tuning the accelerometer thresholds was complex, and performance was inconsistent when switching from a 12V power supply to two 3.7V lithium-ion batteries.
   - **Recommendation:** Implement an adaptive threshold calibration algorithm to dynamically adjust performance based on the power source.

4. **Mode Switching Continuity Issues:**

   - **Issue:** Switching between gesture-based and Bluetooth-based modes sometimes retained motion from the previous mode, leading to unintended behavior.
   - **Recommendation:** Stop the motors during mode toggling to ensure a safe and controlled transition between operational modes.

5. **Battery Life Limitations:**

   - **Issue:** The 3.7V lithium-ion batteries had limited operational duration, requiring frequent recharging.
   - **Recommendation:** Upgrade to higher-capacity batteries or integrate a DC-DC converter to stabilize voltage and improve power efficiency.

5 CONCLUSION

The **Gesturon** project showcases the relevance and potential of assistive robotics in enhancing mobility and independence for individuals with physical disabilities. Its gesture-based control, Bluetooth integration, and real-time obstacle detection underline its importance as a practical and intuitive solution. Future work could focus on improving gesture recognition with machine learning, optimizing power management, and expanding sensor capabilities to adapt to diverse environments. These enhancements would increase scalability and open new applications in healthcare, industrial automation, and smart mobility, cementing **Gesturon's** role as a versatile and impactful innovation.

6 REFERENCES

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