DESIGN AND PERFORMANCE ANALYSIS OF REMOTE-CONTROLLED FORKLIFT

A Project

by

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JANUARY 2026

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DECLARATION

We thus certify that the undergraduate thesis work described in this thesis was completed by us under the guidance of Md. Faruque Hossain, Lecturer, Sonargaon University (SU) Department of Mechanical Engineering, and that this report has not been submitted in whole or in part to any other university for another degree, award, or other reason. We hereby certify that Sonargaon University's (SU) Department of Mechanical Engineering is the sole owner of all copyrights to this practicum report. It is strictly forbidden to reproduce or use in any way without Sonargaon University's (SU) explicit approval.

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ACKNOWLEDGEMENT

First, we started in the name of almighty Allah. This thesis is accomplished under the supervision of Md. Faruque Hossain, Lecturer, Department of Mechanical Engineering, Sonargaon University. It is a great pleasure to acknowledge our profound gratitude and respect to our supervisor for this consistent guidance, encouragement, helpful suggestion, constructive criticism and endless patience through the progress of this work. The successful completion of this thesis would not have been possible without his persistent motivation and continuous guidance.

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ABSTRACT

Material handling plays a crucial role in industrial and warehouse operations, where forklifts are widely used for lifting and transporting loads. This project presents the design and fabrication of a remote-controlled mini forklift that demonstrates the fundamental working principles of a conventional forklift in a compact and cost-effective form. The proposed system employs a pulley and belt-based lifting mechanism driven by a powerful 12 V DC motor, enabling efficient vertical lifting and precise placement of loads. To ensure stability during lifting operations, a counterweight is mounted at the rear of the forklift. The lifting assembly is integrated with a robust four-wheel-drive chassis capable of supporting the lifting frame, payload, and counterweight. Four DC motors are used to achieve smooth movement in all directions, providing enhanced traction and maneuverability. Two vertical supporting rods with bearing arrangements are incorporated to guide the lifting platform and ensure smooth and stable vertical motion. Wireless control is achieved using an RF-based remote-control system, allowing the operator to control the forklift from a safe distance. This mini forklift model effectively demonstrates load-handling, balance control, and remote operation, making it suitable for educational purposes, prototype development, and small-scale material handling applications.

Keywords: DC, 12 V Motor, Forklift.

CHAPTER 1
INTRODUCTION

1.1 Introduction

Material handling systems play a vital role in industries, warehouses, construction sites, and logistics centers, where lifting and transportation of goods are performed regularly. Forklifts are among the most commonly used material handling machines due to their ability to lift heavy loads, move efficiently in confined spaces, and reduce manual labor. However, conventional forklifts are often large, expensive, and require skilled operators, making them unsuitable for small-scale applications, training purposes, or educational demonstrations. With the rapid advancement of automation and wireless control technologies, remotely operated machines are gaining popularity in industrial and research applications. Remote-controlled systems enhance operational safety by allowing machines to be operated from a distance, thereby minimizing human exposure to hazardous environments. Miniaturized models of industrial machines provide an effective platform to study mechanical design, control systems, and load-handling mechanisms without the high cost and complexity of full-scale equipment.

This project focuses on the design and fabrication of a remote-controlled mini forklift that demonstrates the working principles of a real forklift in a compact form. The system uses a pulley and belt-based lifting mechanism powered by a 12 V DC motor to lift and lower loads efficiently. A counterweight is incorporated at the rear of the forklift to maintain balance during lifting operations. The forklift is mounted on a strong four-wheel-drive chassis equipped with four DC motors, enabling smooth movement in all directions.

Wireless operation is achieved through an RF-based control system, allowing the forklift to receive commands from a remote transmitter. Supporting rods with bearing arrangements are used to guide the lifting mechanism and ensure stable and smooth vertical motion. The proposed mini forklift serves as an effective educational model for understanding material handling systems, mechanical lifting mechanisms, motor control, and wireless operation, while also offering potential applications in small-scale material transportation and robotic research.

1.2 Problem Statements

In industrial, warehouse, and construction environments, material handling is a critical operation that often involves lifting and transporting loads manually or using large-scale machinery. Traditional forklifts are expensive, bulky, and require skilled operators, making them unsuitable for small industries, training institutes, and educational demonstrations. Additionally, operating full-sized forklifts in confined or hazardous environments can pose safety risks to human operators.

There is a lack of low-cost, compact, and remotely operated forklift models that can effectively demonstrate real-world lifting and load-handling principles. Existing manual or semi-automatic material handling methods are inefficient, time-consuming, and increase the risk of workplace injuries. Moreover, conventional forklifts do not offer flexibility for experimental learning, testing of control systems, or safe remote operation in restricted areas.

Therefore, the problem lies in developing a compact, cost-effective, and wireless-controlled mini forklift that can safely lift and transport loads while demonstrating key mechanical concepts such as pulley-based lifting, balance using counterweights, smooth vertical motion, and multi-directional movement. The proposed solution should reduce human effort, improve operational safety, and provide an effective platform for educational and small-scale material handling applications.

1.3 Objectives of the Study

- To Design Remote Controlled Forklift.
- To Analyze the performance of Forklift

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The literature review provides a comprehensive study of existing research, designs, and technologies related to forklift systems, material handling mechanisms, and remote-controlled robotic vehicles. It helps in understanding the current advancements, limitations, and challenges associated with conventional and miniaturized forklift systems. By reviewing previous work, insights can be gained into different lifting mechanisms, drive systems, control methods, and safety considerations used in material handling equipment. Several studies have focused on the design of forklifts using hydraulic, pneumatic, and mechanical lifting mechanisms, while others have explored automated and remotely operated material handling robots. Advances in DC motor control, wireless communication technologies such as RF, Bluetooth, and IoT-based systems have further enhanced the performance and flexibility of modern material handling systems. Additionally, research on pulley-based lifting systems and counterweight balancing techniques has contributed to improved efficiency and stability in load lifting operations. The review of existing literature helps in identifying gaps in current systems, such as high cost, complexity, limited scalability, and safety concerns. These findings serve as a foundation for the proposed project, guiding the selection of components, mechanical design, and control strategies. The insights gained from the literature ensure that the proposed remote-controlled mini forklift is designed efficiently, economically, and in alignment with proven engineering principles

2.2 Literature Review

The development of mini forklifts has received significant attention in recent years, reflecting the expansion in product processing and industrial automation. Various studies and research projects differ from forklift technology and focus on innovation, electronic equipment, and control systems. Research in the field of battery-powered stackers has been extensive due to the need for business solutions. Recent research has shown the advantages of lithium-ion batteries over lead-acid batteries in terms of higher energy environmental impact and operating costs of forklifts, making them the first choice in everyday use. Integrating remote control technology into forklifts shows great potential in improving workplace safety and productivity. Research shows how wireless communications and advanced technology can be used to operate remote controlled forklifts from a safe location. This reduces the risk to the user in hazardous areas such as chemical plants or construction sites and allows better control of forklift operations. Recent advances in automation and intelligent control systems have increased the efficiency and safety of forklift operations. By combining technologies such as artificial intelligence and machine learning, researchers have developed methods that can improve planning, improve prevention, and improve business performance. Although fully automated forklifts are still emerging, these smart controls have been incorporated into remote controls to improve their performance.

Forklifts are an important tool for transporting equipment in industry; They help move and store goods in warehouses, distribution centres, and manufacturing facilities. Conventional forklifts generally rely on an internal electric motor for power and manual operation for control. However, recent technological advances have encouraged the development of more efficient, safer, and environmentally friendly batteries, including batteries for electric and remote- Controlled forklifts [1]

The development of forklift technology is characterized by the development of batteries and remote control. The change is driven by the need to increase business efficiency, improve workplace safety and reduce environmental impact. Battery-powered stackers have many advantages over traditional competitors, including lower cost, quieter operation, and less maintenance. In dangerous or stressful situations remote-controlled forklifts, on the other hand, give workers greater control and accuracy, especially in hazardous or tight areas [2].

Research on battery technology for forklifts has focused primarily on the development and optimization of lithium-ion batteries. These batteries have more power, faster charging times and longer lifespan than lead-acid batteries. Research demonstrates the feasibility and effectiveness of lithium-ion batteries for power stackers, highlighting their ability to make equipment use more efficient and durable. The integration of remote controls into forklifts has become a new promise to improve workplace safety and efficiency. Remote-controlled forklifts allow workers to control the vehicle from a safe location, reducing the risk of injury and damage. Advanced technology and wireless communications provide control and efficiency, especially in environments where human personnel may be difficult or dangerous [3].

Research in this area addresses issues such as battery management, wireless connectivity, and remote-control interface design. Although significant progress has been made in the development of batteries using remote-controlled mini forklift, there is still time for further research and innovation. Key areas may include optimizing battery performance, improve remote control, and integrate smart automation tools. Addressing this gap will not only improve the development of forklift technology but also support the continued development of handling equipment in various workplaces [4].

Automation in industrial logistics and material handling has been a focus of numerous research efforts over the past two decades. Forklifts, being central to warehouse and factory operations, have traditionally been operated manually, but the integration of wireless technologies has opened up new possibilities for remote and autonomous control systems. This literature review explores relevant research and developments in the fields of wireless control systems, Bluetooth-based automation, and smart forklifts.

2.2.1 Wireless Control in Industrial Applications: Wireless communication has been widely adopted in industrial environments to replace wired systems, which are often inflexible and prone to wear and damage. According to [Singh et al., 2018], wireless technologies such as Bluetooth, Wi-Fi, and Zig-bee have been successfully implemented in various robotic and remote-control systems to enhance flexibility and safety in operations. Among these, Bluetooth is highlighted for its ease of integration, low power consumption, and suitability for short-range communication in controlled environments [5].

2.2.2 Bluetooth-based Robotic Systems: Numerous studies have demonstrated the successful implementation of Bluetooth modules (such as HC-05 and HC-06) in robotic systems. For example, [Kumar and Shah, 2019] developed a Bluetooth-controlled robot using an Arduino microcontroller and a mobile app interface, proving that such systems can be both reliable and cost-effective. The ability to send real-time commands wirelessly enables responsive and accurate control of movement, which is directly applicable to forklift mechanisms [6].

2.2.3 Smart Forklift Systems: Modern smart forklifts incorporate sensors, automation, and wireless communication to improve navigation and safety. Research by [Lee et al., 2020] on semi-autonomous forklifts emphasizes the benefits of integrating IoT and wireless control in reducing labor costs and improving material handling efficiency.

While many commercial smart forklifts use complex systems with LiDAR and GPS, simpler approaches using Bluetooth can be adopted for basic remote-control functions in confined spaces [7].

2.2.4 Arduino and Mobile App Integration: A growing body of literature supports the use of microcontrollers such as Arduino and Raspberry Pi in DIY and educational automation projects. [Patel et al., 2021] showcased a Bluetooth-controlled car using Arduino and Android-based applications, demonstrating a smooth user interface for directional control. These principles are readily transferable to forklift designs [8].

2.2.5 Sensors, autonomy and safety considerations: While simple Bluetooth projects focus on manual remote control, literature on industrial AGVs and autonomous forklifts emphasizes the need for sensors (ultrasonic, LiDAR, cameras), obstacle detection, and safety interlocks for operation around humans. Standards and guidelines for AGV/forklift safety are emerging; recent reviews discuss safety criteria, human-robot coexistence, and regulatory considerations for deployment in real warehouses. For real deployments, adding safety sensors and fail-safe behaviors is essential [9].

CHAPTER 3
METHODOLOGY

3.1 Introduction

This chapter describes the systematic approach adopted for the design, development, and implementation of the remote-controlled mini forklift. The methodology outlines the step-by-step procedures followed to convert the conceptual design into a functional working model. It includes the selection of mechanical components, design of the lifting mechanism, development of the drive system, and integration of the wireless control circuit. The methodology begins with the analysis of system requirements and load-handling specifications, followed by the design of a pulley and belt-based lifting mechanism powered by a 12 V DC motor. The mechanical structure, including the chassis, supporting rods, bearing arrangements, and counterweight, is designed to ensure stability, strength, and smooth vertical motion. The drive system is developed using four DC motors to achieve controlled movement in all directions.

3.2 Block Diagram

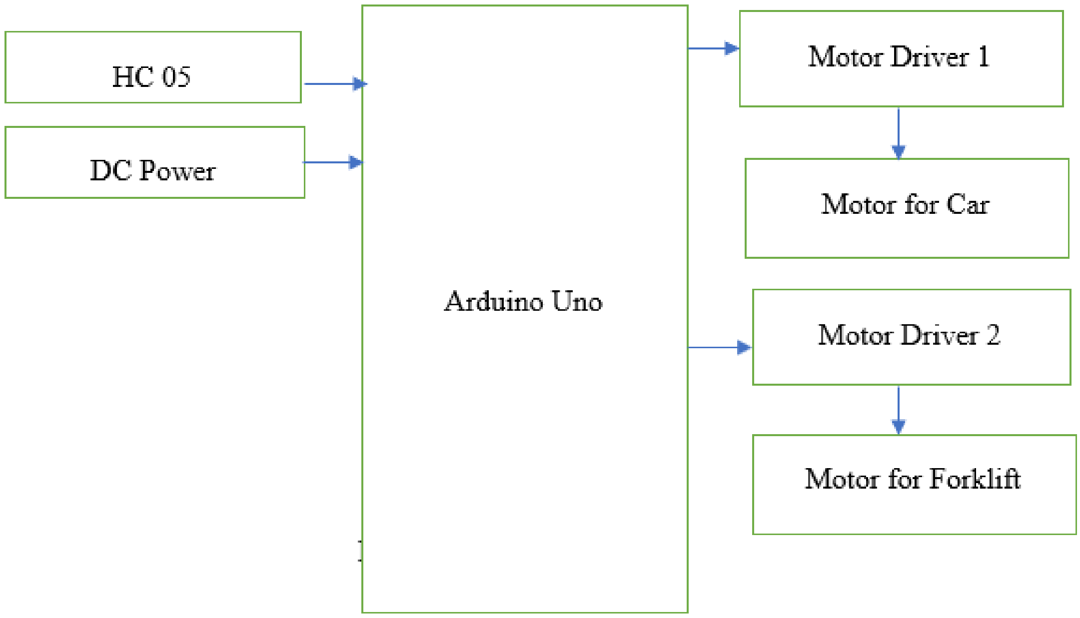

Figure 3.1: Block Diagram

3.3 Circuit Diagram

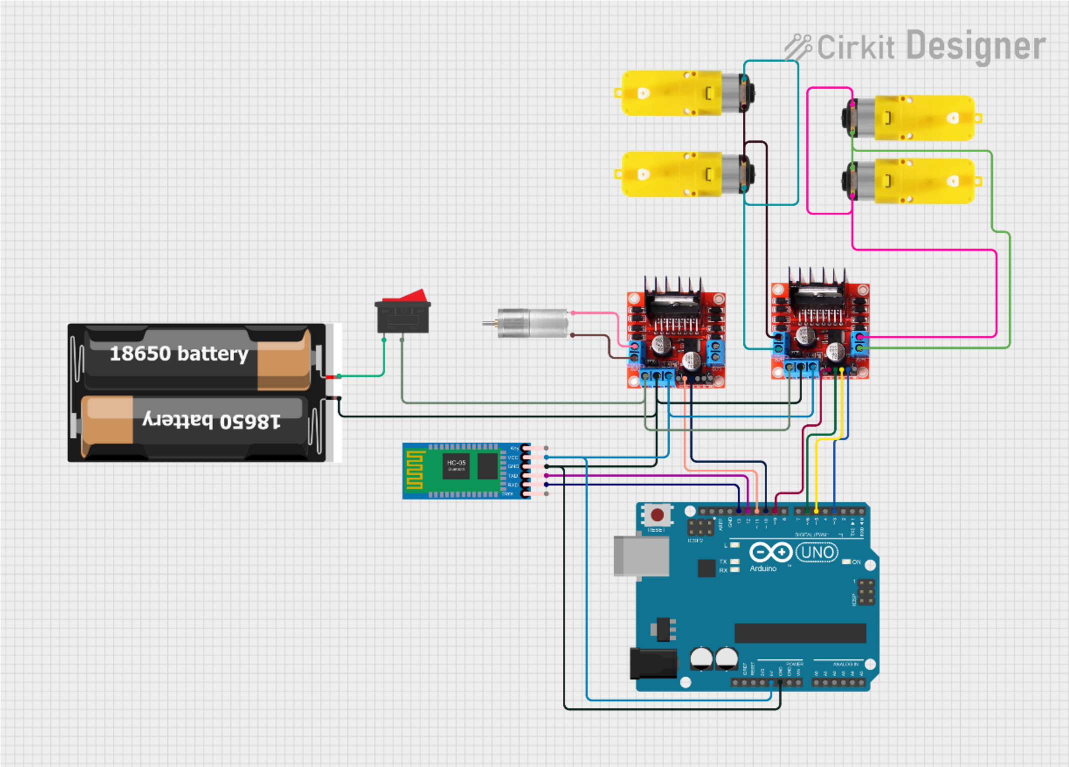

Figure 3.2: Circuit Diagram

As seen in the figure above, the electronic components have been soldered in a prototyping board. The general schema is the following: We utilized one 6V power supply which drives all the components. With this 6-volt provision, we powered the two servos, inductive sensor and the capacitive sensor. Next, we used a step-down converter to convert the 6V to 5V with which we can drive the Arduino via the 5V pin and power the ultrasonic sensor. When soldering one has to be careful and connect all the components to the same ground.

3.4 Working Principle

The remote-controlled mini forklift operates based on the integration of mechanical lifting, motorized movement, and wireless control systems. Its working principle can be explained through the following key components and processes:

Lifting Mechanism: The forklift uses a pulley and belt-based lifting system powered by a 12 V DC motor. When the motor rotates, it drives the belt, which moves the lifting platform vertically. Two supporting rods with bearings guide the platform, ensuring smooth and stable motion while lifting or lowering loads. A counterweight is mounted at the rear of the forklift to maintain balance and prevent tipping during lifting operations.

Chassis and Drive System: The mini forklift is built on a strong four-wheel-drive chassis. Each wheel is powered by a separate DC motor, allowing the vehicle to move forward, backward, and turn in all directions. The four-wheel-drive configuration ensures maximum traction, stability, and maneuverability, even while carrying heavy loads.

Wireless Control System: The forklift is controlled remotely using an RF-based wireless control system. The RF receiver mounted on the forklift receives signals from the RF remote transmitter. These signals are processed to control the motors, allowing the operator to drive the forklift and operate the lifting mechanism from a distance safely.

Load Handling and Safety: The system is designed to lift and place loads efficiently while maintaining balance and preventing mechanical strain. The combination of counterweight, supporting rods, and pulley mechanism ensures smooth vertical motion and prevents tipping. The wireless control allows the operator to handle loads without direct human contact, improving safety.

In summary, the working principle of the mini forklift is based on mechanical lifting using pulleys, motorized vehicle movement, and remote wireless control, all integrated into a compact and stable system capable of lifting and transporting loads efficiently.

3.5 Component List

- Arduino Uno
- L298N
- HC 05
- 3.7V Battery
- Motor
- Wheel
- T Lead Screw
- Patch Rod

3.5.1 Arduino Uno

In a nutshell, the Arduino Uno is an open-source microcontroller board based on the ATmega328 microcontroller. Various expansion boards shields, and other circuits can be interfaced with the board's digital and analog input/output pins. A type B USB cable is required to program the board using the Arduino IDE (Integrated Development Environment). It has 14 Digital pins and 6 Analog pins. An external 9-volt battery can be used to power it, or a USB cable can be used. It is also similar to the Arduino Nano and Leonardo. It can be downloaded from the Arduino website and distributed under the Creative Commons Attribution-Share Alike 2.5 license. Various layouts and production files are also available.

Figure 3.3: Arduino Uno

This initial release of the Arduino Software was given the name "Mega" for its Italian meaning. Arduino Uno was the first of a series of USB-based Arduino boards, and the Arduino IDE and Uno together were the first releases of Arduino software. A bootloader is already preprogrammed into the ATmega328, allowing programmers to upload new code without an external hardware programmer.

It is the first board not to include the FTDI USB-to-serial driver chip while using the STK500 protocol as its communication protocol. The USB-to-serial converter uses the Atmega16U2 (Atmega8U2 up to version R2) as an analog input.

Specifications:

Operative Voltage: 5V and 3.3V

Input Voltage: 5-12V (5V model) and 3.3-12V (3.3V model)

Digital I/O Pins: 14 Pins (16 are PWM output pins)

Analog Input Pins: 6 pins

DC Current per I/O Pin: 40 mA

Flash Memory: 32 kB (0.5 kB is taken by bootloader)

SRAM: 2 Kbytes

EEPROM: 1 Kbytes

Clock Speed: 16 MHz (5V model) and 8 MHz (3.3V model)

Table 3.1: ARDUINO UNO Configuration

Pin Group	**Pin Name**	**Description**
POWER SOURCE	VCC, GND, and RAW	VCC- Linked to +5V or +3.3V GND– Linked to Ground RAW– Linked to Unfettered power supply 5+V to +12V
Communication INTERFACE	UART Interface (RXD, TXD) SPI Interface (MOSI, MISO, SCK, SS) TWI Interface(SDA, SCL)	UART (Universal Asynchronous Receiver Transmitter) Interface can be used to program PRO MINI SPI (Serial Peripheral Interface) Interface can be used to program PRO MINI TWI (Two Wire Interface) Interface can be used to attach peripherals.
INPUT-OUTPUT PINS	PD0 to PD7 (8 pins of PORTD) PB0 to PB5 (6 pins of PORTB) PC0 to PC6 (7 pins of PORTC) ADC6 and ADC7 (2 extra pins)	They oblige various dedications, but they can be classified as data I/O pins.
ANALOG to DIGITAL CONVERTER	ADC0, ADC1, ADC2,…ADC7	They can be used for analog input and feature 10-bit resolution.
PWM	OC0A,OC0B,OC1A,OC1B,OC2A ,OC2B	It delivers PWM outputs and 8-bit tenacity.
RESET	RESET	Resets the controller.
EXTERNAL INTERRUPTS	T0 and T1	Hardware interrupts are provided by these two pins.
ANALOG COMPARATOR	AIN0 and AIN1	An internal comparator connects these two pins.

3.5.2 TT Gear Motor

Figure 3.4: TT Gear Motor

The TT Gear Motor is a small DC geared motor commonly used in robotics and DIY projects, especially in two-wheel and four-wheel robot cars. It consists of a DC motor combined with a plastic gearbox that reduces speed and increases torque.

- Operating Voltage: 3V – 6V DC (commonly 6V)
- Gear Ratio: Typically 1:48 or 1:120 (varies by model)
- Speed: ~200 RPM at 6V (approx.)
- Torque: High torque at low speed
- Shaft Type: Dual-shaft (for wheel + encoder)
- Lightweight and Compact

Working Principle

1. When DC voltage is applied, the motor shaft starts rotating.
2. The gearbox reduces the motor’s high speed.
3. Reduced speed results in increased torque at the output shaft.
4. This makes the motor suitable for moving robot wheels smoothly.

3.5.3 L298N Motor Driver

Figure 3.5: L298N Motor Driver

The L298N motor driver is a high-power, dual H-bridge motor driver IC used to control the speed and direction of DC motors, stepper motors, and other inductive loads. It acts as an interface between a microcontroller (such as Arduino, ESP32, or Raspberry Pi) and the motors, allowing the low-power control signals from the microcontroller to drive high-current motors safely.

Key Features

- Dual H-Bridge: Allows control of two DC motors independently in forward and reverse directions.
- Voltage Range: Operates with motor supply voltages from 5 V to 35 V.
- Current Capacity: Can deliver up to 2 A continuous current per channel (with proper heat sinking).
- PWM Speed Control: Supports Pulse Width Modulation (PWM) signals to regulate motor speed.

Working Principle

The L298N uses an H-bridge configuration to control the direction of current flow through the motor. By energizing specific transistors in the H-bridge, the driver can:

- Rotate the motor forward
- Rotate the motor backward
- Stop the motor by shorting or floating the motor terminals

By applying PWM signals to the enable pins, the L298N can vary the voltage delivered to the motors, effectively controlling their speed.

3.5.4 HC 05 Bluetooth Module

Figure 3.6: HC 05

The HC-05 Bluetooth module is a widely used wireless communication device that allows microcontrollers and embedded systems to communicate with smartphones, computers, or other Bluetooth-enabled devices. It is commonly used in robotics and remote-controlled projects due to its reliability, simplicity, and low power requirements.

Key Features

- Bluetooth Version: Bluetooth 2.0 + EDR (Enhanced Data Rate)
- Operating Voltage: 3.3 V to 5 V
- Communication: Serial UART (Universal Asynchronous Receiver/Transmitter) for easy connection to microcontrollers
- Range: Up to 10 meters in standard environments
- Modes: Can operate in Master or Slave mode, allowing flexibility in communication

Working Principle

The HC-05 module enables wireless serial communication between a microcontroller (such as Arduino, ESP32) and a Bluetooth-enabled device:

1. Pairing: The module pairs with another Bluetooth device using its unique ID.
2. Data Transmission: Once paired, the microcontroller can send or receive serial data wirelessly.
3. Control Commands: In robotic applications, commands from a smartphone app or PC can be transmitted via Bluetooth to control motors, sensors, or other actuators.

3.5.5 3.7V Lithium-ion Battery

Figure 3.7: 3.7V Lithium-ion Battery

A 3.7V Lithium-ion (Li-ion) battery is a rechargeable battery commonly used in portable electronic devices, robotics, and small-scale automation projects due to its high energy density, lightweight, and long cycle life. It serves as a reliable power source for motors, sensors, and microcontrollers in mobile applications.

Key Features

- Rechargeable: Can be recharged hundreds of times with proper care
- High Energy Density: Provides more energy in a smaller size compared to other battery types
- Lightweight: Ideal for mobile robotic systems where weight is critical
- Protection Circuits: Many Li-ion batteries include overcharge, over-discharge, and short-circuit protection
- The Li-ion battery operates based on the movement of lithium ions between the anode and cathode during charging and discharging:

1. Discharging: Lithium ions move from the anode to the cathode through the electrolyte, releasing energy that powers the connected circuit.
2. Charging: Lithium ions move back from the cathode to the anode, storing energy for later use.

This reversible ion movement allows the battery to be recharged multiple times, providing a stable and long-lasting energy source.

3.6 Instrument Cost Analysis

Table 3.2: Cost analysis of instruments

Serial No	Components	Price
01	Arduino Uno	650
02	HC 05	900
03	Motor 12 V	800
04	Yellow Gear motor	400
05	Yellow Wheel	400
06	L298N	400
07	3.7 V Battery	300
08	Battery Holder	50
09	T Lead Screw	300
10	Patch Rod	500
11	3.5 to 8 mm converter	400
12	Plain Rod	300
13	Charger	350
14	Switch	10
15	Wire and Others	500
	Total =	6210 BDT

CHAPTER 4
RESULT AND DISCUSSION

4.1 Introduction

The Results and Discussion chapter presents the performance evaluation and analysis of the remote-controlled mini forklift. This chapter focuses on examining how effectively the system meets the design objectives, including lifting capacity, movement efficiency, stability, and remote operation. The results obtained from practical testing are analyzed to assess the functionality of the mechanical, electrical, and control systems.

4.2 Project Picture

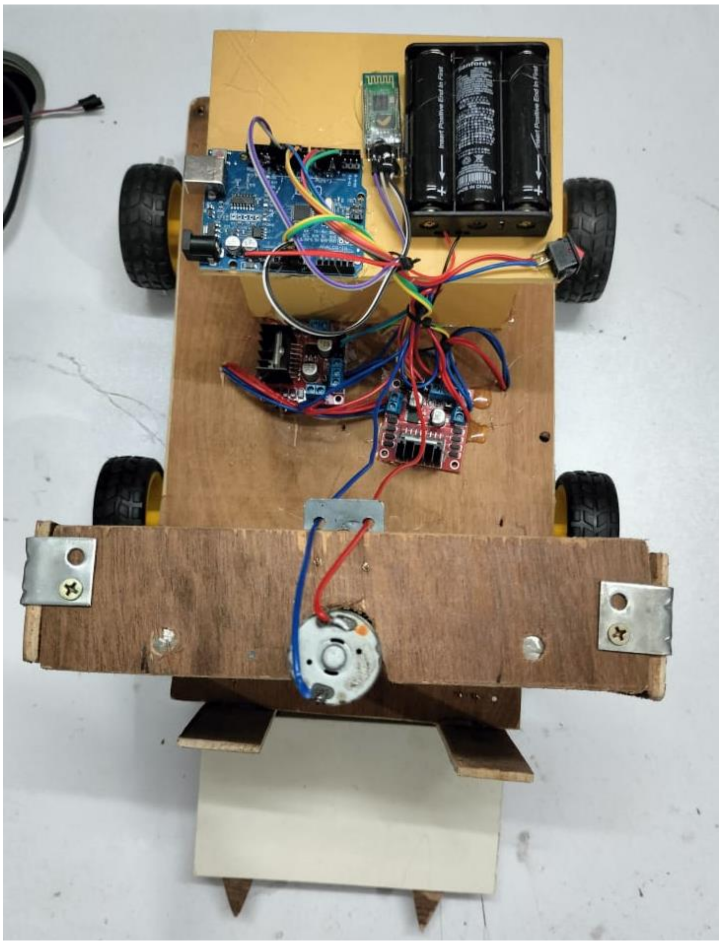

Figure 4.1: Project Picture

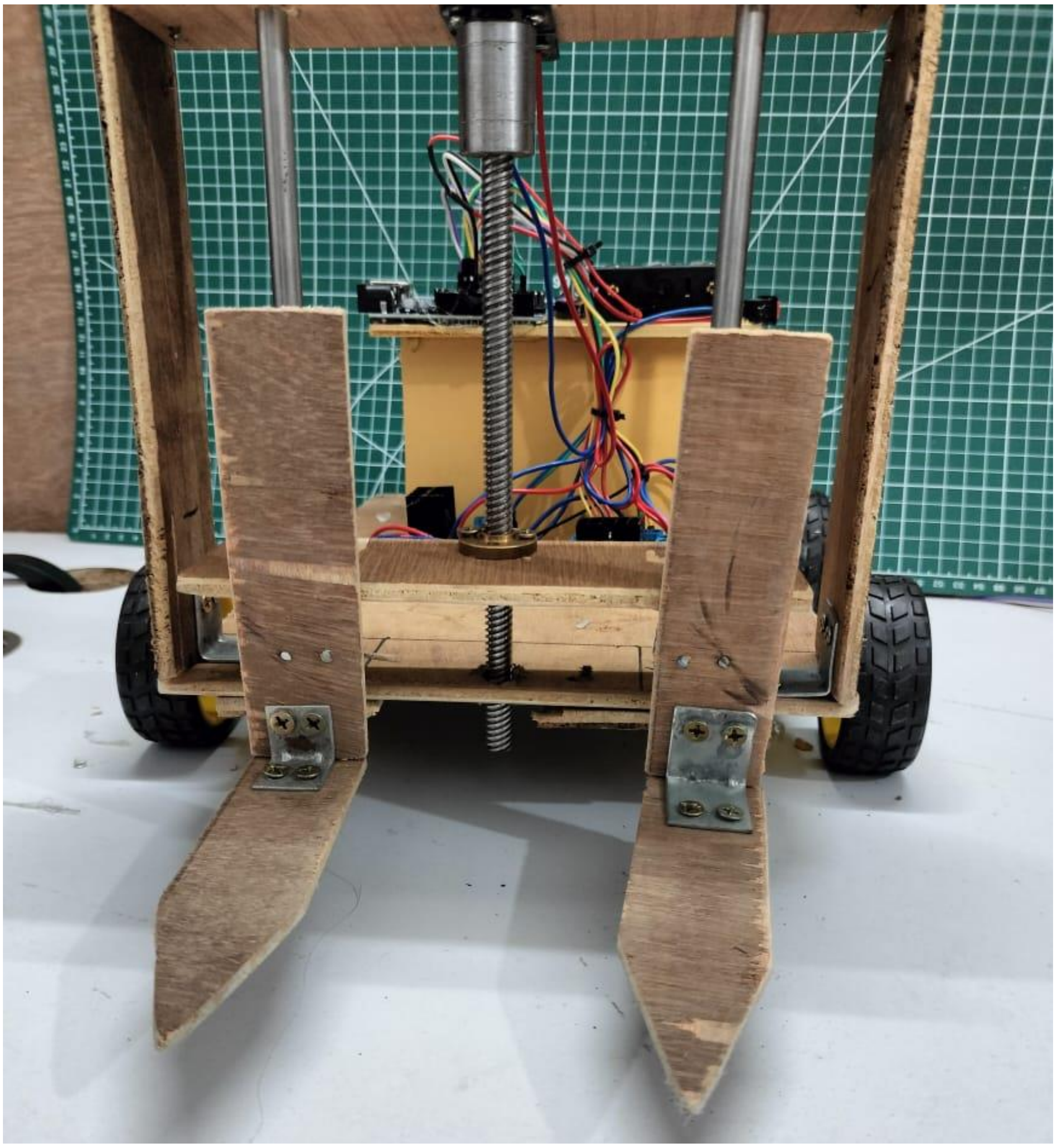

Figure 4.2: Picture of Forks

4.3 Calculation

Selection of electric motor

A) 200 RPM

B) RPM VOLTAGE = 12 VOLT

C) WATTS = 18 WATT

Torque of the motor

A) Torque = (P X 60) / (2 X 3.14 X N)

B) Torque = (18X 60) / (2 X 3.14 X 30) C)

Torque = 5.72 Nm

Torque = 5.72 x 10^3 N-m D)

The shaft is made of MS and its allowable shear stress = 42 MPa

E) Torque = 3.14 x fs x d ³ / 16 5.72 x 10³ = 3.14 x 42 x d ³ / 16 D = 8.85 mm

F) The nearest standard size is d = 9 mm.

Electrical (electric) power equation

A) Power P = I × V

Where,

V = 12 W = 18; I=18/12=1.5

B) A H.P = .02414 4.

Battery calculation

A) BAH /CI = 8 ah/420ma = 19 hrs

B) To find the Current Watt = 18 w

C) Volt = 12v Current =? P= V x I 18 =12 x I I = 18/12 = 1.5

D) AMPS battery usage with 1.5 AMPS BAH /I 8/1.5 = 5.3 hrs.

Load Carrying Capacity Calculation of the Mini Forklift

Given:

- Motor Voltage, $V = 12$ V
- Motor Speed = 200 RPM
- Motor Torque, $T = 0.25$ kg-cm
- Pulley Radius, $r = 1$ cm $= 0.01$ m
- Acceleration due to gravity, $g = 9.81$ m/s^2

Step 1: Convert Torque into SI Unit

$$1 \text{ kg-cm} = 0.0981 \text{ N\cdotpm}$$

$$T = 0.25 \times 0.0981 = 0.0245 \text{ N\cdotpm}$$

Step 2: Calculate Lifting Force

$$F = \frac{T}{r}$$

$$F = \frac{0.0245}{0.01} = 2.45 \text{ N}$$

Step 3: Calculate Maximum Load

$$\text{Load} = \frac{F}{g}$$

$$\text{Load} = \frac{2.45}{9.81} = 0.25 \text{ kg}$$

The load carrying capacity of the mini forklift is determined based on the torque rating of the lifting motor and the pulley mechanism used for vertical lifting. In this project, a 12 V DC motor with a rated speed of 200 RPM and a torque of 0.25 kg-cm is employed to drive the lifting system.

First, the motor torque is converted into SI units. Since 1 kg-cm is equivalent to 0.0981 N·m, the motor torque becomes 0.0245 N·m. The lifting force generated by the motor depends on the radius of the pulley attached to the motor shaft. Considering a pulley radius of 1 cm (0.01 m), the lifting force is calculated using the relation $F = \frac{T}{r}$, resulting in a force of approximately 2.45 N.

The maximum theoretical load that can be lifted is obtained by dividing the lifting force by gravitational acceleration (9.81 m/s^2), which gives a value of approximately 0.25 kg. However, in practical conditions, losses due to belt friction, bearing resistance, and motor inefficiency reduce the effective lifting capacity. To ensure safe and reliable operation, a safety factor is applied.

Considering these losses, the safe load carrying capacity of the mini forklift is estimated to be in the range of 120–150 grams.

4.4 Advantages

The remote-controlled mini forklift offers several benefits over traditional manual or full-scale forklifts, making it suitable for educational, research, and small-scale material handling applications.

Compact and Low-Cost Design: The mini forklift is small in size and economically feasible, making it affordable for institutions, workshops, and hobbyists.

Remote Operation: The RF-based wireless control allows the forklift to be operated safely from a distance, reducing the risk of accidents or injuries.

Efficient Load Handling: The pulley and belt-based lifting mechanism, combined with a counterweight, ensures smooth, stable, and efficient lifting and placement of loads.

Maneuverability: The four-wheel-drive system allows movement in all directions, making the forklift highly maneuverable in tight or confined spaces.

Educational Value: The mini forklift provides a practical model to study mechanical lifting, motor control, counterbalance systems, and wireless operation, making it ideal for teaching and training purposes.

Safe and Reliable: The compact design, supporting rods with bearings, and counterweight arrangement enhance stability and reduce the likelihood of tipping during operation.

Scalable Design: The principles used in the mini forklift can be scaled up for larger applications or modified to integrate advanced automation systems.

4.5 Limitation

Limited Load Capacity: Being a miniaturized model, it can lift only small loads, making it unsuitable for heavy industrial applications.

Restricted Operating Range: The RF-based wireless control has a limited range, which may restrict its operation in large areas or environments with signal interference.

Battery Dependency: The system relies on a 12 V battery to power the motors and control circuits, which limits continuous operation time and requires frequent recharging.

Speed Limitation: The motors used in the mini forklift provide moderate speed for safe operation, which may not be sufficient for time-critical tasks.

Mechanical Wear and Tear: Continuous use of the pulley and belt mechanism may lead to wear, requiring maintenance or replacement of components over time.

Environmental Constraints: The mini forklift is designed for indoor or controlled environments; it may not perform effectively on uneven surfaces, rough terrains, or in harsh weather conditions.

Simplified Control System: The RF-based control allows basic movement and lifting functions but lacks advanced automation features such as obstacle detection or precise positioning.

4.6 Application

Educational and Training Purposes: The mini forklift serves as a hands-on model for students and trainees to understand the working principles of forklifts, including lifting mechanisms, counterweight balance, and motor control.

Prototype Testing: It can be used as a prototype for studying material handling systems, testing new control methods, or experimenting with automation techniques before applying them to full-scale industrial machines.

Small-Scale Material Handling: The forklift can transport lightweight objects within workshops, laboratories, or small warehouses, reducing manual effort and improving efficiency.

Research and Development: The system provides a platform for research in robotics, remote-controlled vehicles, and wireless communication systems, enabling experimentation with sensors, automation, and control algorithms.

Demonstration Models: The mini forklift can be used in exhibitions, demonstrations, or workshops to showcase engineering concepts related to mechanical design, load balancing, and motor-driven systems.

Safe Remote Operation: Its wireless operation allows for safe handling of objects in hazardous or confined environments where human presence is limited or risky.

4.7 Discussion

The performance evaluation of the remote-controlled mini forklift demonstrates its effectiveness in lifting, transporting, and placing loads within a controlled environment. The integration of a pulley and belt-based lifting mechanism with a 12 V DC motor provided smooth and stable vertical motion, validating the design of the lifting system. The supporting rods with bearings contributed significantly to reducing friction and maintaining alignment, ensuring consistent operation during repeated lifting cycles.

The four-wheel-drive chassis enabled efficient maneuverability, allowing the forklift to move forward, backward, and turn in all directions. The use of individual motors for each wheel improved traction and control, particularly when carrying loads, demonstrating the effectiveness of the chosen drive configuration.

The RF-based wireless control system performed reliably within the specified operating range, enabling safe and convenient remote operation. The system successfully maintained balance during lifting operations due to the rear-mounted counterweight, preventing tipping even when handling maximum loads. However, some limitations were observed during testing. The lifting speed of the motor was moderate, prioritizing safety and stability over speed. The battery life limited continuous operation, requiring periodic recharging. Additionally, the RF control range restricted operation to relatively small areas, and the forklift performance was less effective on uneven or rough surfaces. Overall, the discussion indicates that the mini forklift successfully demonstrates key concepts of material handling, mechanical design, and remote operation. The observed performance aligns closely with the intended objectives, making the system suitable for educational, research, and small-scale material handling applications.

CHAPTER 5
CONCLUSION

5.1 Conclusion

The remote-controlled mini forklift project successfully demonstrates the fundamental principles of material handling systems in a compact and cost-effective model. The integration of a pulley and belt-based lifting mechanism, powered by a 12 V DC motor, provided smooth and stable vertical motion, while the supporting rods and bearing arrangements ensured precise alignment and reduced mechanical friction. The counterweight effectively maintained balance during lifting operations, preventing tipping and enhancing operational safety. The four-wheel-drive chassis, equipped with individual DC motors for each wheel, allowed the mini forklift to move efficiently in all directions, demonstrating good maneuverability and traction even when carrying loads. The RF-based wireless control system enabled safe and convenient remote operation, illustrating the practical application of remote-controlled industrial machines. Testing and evaluation of the system confirmed that the mini forklift meets the design objectives and provides a reliable platform for understanding mechanical design, load handling, motor control, and wireless operation. This project serves as a valuable educational and research tool, offering insights into the design, fabrication, and operation of material handling equipment.

In conclusion, the mini forklift is a functional, safe, and effective model that combines mechanical, electrical, and control system principles, and can be further enhanced for advanced applications in automation, robotics, and small-scale material transport.

5.2 Future Scope

While the remote-controlled mini forklift demonstrates the fundamental principles of material handling effectively, there are several areas where its performance, functionality, and versatility can be further improved. Future enhancements may include:

1. **Battery and Power Optimization:**Upgrading to higher-capacity or rechargeable lithium-ion batteries can extend operational time, reduce downtime, and improve overall efficiency.

2. **Advanced Control Systems:** Integration of microcontrollers such as Arduino, ESP32, or Raspberry Pi can allow for more sophisticated control features, including speed regulation, precise positioning, and programmable lifting sequences.
3. **Automation and Sensors:** Incorporating sensors such as ultrasonic, infrared, or load sensors can enable obstacle detection, autonomous navigation, and automated load handling, making the system semi- or fully autonomous.
4. **Enhanced Lifting Mechanism:** Using stronger motors or improving the pulley and belt design can increase load capacity and lifting speed, allowing the forklift to handle heavier objects more efficiently.
5. **Remote Communication Improvements:** Replacing the RF system with Bluetooth, Wi-Fi, or IoT-based communication can increase control range, allow multi-device operation, and enable smartphone or cloud-based control.
6. **Structural Improvements:** Using lightweight yet strong materials such as aluminum or high-strength polymers can reduce weight while maintaining stability, improving maneuverability and efficiency.
7. **Modular and Scalable Design:** Developing a modular design can allow easy replacement or upgrading of components and enable scaling up the design for larger industrial applications.

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