International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 05 Issue: 05 | May – 2026 DOI:10.55041/ISJEM06984
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Development of a 5-DOF Wireless DIY Robotic Arm for Educational Applications

Ashish Rajendra Phadatare

Abstract— Practical learning is essential in improving the understanding of the fundamentals of engineering and technology. Nonetheless, the availability of cheap and practical robotics kits is lacking among beginners and organizations that do not have enough budget. In this regard, this paper discusses the development of a 5 Degree-Of-Freedom wireless robotics kit suitable for learning purposes.

The system design entails the use of Arduino Nano boards on the transmitter and receiver ends, and NRF24L01 wireless transmitters to facilitate live control. The robot arm employs MG995 and SG90 servos, with joint movements executed using PWM control signals. In addition, there will be a remote control consisting of a joystick and potentiometer interfaces for easy robotic arm manipulation.

The system incorporates a modular mechanism design and electronic circuitry on a printed circuit board. It has been proven that the system offers smooth movement control, good wireless communications capability, and ease of assembly, which makes the system ideal for classroom learning and teaching introductory robotics.

Moreover, the software adheres to an open-source model, which allows the learners to change, play around with, and improve the software based on their needs. The robot arm introduced is a stepping stone towards building a structured curriculum for robotic studies.

INTRODUCTION

A. Background

Robots have emerged as one of the major technologies used in various modern industries such as manufacturing, healthcare, and logistics. In light of the emerging trend of Industry 4.0, the need for robotics experts has risen drastically. Consequently, it has become imperative to integrate robotics in the curriculum of schools and universities.

Robotics arm manipulators are one of the most frequently utilized types of robots and are generally used in operations like material handling, assembly, and picking

and placing processes. In education, robotics arms can be considered effective tools for learning about topics such as degrees of freedom, actuator control, and embedded programming. They help students learn by actually interacting with physical mechanisms.

B. Problem Statement

Although there is an increasing need for robotics education, there is still a lack of available learning tools that can be afforded by students and schools. The use of industrial robotic arms is too costly and complicated for the uninitiated. Most of the cheap robotic kits do not have programming capabilities.

This has led to students' dependency on theories and simulation, thus hindering their learning of practical robotic systems. It becomes evident that there exists an urgent need for the development of a simple and affordable robotic platform that can be programmed easily.

C. Research Gap

Current robotic arm kits and systems are geared either toward simple assembly or are sophisticated enough to be programmed, but at an expensive price point. Certain systems have been known to operate via wired or Bluetooth control.

Current robotic arms are limited by being either simple to assemble and lacking in sophistication or very sophisticated but expensive. Control mechanisms for some current designs may be done through wires or via Bluetooth technology, which may have limitations.

International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 05 Issue: 05 | May – 2026 DOI:10.55041/ISJEM06984
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

D. Contribution of the Proposed Work

This paper discusses the design and implementation of a 5 Degrees of Freedom (DOF) wireless robotic arm that can be built by hobbyists. The following are the main features of the proposed system:

- Servo-based 5 DOF Robotic Arm
- Wireless Communication via NRF24L01 Modules
- Arduino Nano Microcontroller for Embedded System Design
- Joystick User Interface
- Custom PCB Assembly for Enhanced Reliability
- Open Source Design Approach

I.Comprehensive Literature Review

A.Educational Robotics and Learning

Robotics can be considered a valuable instrument for improving STEM education because it encourages practical application of knowledge. Research suggests that using robotics in the process of studying positively influences the development of problem-solving skills, logic and, most importantly, motivates students more than conventional teaching methods. With robots, one can learn more about engineering.

B. Robotic Arm Systems

Robot arms find applications in industries where automation is employed for purposes like picking, assembling, and moving materials. In educational settings, simple robot arms are utilized to illustrate basic principles like joint operations and control systems. Nevertheless, robot arms found in industry are too costly and sophisticated to be applied in beginners' level education.

C. DIY Robotic Kits and Open – Source Platform

The advent of affordable and do-it-yourself robotic kits that rely on Arduino platforms is one of the factors that have made robotics more popular. Such kits are simple to code and have great support from the open-source community. Robotic arms that utilize servo motors have been used in educational settings because of their ease of use and accuracy in positioning.

D. Control Techniques for Robotic Arms

In most cases, the robot arms used in education utilize servos driven by Pulse Width Modulation (PWM). PWM provides accurate control over the angular position that ranges between 0° and 180°. In some systems, control can be either wired or Bluetooth, but there have been recent advancements in wireless connectivity.

E. Limitation of Existing system

Even with all the developments in the field of educational robots, the following challenges still remain in current designs:

- Expensive programmable robotic arms
- Minimal combination of mechanical, electrical, and programming elements
- Use of wired or inefficient communication systems
- Poor portability and ease of use

F. Research Gap

Based on the literature review, it is noted that most existing systems lack a comprehensive package which would include all the above mentioned criteria and be affordable and user-friendly for students. There is a need for an integration of all these aspects into one product.

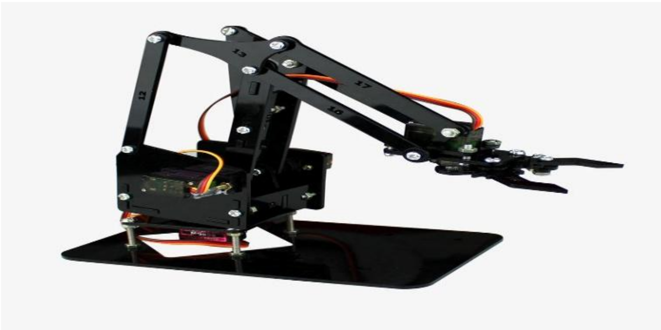
G. Need for Proposed System

In order to overcome these limitations, the suggested system concentrates on making a cheap, wireless, and user-friendly robot hand with Arduino Nano and NRF24L01 modules. The suggested system is designed in such a way that it makes the learning process more meaningful for students.

Comparison of Existing System and Proposed System

Parameter	Wired System	Bluetooth Arm	NRF24 Arm
Range	1m	10m	30 m
Cost	Low	Medium	Low
Speed	High	Medium	High
Portability	Poor	Good	Excellent

ISSN: 2583-6129
DOI:10.55041/ISJEM06984



II.Device Structure

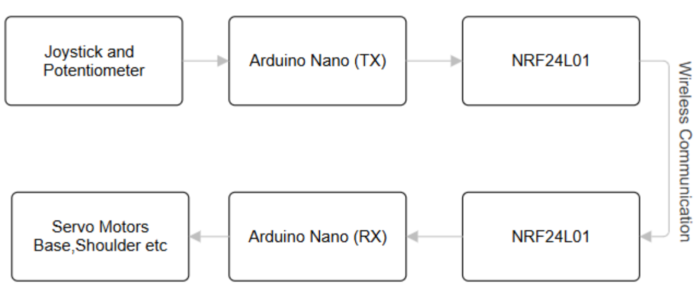
A.Overview of Device Architecture

This system design involves two major components: transmitter and receiver. Transmitter takes care of the user input data, while the receiver component handles the received data and directs the robotic arm.

Transmitter components include joystick modules and a potentiometer that produce analog values according to the user command inputs. The analog data is then transmitted through an Arduino Nano chip using the NRF24L01 module.

Receiver components include Arduino Nano, NRF24L01 module, and five servo motors. The data sent by the transmitter is decoded and converted into PWM signal to direct the movements of joints of the robotic arm.

Overall System Architecture



B. Mechanical Structure

The robotic arm is an implementation of a 5-degrees-of-freedom (5-DOF) device, where the joints move independently. The rotation is controlled by the base, which lifts the load through the shoulder and extends its arm through the elbow. The orientation is adjusted through the wrist, and the object can be held using the gripper.

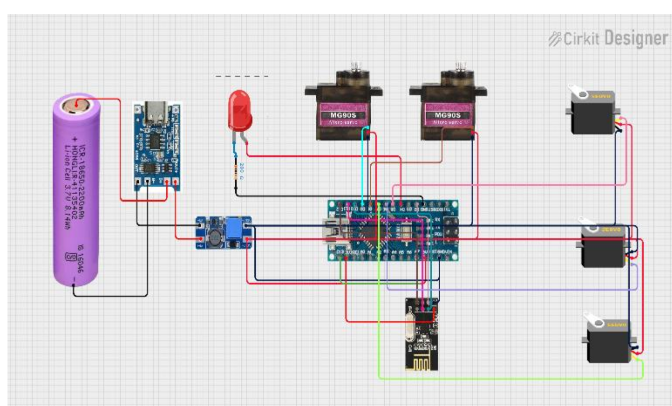
The high-torque MG995 servomotors are chosen for the base, shoulder, and elbow joints as they need more force than the other two joints. Light servomotors SG90 are selected for the wrist and gripper since the joints require fine control.

C. Electronic System Design

This system has two Arduino Nano devices along with NRF24L01 wireless transmitters. The transmitter gathers the analog values through the joystick and potentiometer and transmits it via radio waves. The receiver decodes the information and produces the PWM signal to operate the servo motors.

This system uses a custom-designed PCB board to simplify wiring connections. The system also has LEDs to indicate the connectivity of the system.

Circuit Diagram of Robotic Arm System



D. Actuation System

The actuators of the robot arm are the servo motors. The servo motors are controlled through Pulse Width Modulation (PWM) signals sent by the Arduino Nano.

PWM frequency: 50 Hz
Pulse width range:
1 ms → 0°
1.5 ms → 90°
2 ms → 180°

This helps to control the angle of each joint of the robotic arm.

E. Power Supply System

Powering of the system is done by a Li-ion rechargeable battery. For the conversion of the voltage to 5V required for Arduino and servo control, a boost converter is employed. Because of the large current consumed by the MG995 servos, it becomes imperative to maintain a constant power supply.

A proper ground connection is made between all the parts of the system.

F. Control System

The control system is designed based on real-time inputs received from the user. Joystick and potentiometer inputs are converted to servo positions (0°-180°). These values are then sent using a wireless connection to the servos.

This system allows a very smooth operation of the robot arm and is thus recommended for beginners.

IV.System Design and Developement

A.System Design

This is done through segmentation of the system into two parts: the transmitter and the receiver. The transmitter serves to collect information from the user, whereas the receiver directs the robot arm based on the collected information.

Some key areas in the design include:

- User-friendly user interface
- Stable wireless transmission
- Compact design

B. Mechanical Design

The design of the robot arm uses 3D-printed parts. It has five joints with five degrees of freedom.

- Base → rotation
- Shoulder → lifting
- Elbow → extension
- Wrist → orientation
- Gripper → object handling

Selection of servo motors depends on the load:

- MG995 for heavy joints
- SG90 for light joints

C. Circuit Design

Arduino Nano is chosen to be the microcontroller in this circuit. NRF24L01 wireless module and Servo motors are interfaced through digital PWM pins.

Power supply management involves use of Li-ion battery and boost converter to maintain the 5V supply.

D. Transmitter Design

Components of Transmitter:

- Two joystick components
- Potentiometer
- Arduino nano
- NRF24L01 component

The joysticks and potentiometer produce analog values that are read and analyzed by the Arduino Nano. These values are then transferred to the receiver by wireless communication.

ISSN: 2583-6129
DOI:10.55041/ISJEM06984

E. Receiver Design

The components of the receiver consist of:

- Arduino Nano board
- NRF24L01 wireless module
- Five servo motors

The Arduino on the receiver side reads the received data and provides PWM signals for driving the servo motors.

F. Software Development

Programming of the system is done using Arduino IDE. The two programs that are coded include:

Transmitter program – inputs and transmits data
Receiver program – receives data and operates servos

Libraries used:

RF24.h
Servo.h
SPI.h

G. Testing and Development

The following tests were performed to test the robot:

Testing of individual servo motors
Wireless transmission testing of NRF24
Testing of joystick calibration
Robotic arm movements integration testing

The robotic arm works perfectly in response to the operator's input.

V.Result and Discussion

A.Experimental Setup

Testing for the Robotic Arm System was done by operating it using the transmitter (joystick controller) and receiver (robotic arm controller). Power was supplied to the system using an Li-ion battery together with a boost converter providing constant 5V power supply.

Testing and performance criteria were measured in terms of:

- Range of wireless communication
- Response Time
- Servo Accuracy

B. Observations

The above were some of the things that were noted when testing:

- Robot arm operated smoothly through joystick inputs
- There was stable wireless transmission within 25-30meters range
- Servo motors were precise in their movements
- User interface was simple and easy to use by anyone
- There was no delay noted in operations

C. Performance Analysis

The performance of the system is summarized in the table below:

Parameter	Observed Value
Communication Range	25-30 meters
Response Time	< 100 ms
Degrees of Freedom	5 DOF
Control Type	Wireless(NRF24)
Power Supply	Li-ion + Boost Converter

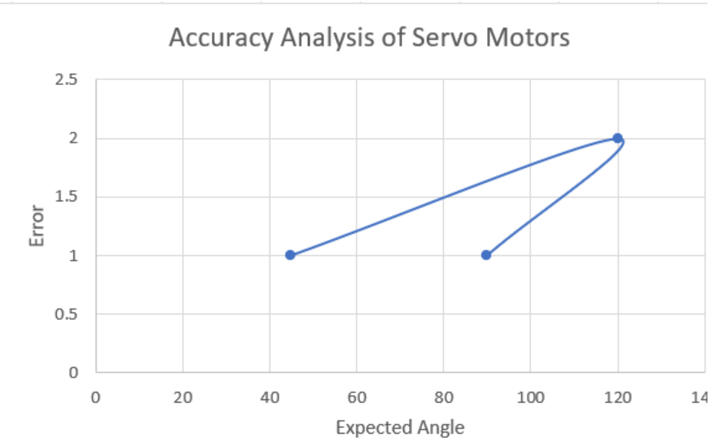
D. Accuracy Analysis

The accuracy of servo movement was tested by comparing expected and actual angles.

Test	Expected Angle	Actual Angle	Error
1	90	89	1
2	120	118	2
3	45	46	1

International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 05 Issue: 05 | May – 2026 DOI:10.55041/ISJEM06984
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Angle VS Error Graph



E. Discussion

Experimental results indicate that the suggested system operates efficiently as a wireless robotic arm for educational purposes. It exhibits stable wireless connectivity, precise servo control, and proper operation.

The implementation of NRF24L01 components allows obtaining effective wireless data exchange with minimal delays. The use of servomotors enables proper manipulation of each joint. Moreover, the joystick controller ensures efficient system operation by allowing the operator to control the device easily.

Therefore, the purpose set out at the very beginning of the research work has been achieved.

VI.Conclusion

A.Conclusion

A 5-DOF wireless robotic arm has been successfully developed utilizing the capabilities of Arduino Nano and NRF24L01. The system supports real-time operation of the robot with the help of a joystick controller, making it simple to operate and appropriate for beginners.

A great deal of accuracy and ease of maneuvering is exhibited by the robotic arm with the use of servo motors and their control by means of PWM. Communication through wireless medium using the NRF24L01 modules gives excellent and lag-free performance. The use of PCB and rechargeable power source has improved its portability.

The present robotic system has proven to be an effective tool for learning about robotics. Students have been able to learn about embedded system design, wireless communications, actuator design, etc. The developed system fulfills all the objectives of being affordable and usable for students.

B. Advantages

- Low-cost and affordable system
- Wireless control with good range
- Easy to operate and beginner-friendly
- Portable and rechargeable
- Open-source design for learning and experimentation

C. Limitations

- Small payload capacity because of servo torque limitation
- Manual controls only, without any automation
- Limited range when compared to other more advanced technologies
- Accuracy is dependent on servos

D. Applications

- Robotics education and training
- Science, technology, engineering, mathematics learning kits
- Projects demonstrating in schools and colleges
- Simple pick-and-place applications

E. Future Scope

- Automatic mode (save and replay) implementation
- Mobile application integration or Bluetooth control
- Inverse kinematics use for accurate movement
- Incorporation of camera object detection system
- Robotic learning module development.

VII.Refrences

1. **Benitti, F. B. V. (2012).**
Exploring the educational potential of robotics in schools: A systematic review. *Computers & Education, 58*(3), 978–988.
https://doi.org/10.1016/j.compedu.2011.10.006
2. **Eguchi, A. (2014).**
Robotics as a learning tool for educational transformation. *Proceedings of the 4th International Workshop Teaching Robotics*.
3. **Papert, S. (1980).**
Mindstorms: Children, Computers, and Powerful Ideas. New York: Basic Books.
4. **Alimisis, D. (2013).**
Educational robotics: Open questions and new challenges. *Themes in Science and Technology Education, 6*(1), 63–71.
5. **Johnson, C. C., Peters-Burton, E. E., & Moore, T. J. (2016).**
STEM Road Map: A Framework for Integrated STEM Education. Routledge.
6. **Resnick, M., et al. (2009).**
Scratch: Programming for all. *Communications of the ACM, 52*(11), 60–67.
7. **National Research Council. (2012).**
A Framework for K-12 Science Education. Washington, DC: National Academies Press.

References (IEEE Format)

1. F. Benitti, “Exploring the educational potential of robotics in schools,” *Computers & Education*, vol. 58, no. 3, pp. 978–988, 2012.
2. A. Eguchi, “Robotics as a learning tool for educational transformation,” in *Proc. Int. Workshop Teaching Robotics*, 2014.
3. S. Papert, *Mindstorms: Children, Computers, and Powerful Ideas*. New York, USA: Basic Books, 1980.