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Arduino-Based Humanoid Robot

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Abstract: *This project presents a simplified humanoid robot designed for basic speech and movement functionalities. The robot is programmed to speak only pre-inputted phrases and performs limited motions, including moving left, right, forward, and backward, as well as controlled head, arm, and whole-hand movements. The system relies on pre-defined voice modules and servo motor mechanisms to execute these actions, ensuring precise yet restricted operation. Unlike advanced AI-driven humanoids, this model operates within a closed-loop framework, making it suitable for applications requiring predictable behaviour, such as educational demonstrations, customer service roles, or interactive exhibits. Key advantages include ease of programming, low computational requirements, and reliable performance. However, its lack of autonomous decision-making and natural language processing limits adaptability. Future enhancements could integrate sensor-based feedback for improved responsiveness while retaining simplicity.*

Keywords: BLDC Motor, OLED, Humanoid, ESP32, HC-SR04, HC-05

I. INTRODUCTION

In recent years, the development of humanoid robots has gained significant attention due to their ability to replicate human-like actions and interactions. These robots are not only fascinating but also serve practical purposes in areas such as education, healthcare, customer service, and personal assistance. A humanoid robot is designed to resemble the human body in structure and movement, incorporating limbs, sensors, and intelligent control to perform tasks autonomously or semi-autonomously. This paper focuses on designing and constructing a cost-effective, Arduino-based humanoid robot that utilizes multiple servo motors for limb movement, BLDC motors for locomotion, and various sensors and output devices for interaction with its environment. The robot uses an Arduino Uno microcontroller as the brain of the system, which processes inputs from an ultrasonic sensor for obstacle detection, and receives commands via the HC-05 Bluetooth module for wireless control. The system also integrates an OLED display for visual feedback, a sound module for audio alerts or responses, and LED lighting to enhance its expressive capabilities. The combination of six servo motors allows for realistic limb articulation, while the BLDC motors, managed by an L298N motor driver, provide stable and controlled movement across surfaces.

This humanoid robot not only demonstrates the synergy between electronics and mechanical systems but also encourages hands-on learning in embedded systems, programming, and robotics. The modular and scalable nature of the design means that additional features like voice recognition, camera vision, or AI-based decision-making can be integrated in future iterations.

By leveraging the open-source Arduino platform and affordable electronic components, this robot offers an accessible pathway for students, enthusiasts, and researchers to explore robotics and automation. The overall objective is to build a functional humanoid that is interactive, responsive, and capable of mimicking basic human actions—paving the way for more complex robotic systems.

II. LITERATURE SURVEY

S. Kumar et al., "Design and Implementation of Arduino-based Humanoid Robot," (2018) – This paper detailed a prototype humanoid robot controlled by Arduino with servo motor-based limb movement and ultrasonic sensors for

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navigation. The study highlighted Arduino's suitability for hobbyist and research-oriented robot development due to its low cost and community support.

R. Singh and A. R. Patel, "A Low-Cost Arduino Humanoid Robot for Educational Purpose," IJERT (2020) – This research focused on creating an affordable humanoid platform for school- level education, integrating Bluetooth control and visual feedback via LEDs. Their emphasis was on real-time interaction and ease of programming.

T. Gupta et al., "Voice-Controlled Humanoid Robot Using Arduino," IEEE (2019) – The study showed a voice-command-enabled robot utilizing Arduino Uno and Bluetooth communication for hands-free control. Their findings demonstrated high user engagement and potential for assistive technology use.

Arduino Official Documentation – Extensive documentation and tutorials on servo control, Bluetooth modules (HC-05), motor drivers (L298N), and OLED display interfacing provided practical insights and guided implementation phases of the current project.

III. PROPOSED SYSTEM

The proposed system is a low-cost, Arduino-controlled humanoid robot capable of performing basic human-like actions such as walking, turning, and interacting with its environment. It aims to bridge the gap between high-end commercial humanoid robots and accessible educational platforms by using open-source hardware and affordable components. This system incorporates multiple types of actuators, sensors, and communication modules to simulate human motion and interaction. The control unit, an Arduino Uno, acts as the brain of the robot—processing sensor inputs and executing motor control commands accordingly.

Key Features of the Proposed System:

- **Motion and Locomotion:** Five Servo Motors are used to control the limbs and simulate movements such as arm waving, joint bending, or head turning. Two BLDC Motors, connected through an L298N Motor Driver, enable the robot to move across surfaces.
- **Environmental Interaction:** An Ultrasonic Sensor (HC-SR04 Pin out) helps the robot detect obstacles and avoid collisions by measuring distance from nearby objects.
- **Wireless Communication:** The HC-05 Bluetooth Module allows the user to remotely control the robot using a smartphone or computer, enhancing flexibility and ease of operation.
- **Feedback and Display:** A compact OLED Display provides visual feedback such as sensor data, movement status, or communication responses. LED Light acts as an indicator or status notifier. A Sound Module provides basic audio alerts or feedback.
- **Power Management:** The entire system is powered by a rechargeable battery pack, ensuring portability and autonomous operation. Proper voltage regulation ensures that sensitive components like servos and the microcontroller receive consistent power.
- **Software Implementation:** The robot is programmed using the Arduino IDE with C/C++-based code. Bluetooth commands are parsed and mapped to actions like move forward, turn, stop, light LED, etc. Sensor values are continuously monitored, and motion routines are adjusted in real-time based on the data

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IV. BLOCK DIAGRAM

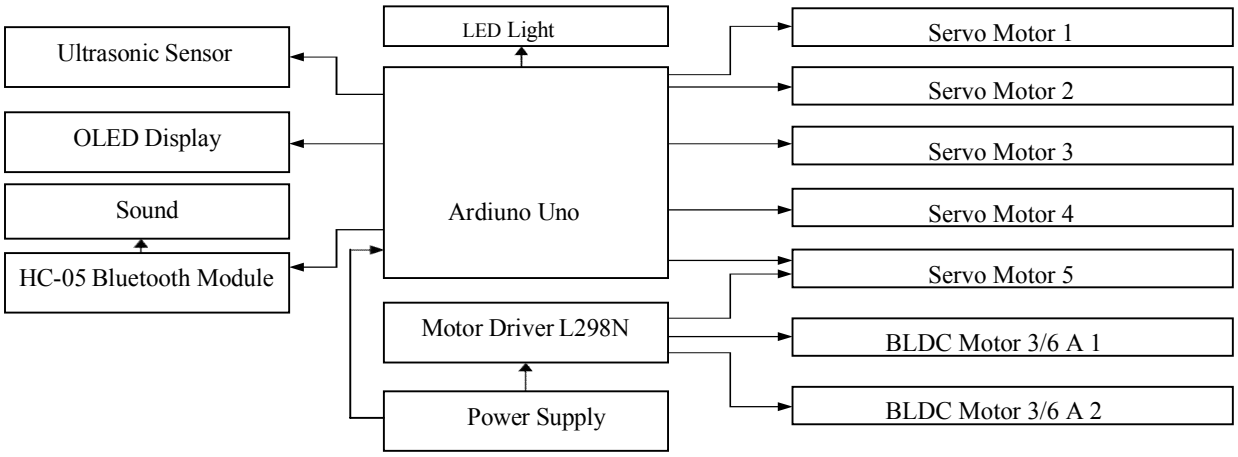

Fig. 4.1 Block Diagram

The block diagram represents the functional structure and interconnections between different components in the Arduino-based humanoid robot system. Each block corresponds to a key part of the system, with arrows indicating the direction of signal flow and control.

Arduino Uno (Microcontroller - Central Unit): This is the brain of the robot, responsible for receiving inputs, processing data, and controlling outputs. All components like sensors, motors, and modules are interfaced directly or indirectly with it. It uses digital and analog I/O pins for communication with other components.

Input Modules:

- Ultrasonic Sensor (HC-SR04): Used for obstacle detection by measuring the distance between the robot and nearby objects. Sends distance data to the Arduino, which can trigger movement changes (e.g., stop, turn).
- Bluetooth Module (HC-05): Enables wireless communication between the robot and a mobile phone or PC. Receives control commands like "forward," "backward," "wave," or "light on" from a user.
- Sound Module (Microphone/Sound Sensor): Detects sounds or claps as basic input signals. Can be used for sound-based triggering of specific actions (e.g., start walking on a clap).

Output Modules:

- Servo Motors (x7): These motors control various joints of the humanoid robot, such as arms, head, or legs. Each motor receives precise angle signals from the Arduino for smooth articulation.
- BLDC Motors (x2): These are used for locomotion (e.g., moving forward/backward). Controlled through the motor driver (L298N), which receives commands from the Arduino.
- Motor Driver (L298N): Acts as an interface between Arduino and BLDC motors. Allows Arduino to safely control high-power motors by managing voltage and current requirements.
- LED Light: Provides visual feedback or status indication (e.g., robot is active, warning alert, etc.).
- OLED Display: A small screen used to display messages, sensor values, or Bluetooth connection status. Enhances human-robot interaction through readable feedback.

Power Supply (Battery): The entire system is powered by a rechargeable battery (e.g., Li-ion or 12V DC pack). Supplies power to:

Arduino Uno

Servo and BLDC motors (via motor driver)

Peripheral modules (OLED, LED, sensors)

Power is distributed based on voltage requirements, often with regulators or direct wiring.

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TABLE I: HARDWARE & SOFTWARE REQUIREMENTS

Sr. No.	Requirements	
	Hardware	Software
1	Arduino Uno	Arduino IDE
2	Arduino Uno USB Cable (Type-B)	Embedded C / Arduino C++
3	Servo Motors (SG90/MG90)	Bluetooth Terminal App
4	BLDC Motors with Wheels	Humanoid Robot Control App
5	L298N Motor Driver Module	Fritzing / Tinkercad / Proteus
6	Ultrasonic Sensor (HC-SR04)	Microsoft Word / Google Docs
7	Bluetooth Module (HC-05)	Paint / Canva / Draw.io
8	Sound Sensor / Buzzer Module	
9	OLED Display (0.96")	
10	LED Lights	
11	Rechargeable Battery Pack	
12	Battery Charger	
13	Switches, Resistors, Wires	
14	Breadboard / PCB	
15	Humanoid Frame / Chassis	

V. CIRCUIT DIAGRAM

The Arduino-based humanoid robot is a multifunctional project that integrates various components to mimic human-like behavior and interaction. At the heart of the robot is the Arduino Uno, which acts as the central controller, coordinating the actions of sensors, actuators, and output devices. The robot uses five servo motors to control different parts of its body—namely, the head, left hand, right hand, and two arms labeled "Water Left" and "Water Right." These servos enable the robot to perform gestures like nodding its head or moving its arms and hands, simulating human movement.

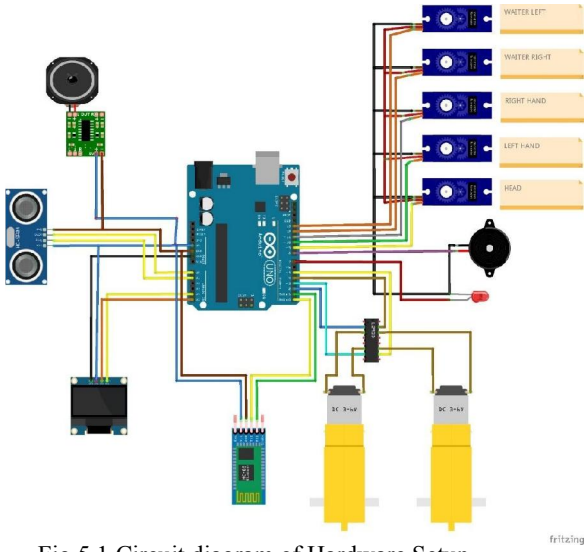

Fig.5.1 Circuit diagram of Hardware Setup

For mobility, the robot is equipped with two DC motors connected through an L298N motor driver, allowing it to move forward, backward, and turn. An ultrasonic sensor is mounted on the front to detect obstacles and help in navigation or interaction with nearby objects or people. A Bluetooth module (HC-05) is used for wireless communication, enabling

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the robot to be controlled remotely using a smartphone or computer. The OLED display is likely used to show visual feedback such as expressions, messages, or status updates, adding an element of personality to the robot. Additionally, a sound module and speaker are included to enable the robot to produce speech or sound effects, enhancing user engagement. The presence of a buzzer and LED indicates the robot can provide audio-visual alerts or signals during operation. Together, these components allow the robot to interact intelligently with its environment and users, making it suitable for educational, demonstrational, or entertainment purposes.

VI. IMPLEMENTATION STEPS

Here are the implementation steps for building and running the Arduino-based humanoid robot:

1. Component Collection: Collect all the required components.

2. Circuit Assembly: Connect components as per the diagram

3. Arduino Code Development: Use Arduino IDE to program the robot.

4. Upload & Test :

- Connect Arduino via USB.
- Upload the program.
- Open Serial Monitor for debugging.
- Test individual modules

5. Power Supply Setup: Use a 9V or 12V battery pack (with regulator) to power motors.

6. Mobile Control: Install a Bluetooth controller app like "Arduino Bluetooth Controller" on your phone.

7. Final Integration & Enclosure:

- Mount all components onto a robot frame.
- Secure wiring to prevent loose connections.
- Adjust servo angles and motor directions as needed.
- Run full system test for motion, gestures, obstacle avoidance, and audio output.

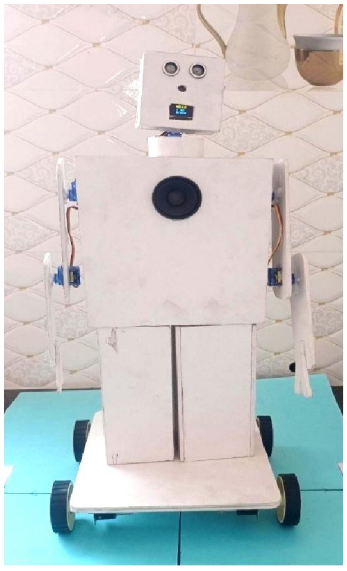

Fig.6.1 Arduino-Based Humanoid Robot

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VII. RESULT

The development of the Arduino-Based Humanoid Robot was successfully completed with all essential functionalities integrated and tested. The final prototype was able to:

Perform Human-like Movements

Using servo motors, the robot was able to move arms, nod its head, and simulate gestures effectively.

Respond to Wireless Commands

The Bluetooth module (HC-05) and ESP32 enabled wireless control via a mobile application, allowing real-time instructions to be received and executed.

Navigate and Avoid Obstacles

With the HC-SR04 Ultrasonic Sensor, the robot could detect obstacles within a range of ~2cm to 400cm and automatically stop or change direction.

Display Live Data and Status

The OLED display successfully showed messages like direction of movement, sensor readings, and command feedback.

Provide Audio Feedback

Using the buzzer/speaker module, the robot produced beeping sounds or short audio clips as responses to certain actions (e.g., greeting or alert).

Maintain Power Autonomy

The use of a rechargeable battery/SMF battery ensured wireless operation, making the robot fully mobile and independent of direct power supply.

VIII. CONCLUSION

The Arduino-Based Humanoid Robot project successfully achieved its core objectives of simulating basic human movements, receiving wireless commands, detecting obstacles, and displaying interactive feedback. The integration of key components like Arduino Uno / ESP32, servo motors, ultrasonic sensor, motor driver, and Bluetooth module resulted in a working prototype capable of gesture mimicry, autonomous navigation, and user communication via sound and display.

This project not only demonstrates the practical application of embedded systems and robotics but also encourages innovation in the field of human-robot interaction. It proves that with basic components and open-source hardware/software, an efficient and interactive humanoid robot can be developed at a low cost.

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