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Design and Fabrication of Remote Controlled Screw Operated Mini Forklift

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Abstract:

This project involves the development of a remote-controlled mini forklift using Arduino and HC05 Bluetooth module. The primary objective of this project is to fabricate a mini forklift that can be remotely controlled through wireless communication. The mini forklift is powered by a 12V lead-acid battery and utilizes four DC gear motors for movement and one Johnson gear motor for lifting. The motors are controlled using a 4-channel relay module connected to the Arduino nano. The Bluetooth module is used to establish wireless communication between the remote controller and the forklift. The remote controller sends signals to the forklift through wireless communication, and the Arduino on the forklift receives and processes these signals to control the motors and lifting mechanism. The chassis and support frame for the forklift are made using sheet metal, and the components are connected using jumper wires and burg strips. The PCB is used for mounting the components and to minimize the number of wires required for connections. This remote-controlled mini forklift has several advantages, including its compact size, maneuverability, and ease of use. It can be used in various industrial applications, such as material handling and logistics. However, there are also some limitations to this project, such as its limited load-carrying capacity and the limited range of the Bluetooth module. Furthermore, the forklift's lifting mechanism may not be suitable for heavy lifting applications.

Keywords: Forklift, Arduino, HC05 Bluetooth module, Johnson gear motor, 4-channel relay module, wireless communication, material handling.

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INTRODUCTION

In general, the forklift can be defined as a tool capable of lifting hundreds of kilograms. A forklift is a vehicle similar to a small truck that has two metal forks on the front used to lift cargo. The forklift operator drives the forklift forward until the forks push under the cargo, and can then lift the cargo several feet in the air by operating the forks. The forks, also known as blades or tines, are usually made out of steel and can lift up to a few tons. Forklifts are either powered by gasoline, propane, or electricity. Electric forklifts relay on batteries to operate. Gasoline or propane forklifts are sometimes stronger or faster than electric forklifts, but they are more difficult to maintain, and fuel can be costly. Electric forklifts are great for warehouse use because they do not give off noxious fumes like gas powered machines do.

Forklifts are most often used in warehouses, but some are meant to be used in outdoors. The vast majority of rough terrain forklifts operate on gasoline, but some use diesel or natural gas. Rough terrain forklifts have the highest lifting capacity of all forklifts because it has heavy duty making tyres it possible to drive them on uneven surfaces, outdoors. It is important for forklift operators to follow all safety precautions when using a forklift. Drivers should be careful not to exceed the forklift's weight capacity. Forklift operators also need to be able to handle forklift's rear wheel steering. Driving a forklift is similar to driving a car in reverse, meaning that the driver must constantly steer to keep it moving in a straight line. The driver must be aware of the forklift's ever-changing center of gravity and avoid making any quick sharp turns or going too fast. It is advisable that anyone who operates a forklift be fully trained and licensed. Forklifts have revolutionized warehouse work. They made it possible for one person to move thousands of pounds at once. Well-maintained and safely operated forklifts make lifting and transporting cargo infinitely easier.

OBJECTIVE

The objective of this project is to fabricate a compact and maneuverable remote-controlled mini forklift that is capable of lifting small loads using Arduino and Bluetooth technology. The aim is to demonstrate the feasibility of using this type of technology in small-scale industrial applications. The forklift should be capable of moving easily through narrow

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spaces, making it suitable for use in warehouses, factories, and other industrial settings where space is limited. The use of Bluetooth technology enables wireless communication between the remote controller and the forklift, increasing safety and flexibility. The project aims to showcase the capabilities of Arduino technology, which is widely used in the field of automation and control, by programming the forklift to perform specific tasks, increasing its efficiency and versatility. Overall, the objective is to demonstrate the potential of remote-controlled mini forklifts in small-scale industrial applications and to explore the possibilities offered by modern technologies in this field.

LITERATURE SURVEY

1) “Design and Fabrication of Driverless Remote Operated Forklift” by Rohit Shelote, Saurabh Malwe et al. (March 2015): This paper describes the development of a Driverless Remote Operated forklift with a vision system for handling wood pallets. The authors explain the design and construction of the forklift and the vision system, which uses a camera and image processing techniques to detect and locate the pallets. The paper also includes a demonstration of the forklift in operation.
2) "A review of control systems for autonomous forklifts in warehouse environments" by M. N. Nordin, N. A. Rashid, and M. A. Salam et al. (January 2017): This paper provides a comprehensive review of control systems for autonomous forklifts in warehouse environments. The authors discuss different control techniques used in autonomous forklifts, including fuzzy logic, neural networks, and genetic algorithms, and compare their effectiveness in different scenarios. The paper also highlights the challenges faced in developing control systems for autonomous forklifts, such as uncertainty in the environment and the need for real-time decision-making.
3) “Design and Development of Mechanical Forklift” by Lobo Allwyn M and Khebude Karan N et al. (March 2018): This paper proposes design and development of mechanical forklift in a warehouse environment. The system includes obstacle detection and collision avoidance using laser sensors and a vision-based tracking system. The authors also propose a novel control algorithm that takes into account the position and orientation of the forklift and the load being carried.

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4) "Fabrication of mini forklift using WIFI module" by K.Sudheer kumar, A.Srikanth reddy et al. (September 2018): This paper presents the design and fabrication of mini forklift using WIFI module using Bluetooth communication and an Arduino board. The authors describe the components used in the project, including the DC motors, relay module, wheels, and battery, and provide a detailed explanation of the programming and circuit design used. The paper also includes a demonstration of the forklift in operation.
5) "Forklift path planning in warehouse environments" by T. K. Chu, K. M. Li, and K. C. Chan et al. (May 2019): This paper discusses the path planning problem for forklifts in warehouse environments. The authors propose a hybrid path planning algorithm that combines A* search and particle swarm optimization to find the optimal path for a forklift to move from one location to another in a warehouse. The paper includes simulation results demonstrating the effectiveness of the proposed algorithm.
6) "Development of an autonomous forklift system using a vision-based tracking system" by H. Lee, H. Kim, and H. Kim et al. (June 2020): This paper describes the development of an autonomous forklift system using a vision-based tracking system. The authors explain the design and construction of the forklift and the vision system, which uses a camera and image processing techniques to track the forklift's position and orientation. The paper also includes a demonstration of the forklift in operation, showing its ability to navigate autonomously through a warehouse environment.

COMPONENTS DESCRIPTION

1) **Arduino Nano:** The Arduino Nano is a small, compact board that is used as the main controller for the remote-controlled mini forklift. It features an ATmega328P microcontroller, which runs at 16 MHz and has 32KB of flash memory. The board is designed to be easy to use, with a simple USB interface for programming and power supply.
2) **HC-05 Bluetooth module:** The HC-05 Bluetooth module is used to establish wireless communication between the remote controller and the forklift. It operates at a frequency range of 2.4GHz to 2.4835GHz and has a maximum range of 30 meters. It

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uses Bluetooth version 2.0 and supports SPP (Serial Port Profile) communication protocol.

3) **4-channel relay module:** The 4-channel relay module is used to control the four DC gear motors for movement and one Johnson gear motor for lifting. It is connected to the Arduino nano and operates on a 5V DC power supply. The relay module features four SPDT relays, each with a maximum switching voltage of 30VDC and a maximum switching current of 10A.
4) **Jumper wires and burg strips:** Jumper wires and burg strips are used for making connections between the components of the forklift. Jumper wires are pre-cut wires with pins at both ends that can be easily inserted into the headers on the Arduino and other components. Burg strips are connectors that allow multiple wires to be connected to a single header.
5) **Lead-acid battery:** The 12V lead-acid battery is used to power the forklift. It has a capacity of 1.3Ah and operates on a nominal voltage of 12VDC. It is a rechargeable battery and is commonly used in applications such as backup power supply and electric vehicles.
6) **DC gear motors:** The forklift utilizes four DC gear motors for movement. These motors have a power rating of 12V, 2A, and a speed of 100 rpm. They are high-torque motors that provide the necessary power to drive the forklift's movement.
7) **Johnson gear motor:** The Johnson gear motor is used for lifting the objects. It has a power rating of 12V, 2A, and a speed of 60 rpm. The Johnson gear motor is a high-torque motor that is capable of lifting the weight of the objects placed on the forklift.
8) **Adapter:** The 12V adapter is used to charge the lead-acid battery. It is a power supply that operates on AC voltage and provides a DC output of 12V.
9) **PCB:** The PCB is used for mounting the components of the forklift. It is a board made of fiberglass or plastic, with conductive pathways etched onto its surface. The PCB helps to reduce the number of wires required for connections and makes the forklift more compact.
10) **SPST switches:** The forklift utilizes SPST (Single Pole Single Throw) switches for controlling the movement and lifting of the forklift. These switches have two

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terminals and are used to make or break a connection. The SPST switches used in this project are rated at 5A and operate on a voltage of 12V.

11) **Lead screw:** The lead screw is used for lifting the objects on the forklift. It has a screw thread of 10mm and a pitch of 1.5mm, which allows for precise and controlled lifting of the objects.
12) **Sheet metal:** The sheet metal of 0.9mm thickness is used to create the chassis and support frame for the forklift. It is a durable and strong material.

METHODOLOGY

To fabricate the Remote Controlled Mini Forklift, it all begins with a systematic plan where the fabrication involves eight steps of processes. The steps are as follows:

1) **Design and Planning:** The first step is to design the mini forklift and plan the required components, tools, and equipment. The design includes the dimensions, weight capacity, and the number of wheels required for the forklift.
2) **Circuit Design and Implementation:** The circuit design involves designing the electrical circuit that powers the forklift and connects the Bluetooth module with the Arduino Nano. The circuit is implemented using a printed circuit board (PCB), jumper wires, and burg strips.
3) **Component Assembly:** The next step is to assemble the components required for the project. This includes the Arduino Nano, Bluetooth module (HC05), DC gear motors, Johnson gear motor, lead-acid battery, relay, and other electronic components
4) **Programming:** The next step is to write the code for the forklift's Arduino Nano controller. The code is written in C language and uploaded to the controller using a USB cable.
5) **Mechanical Assembly:** Once the circuit and code are ready, the mechanical assembly of the forklift can begin. This involves cutting and bending the sheet metal to create the chassis and support frame. The motors and wheels are then attached to the chassis and connected to the electronic components.
6) **Testing and Debugging:** After the assembly is complete, the forklift is tested to ensure that it is functioning correctly. The debugging process involves identifying and correcting any issues that arise during the testing phase.

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7) **Final Assembly:** Once the testing and debugging are complete, the final assembly of the forklift is done. The battery and adapter are connected to the electronic components, and any final adjustments or modifications are made.
8) **Performance Evaluation:** Finally, the performance of the forklift is evaluated to determine if it meets the objectives. This involves testing the lifting capacity, speed, and maneuverability of the forklift under various conditions.

Overall the methodology involves a combination of mechanical design, electrical engineering, programming, and testing to create a functioning remote controlled mini forklift.

WORKING PRINCIPLE

The remote-controlled mini forklift is a small-scale model of a forklift that can be controlled wirelessly using a remote controller. The project uses an HC05 Bluetooth module and an Arduino Nano board to enable wireless communication between the remote controller and the forklift. The Bluetooth module is a small electronic component that allows wireless communication over a distance of up to 50 meters. It receives the signals from the remote controller and sends them to the Arduino Nano board. The Arduino board acts as the brain of the forklift and processes the signals received from the Bluetooth module.

The forklift is powered by a 12V lead-acid battery and uses four DC gear motors for the wheels and one Johnson gear motor for the lifting mechanism. Each of the four DC gear motors is rated at 12V, 2A, and 100 RPM, while the Johnson gear motor is rated at 12V, 2A, and 60 RPM. The motors are connected to the Arduino board through a 4-channel relay module. The forklift's chassis and support frame are made from sheet metal that is 1 to 1.5 mm thick. The lifting mechanism consists of a small hook that is attached to a lifting arm controlled by a small servo motor. The servo motor rotates to move the lifting arm up or down, allowing the hook to lift or lower objects.

To control the movement of the forklift, the Arduino board sends signals to the relay module, which controls the DC gear motors for the wheels. The motors are connected to the wheels through a gearbox, which enables precise control of the forklift's movement. By varying the speed and direction of the motors, the forklift can move forward, backward, and

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turn left or right. The remote controller sends signals to the HC05 Bluetooth module to control the movement of the forklift. The controller has four buttons, each of which corresponds to a specific movement of the forklift. When a button is pressed, the remote controller sends a signal to the Bluetooth module, which sends it to the Arduino board. The Arduino board processes the signal and sends the appropriate signals to the relay module, which controls the motors and enables the forklift to move in the desired direction.

In summary, the remote-controlled mini forklift uses wireless communication between the remote controller and the forklift to enable precise control of the movement and lifting mechanism. The project uses an HC05 Bluetooth module and an Arduino Nano board to enable wireless communication, and four DC gear motors and one Johnson gear motor for the wheels and lifting mechanism.

DESIGN ANALYSIS and RESULTS

Design of lead screw:

p = pitch of the lead screw = 1.5mm.

d = diameter of the lead screw = 10mm.

m = mass carried by the lead screw = 3kg.

g = Acceleration due to gravity = $9.81ms^{-2}$

l = lead of the lead screw = 1.5mm

1. Total load -

Total Load (W) = Mass (m) × Acceleration due to gravity (g)

= 3*9.81

= 29.43N.

2. Mean Diameter of the lead screw (d_m) –

Mean diameter **(**d_m) = d-(0.5*p)

= 10-(0.5*1.5)

= 9.25mm.

3.Helix Angle of the lead screw (α) –

The lead screw has single start threads.

Therefore, l = p = 1.5 mm

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$\tan\alpha = \frac{l}{(\pi * \mathrm{dm})} = \frac{1.5}{(\pi * 9.25)}$

$\alpha = \tan^{-1}(0.051644)$

$\alpha = 2.95°$

4.Friction Angle (Ø) –

Coefficient of friction(μ) = 0.08

$\tan Ø = \mu$

$Ø = \tan^{-1}(0.08)$

$Ø = 4.57°$

5.Torque required to lift and lower the load –

Torque(T) = $(W*d_m)/2 \times \tan(Ø \pm \alpha)$

For lifting:

T_1 = Torque required for lifting the load

$T_1 = (W*d_m)/2 \times \tan(Ø+\alpha)$

$= \frac{29.43*9.25}{2} * \tan(2.95 + 4.57)$

= 136.113*0.132119

= 17.983 N-mm.

For lowering:

T_2 = Torque required for lowering the load

$T_2 = (W*d_m)/2 \times \tan(Ø-\alpha)$

$= \frac{29.43*9.25}{2} * \tan(4.57 - 2.95)$

= 136.113*0.02817

= 3.834 N-mm.

6. Holding Torque of the Johnson Motor (T_h) -

Voltage of the motor (V) = 12v

Current of the motor (I) = 2 amp

Speed of the motor = 60rpm

Power (P) = V*I

=12*2

=24watt

Holding torque (T_h) = $\frac{p*60}{2\pi N}$

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$$= \frac{24*60}{2*\pi*60}$$

= 3.82 N-m

= 38.95kg-cm

7. Mechanical Efficiency (η)-

$$\eta = \frac{tan\alpha}{\tan(\alpha+\emptyset)}$$

$$= \frac{\tan(2.95)}{\tan(2.95+4.57)}$$

$$= \frac{0.051643}{0.132119}$$

= 0.39088*100

= 39.08%

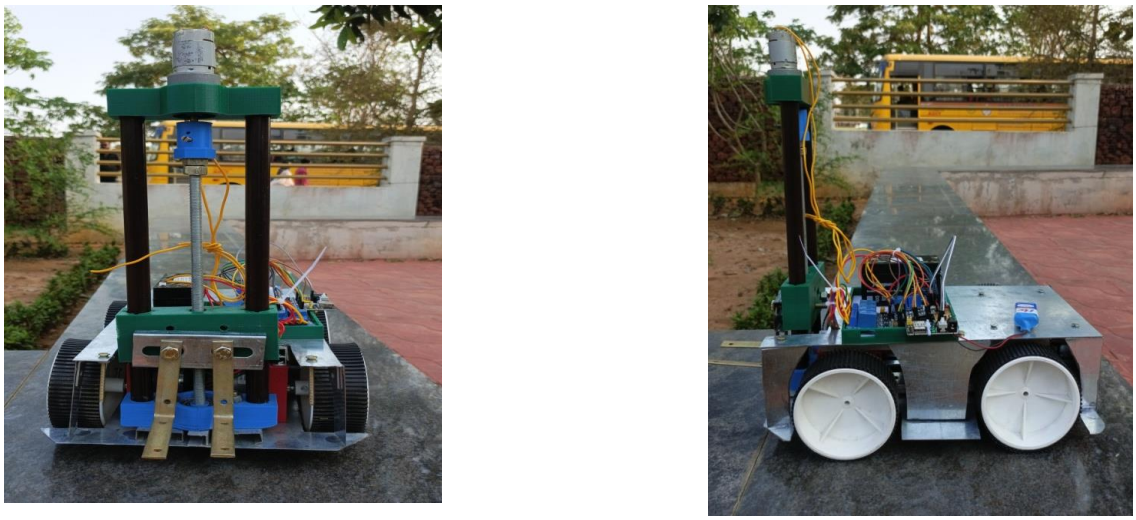

Figure: Remote Controlled Mini Forklift

CONCLUSION

The remote-controlled mini forklift project has been successfully fabricated using Arduino and HC-05 Bluetooth module. The forklift is controlled by a remote controller through wireless communication. The forklift is capable of lifting a weight up to 4kgs and can move forward, backward, left, and right. This project has several advantages, including cost-effectiveness, ease of use, and the ability to operate in tight spaces. It has potential applications in various industries, such as warehouses, factories, and construction sites, where the movement of goods is required.

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Future scope

Future work could involve improving the lifting capacity and range of the forklift, enhancing its stability, and implementing advanced safety features. Furthermore, integrating the forklift with a computerized inventory system could further enhance the efficiency of material handling in industries. Overall, this project has successfully demonstrated the potential of remote-controlled forklifts to revolutionize the material handling process in various industries. With further development and improvements, remote-controlled forklifts could become a standard tool in material handling and logistics operations.

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