IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

# Design And Implementation Of A Portable Robotic Arm For On-Demand Tasks

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***Abstract:*** The 'Portable Robotic Arm' is a compact, wireless, low-cost robotic system that offers real-time remote control through a smartphone system. The primary objective of this work is to develop an accessible and programmable robotic platform that integrates seamlessly with open-source hardware and software. The system is built using an Arduino Nano microcontroller, four SG90 servo motors, and a PCA9685 PWM servo driver, which together enable a multi-joint articulation of the robotic arm. For wireless communication, the system employs an HC-05 Bluetooth module interfaced with an Android-based application, allowing the user to control the robotic arm without any physical connection.

***Index Terms*** — Arduino, Portable Robotics, Servo Motors, Embedded Control, On-Demand Automation

## *I. INTRODUCTION*

Robotics is a rapidly developing field with significant applications in various sectors. Despite this growth, traditional robotic systems often remain inaccessible to students, hobbyists, and early-stage developers due to their high cost, dependence on specialised programming environments, and complex hardware configurations.
In response to these challenges, the present work explores the development of a Bluetooth- controlled portable robotic arm utilising the Arduino nano platform- an open source, user-friendly microcontroller widely adopted in educational and DIY electronics communities. The objective is to design a low-cost, wirelessly controlled robotic arm that can be operated through an Android-based mobile application, thereby eliminating the need for physical tethering or advanced coding expertise.

The primary motivation behind this project is to democratise access to robotics by providing a modular, scalable, and intuitive system that can be easily assembled, programmed, and controlled by beginners. Most commercially available robotic arms either employ wired interfaces or rely on complex microcontroller platforms, making them impractical for widespread academic or personal use. This Robotic Arm distinguishes itself through its simplified design architecture, which combines off-the-shelf components such as SG90 servo motors, an HC-05 Bluetooth module, and a PCA9685 servo driver, integrated through Arduino IDE.

The novelty of this system lies in its minimalist approach- delivering essential robotic functions while offering an accessible entry point for further exploration in automation, embedded systems, and human-machine interaction.

This research highlights how the integration of Bluetooth-based control, Arduino programming, and open-source components can provide an efficient, scalable platform for exploring robotic automation. The proposed system lays the groundwork for further development in low-cost robotic manipulators and introduces a versatile approach to embedded control and human-robot interaction.

## *II. LITERATURE REVIEW*

Robotic arms have become integral to numerous applications ranging from industrial automation and biomedical diagnostics to prosthetic assistance and educational training. As the field progresses, researchers have explored a variety of enhancements including wireless control, sensor integration, and sophisticated human-machine interfaces to improve the performance and accessibility of robotic systems. In a notable study, Wang et al. (2016) proposed a mobile-controlled robotic arm for microwave imaging diagnostics. Their system incorporated a CrustCrawler robotic platform, NI MyRIO controller, LabVIEW-based interface, and a dual Vivaldi antenna setup to scan human tissue for medical analysis. Although their implementation emphasized medical imaging, their use of mobile-controlled wireless communication parallels our work with Bluetooth-based control. However, their setup is relatively complex and costly, relying on high-end industrial-grade hardware, which limits its usability in educational or low-cost environments.

Similarly, research by Malegam and D'Silva introduced an anthropomorphic robotic arm that replicates human hand motion using a network of flex sensors and accelerometers. This system employs 14 analog inputs, gesture detection algorithms, and dual microcontroller communication to achieve real-time responsiveness. While the system excels in motion fidelity and biomimicry, it also demands a high level of technical expertise and is cost-prohibitive for amateur developers or classroom settings. In contrast, the proposed work in this paper addresses the need for a simplified, cost-effective, and beginner-friendly robotic solution. By integrating Arduino Nano, the HC-05 Bluetooth module, and SG90 servo motors, the robotic arm offers wireless, real-time control via an Android smartphone application. This approach eliminates the complexities of advanced sensor fusion or proprietary software, making it an ideal platform for DIY projects, robotics education, and rapid prototyping in constrained environments.

## *III. METHODOLOGY*

The proposed system aims to develop a portable, Bluetooth-enabled robotic arm designed for ease of use, low cost, and accessibility. The system integrates open-source hardware with a minimalistic mechanical structure to deliver a reliable and responsive robotic solution for on-demand applications such as education, DIY prototyping, and assistive tasks.

A. System Overview

The architecture comprises of four key components:

1. Arduino Nano Microcontroller
   Acts as the central control unit, responsible for receiving commands via Bluetooth and generating corresponding PWM signals for servo control.
2. HC-05 Bluetooth Module
   Provides wireless communication between the robotic arm and the user's Android smartphone. This module enables real-time control via the SriTu Hobby app, allowing users to manipulate the robotic arm remotely through a graphical mobile interface.
3. PCA9685 16-Channel PWM Servo Driver Serves as a multi-channel interface to control the servo motors. It communicates with the Arduino Nano using the I2C protocol, offloading the PWM generation to ensure smooth and jitter-free movement even under simultaneous multi-servo actuation.
4. SG90 Servo Motors (x4) These micro servos are used to articulate the robotic arm, enabling motions such as base rotation, vertical lift (shoulder), elbow flexion, and gripper control.

The system is powered by a regulated 5V–6V DC power supply, distributed to both the logic and actuation circuits.

B. Communication and Control Flow

The user initiates commands via a Bluetooth-enabled Android smartphone using the SriTu Hobby application. The app sends serial data to the HC-05 module, which is connected to the Arduino Nano through the RX and TX pins. Upon receiving data, the Arduino interprets the command using preloaded code written in the Arduino IDE, where each instruction is mapped to a specific movement or position. The Arduino communicates with the PCA9685 servo driver via the I2C interface (SCL and SDA pins), which then delivers precise PWM signals to the four servo motors. This decoupling of PWM generation from the Arduino's main processing thread improves responsiveness and reduces latency.

C. Mechanical Configuration

The mechanical structure of the robotic arm is built using a robot arm kit, with mountings for four SG90 servos. These motors control:

Base rotation, Shoulder elevation, Elbow movement, Gripper actuation

Each joint is designed for a ±90° range of motion, offering adequate flexibility for basic pick-and place tasks. The overall frame is lightweight, allowing portability without compromising structural stability.

D. Circuit and Power Distribution

The power distribution is designed to isolate logic-level components (Arduino, HC-05, PCA9685) from the higher current demands of the servo motors. A dedicated external 5V–6V power source supplies the servo motors, while the Arduino and Bluetooth module operate on the onboard 5V regulated line. The connections are made using a breadboard and jumper wires, offering modularity and ease of reconfiguration.

E. Software Implementation

The firmware is developed using the Arduino IDE, and includes:

1. Bluetooth serial communication handlers
2. Command-parsing logic for interpreting user inputs
3. PWM signal mapping functions for controlling servo angles
4. Error-handling routines for out-of-range inputs or power anomalies

Each servo is mapped to a specific function in the robotic arm, and user inputs are translated into corresponding angular movements using Servo.write() commands routed via the PCA9685 driver's address.

F. User Interface and Interaction

The SriTu Hobby mobile app provides an intuitive graphical interface where users can tap directional arrows or sliders to control individual joints of the robotic arm. The app communicates using standard AT command-based serial transmission, which simplifies integration and enables customizability for future app extensions or third-party controls.

G. Design Goals and Advantages

This system was developed with the following goals in mind:

Affordability: All components are low-cost and widely available.
Modularity: Allows upgrades or reconfiguration without full redesign.
Portability: Lightweight structure, easy to transport and deploy.
Accessibility: Easy for beginners and students with limited coding experience.
Open-Source Compatibility: All software and hardware are compatible with open-source platforms.

## *IV. IMPLEMENTATION*

A. Hardware Configuration

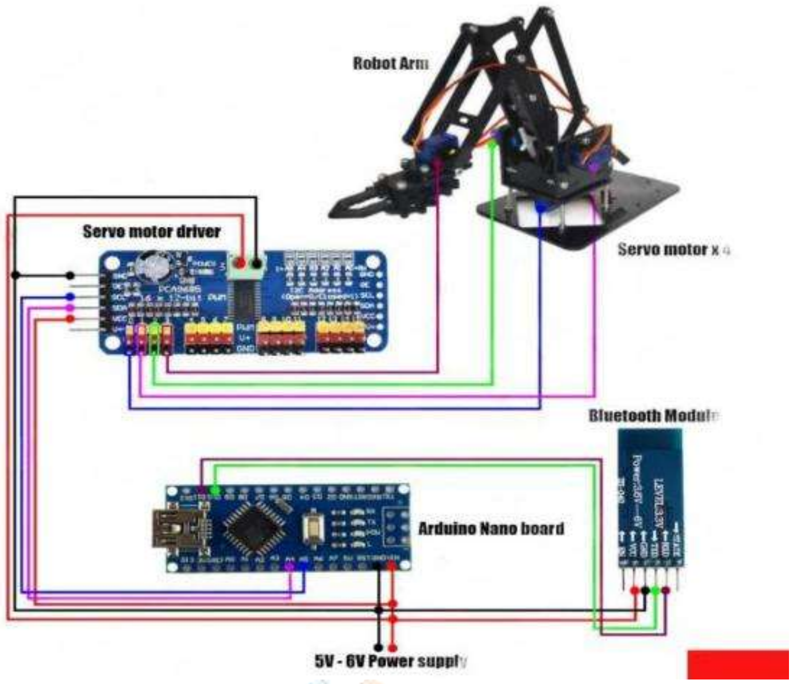
The following hardware components were employed:

Arduino Nano Board (x1): Acts as the central processing unit for signal interpretation and control logic.
PCA9685 Servo Driver (x1): Generates PWM signals with 12-bit resolution to drive up to 16 servo motors (4 used in this project).
SG90 Servo Motors (x4): Lightweight, 180° servo motors used for robotic arm articulation.
HC-05 Bluetooth Module (x1): Provides serial wireless communication with the user's smartphone.
Robot Arm Kit (x1): Mechanical structure for assembling the servo motors into a functioning arm.
5V–6V Power Supply (x1): Powers the entire system, including the Arduino board and the servo motors.
Breadboard and Jumper Wires: Used for prototyping and interconnecting modules.

B. Circuit Diagram

As shown in the schematic (see Fig. 1), the PCA9685 servo driver is interfaced with the Arduino Nano via the SDA (A4) and SCL (A5) pins using the I2C protocol. The PWM outputs of the driver are connected to each of the four servo motors. The HC-05 Bluetooth module is connected to the TX and RX pins of the Arduino Nano to receive command signals from the mobile app.

The PCA9685 and HC-05 module are both powered through a regulated 5V supply. A separate 5V–6V external power source is used to power the servo motors, ensuring stable operation without overloading the Arduino.




C. Software and Control Logic
The Arduino IDE was used to develop the control algorithm. A loop continuously reads Bluetooth commands received via the HC-05 module and maps these inputs to predefined PWM values for servo control. The use of a lookup table or switch-case structure allows precise control of each joint of the robotic arm.
The Android-based SriTu Hobby App sends individual commands for each axis of motion, which are processed and reflected in real-time by the robotic arm. The control interface allows movement of the arm base, vertical lift, elbow, and gripper independently.
D. Deployment and Testing
Upon successful hardware assembly, the system was tested for:
Responsiveness: Real-time actuation upon receiving Bluetooth commands.
Accuracy: Precise angular positioning of each joint.
Stability: Power stability under full load with all four servos active.
Range: Effective Bluetooth control within 10–15 meters line-of-sight.
The robotic arm successfully performed basic pick-and-place operations under remote control, validating its functionality as a lightweight and portable automation tool.

## *V. Results and Discussions*

1. Features:
i. The robotic arm is appropriate for students and hobbyists due to its straightforward and affordable hardware configuration, which consists of an Arduino UNO, HC-05 Bluetooth module, and servo motors.
ii. Through an intuitive mobile application, the user can move the robotic arm in real time using the system's wireless control via an Android smartphone.
iii. The system's modular design makes it simple to replace or modify parts like servos or the base platform, which can be altered to suit various use cases.
iv. The system is programmed using Arduino language (a simplified version of **C/C++)**, which allows users to write and upload control logic easily via the Arduino IDE.
2. User Interaction:
By pairing the smartphone with the Bluetooth module, users can operate the robotic arm wirelessly. The user can control each servo motor precisely by using the buttons or sliders provided by the mobile app.
3. Results:
This project effectively illustrates that a dependable robotic system can be constructed at a low cost using readily available hardware. It is a useful educational resource for learning about wireless communication, embedded systems, and robotics. Additionally, it makes room for upcoming additions like feedback systems, camera modules, and sensors.

4. Limitations:
Limited Payload: The arm's lifting capacity is limited by the use of lightweight servo motors, making it appropriate only for light-duty tasks.
Range Dependency: The system's control range is limited by Bluetooth's short range, which is usually 10 meters.
Lack of Feedback Mechanism: In more complex applications, precise control is limited because the current version lacks sensors to provide feedback regarding position or torque.

## *VI. CONCLUSION*

The Portable Robotic Arm created in this project effectively proves an affordable, low-cost, and wireless solution for remote manipulation operations. Utilizing open-source elements like the Arduino Nano, SG90 servo motors, PCA9685 servo driver, and the HC-05 Bluetooth module, the system provides an open-source, programmable, and scalable platform ideal for hobbyists, educators, and beginners. The Android app-based interface gives easy, real-time control over the movement of the arm, making it more usable and interactive. Although there are some restrictions in payload weight and distance, the system performs well in its main goals of portability, usability, and operational wireless control. Future developments can involve introducing feedback mechanisms, enhancing mechanical stiffness, and increasing the degrees of freedom. The project is generally a good basis for further more complex developments in personal robots and embedded automation systems.

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