Journal of Applied Science, Engineering, Technology and Management
Vol. 1, Issue 1, June 2023 pp. 01 - 05

Automated Guided Vehicle Using Advanced Line Follower Algorithm For Transporting Heavy Payloads

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***Abstract*—Automation describes a wide range of technologies that reduce human intervention in processes. In general, automation can be defined as a technology concerned with performing a process by means of programmed commands combined with automatic feedback control to ensure proper execution of the instructions. In this paper, the authors describe an approach that was initiated towards automated transportation of heavy components, which has multiple industrial and commercial applications such as warehouses, libraries, hospitals etc. This work uses Arduino Uno microcontroller, IR sensors for path detection, and DC Motors to move the trolley using the input signals from the user. Therefore, providing a low cost, power efficient product to aid the user. Through implementation of advanced line follower system, the trolley is programmed to move along a preplanned route to traverse across multiple sections of the library carrying a huge payload (up to 100 kg). This paper presents the development of an automated trolley to be implemented in a library environment. "Automated Library Trolley" aids in hands free transportation of books without compromising its working conditions and increasing its efficiency.**

Keywords*—Automation, Arduino Uno, IR sensors, Human intervention, Feedback, Components, IR sensors, DC motors, payload, efficiency

I. Introduction

A library is a collection of information, sources, resources, books, and services, and the structure in which it is housed. Libraries have materials arranged in a specified order according to a library classification system so that items may be located quickly and collections may be browsed efficiently [1].

The central library at our institution, *Federal Institute of Science and Technology*, Angamaly, Kerala, India was taken as the cite for implementing this automated trolley. Here, the average weight of books transported within the library during a day comes around 80-120 kilograms. This work integrates an automated transportation system in the library, to help library staff carry heavy payload without physical labour, i.e. to propose an automated transportation system for books in a library.

The newly designed trolley uses an advanced line follower mechanism and works without compromising the efficiency and increase convenience.

The same model can be adapted at multiple Industrial and commercial workspace where hands free transportation can also encourage safety of the workers (e.g. Warehouses, chemical plants etc.). The innovation is targeted to be a choice to implement at areas requiring transportation of heavy goods decreasing involvement of a human individual and increase the efficiency of task through advanced navigating technique and faster execution [2-4].

II. Design and Fabrication

A. Design Specifications and model

The automated trolley is capable of taking various degrees of turns, as in traverse complex routes without compromise in speed and time and have advantage over manual labour. The trolley must be insensitive to environmental factors such as lighting and noise and maintain a state of low independency on external factors for completion of the assigned task [5-8].

The trolley is 58cm wide so that it can pass in between the library shelves. The length of the trolley is 77cm, height of the base compartment is 25cm and the height of the storage compartment is 23cm. These dimensions were selected to accommodate the ideal number of books without overloading the motors. The dimensions are also ideal for the trolley to

Received for review: 07-02-2023
Accepted for publication: 16-05-2023
Published: 26-05-2023

traverse throughout the library. The corresponding dimensions are shown on Fig. 1.

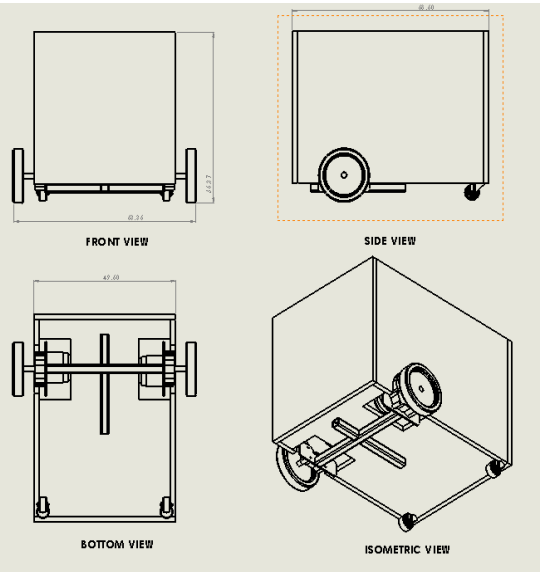

Fig. 1. Schematic 2-D drawing

The trolley is constructed using multi-wood panels having 17mm thickness, and square members of 20x20 cross-section and 3mm thickness. The motors are fitted onto a metal plate of 8mm thickness and this plate is directly welded to the beam. The beam is screwed onto the base of the multi-wood structure. This restricts all six degrees of freedom.

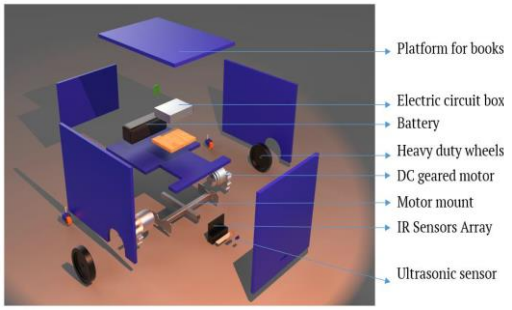

Fig. 2. Exploded View – design of Automated Trolley

The castor wheels are directly screwed onto the base of the multi-wood structure. The bottom compartment will have enough space for the electronic components to be placed.

Fig. 3. Automated Library Trolley after fabrication

The cross shaped beam was designed to transfer the maximum amount of power to move the body without overstressing the multi-wood. The usage of the motor mount plate helps to stabilize the motor and it can handle the torque of the motor without failure [9,10].

B. Structural analysis of motor-mount

The cross-beam structure is used as a strong support for the motors and to reduce the load taken by the multi-wood. A static structural test in ANSYS is done to check the maximum stress occurring in the beam to check if the stresses exceed the yield stress of the beam (250 MPa). The maximum stress is at the holes.

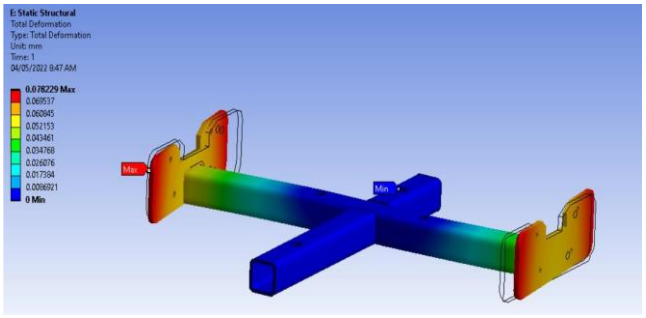

Fig. 4. Total deformation on the motor mount

The deformation test also suggests that even when the motors are rotating in the opposite direction, the deformation occurring in the mount is negligible.

C. Hardware and components

a) Arduino Uno R3 board:

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P, the board is equipped with sets of digital and analog input/output (I/O) pins which can be interfaced with different circuits or outputs.

The board has 14 digital I/O pins (six capable of PWM output), 6 analogue I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type-B USB cable. It can be powered by the USB cable or by an external battery. It is a low-cost, flexible, and easy-to-use programmable open-source micro-controller board that can be integrated into a variety of electronic projects.

Fig. 5. Arduino Uno

Specifications:

- ATmega328 micro-controller
- Input voltage: 7-12V
- 14 Digital I/O Pins (6 PWM outputs)
- 6 Analog Inputs

- 32k Flash Memory
- 16Mhz Clock Speed

b) DPDT Relay:

A DPDT relay is an electrical switch which consists of a set of input terminals for a single or multiple control signals, and a set of operating contact terminals. Here, the relay is used to switch motor direction (by switching its polarity), this helps the motor to turn and come to a stop [11].

Fig. 6. DPDT Relay

c) MOS Driver Module:

IFR520 MOS Driver Module which consist of a MOSFET transistor that is designed to switch heavy DC loads from a single digital pin of your microcontroller. Its main purpose is to provide a low cost way to drive a DC motor for robotics applications, but the module can be used to control most high current DC loads [12]. Screw terminals are provided as an interface to the load and external power source. An LED indicator provides a visual indication of when your load is being switched. Here, it is used to control the relay using the Arduino Uno.

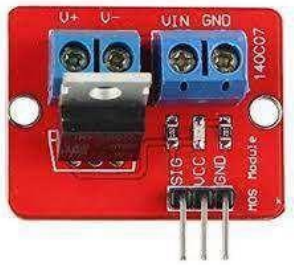

Fig. 7. MOS Driver Module

d) DC Geared Motor:

This is a very popular high torque reduction motor and extremely reliable with its power requirements. It is the most commonly used motor for scooters, bikes, and wheelchair. This motor is capable of rotation in both, the clockwise or counter clockwise direction by reversing the motor's power wires [13,14].

Fig. 68. DC Geared Motor

e) Battery:

LiFePO4 Rechargeable Battery Pack is a battery pack with a nominal voltage of 24V and can be fully charged up to 29.2V. This battery pack has 24 cells which gives it a capacity for 1C (18A) continuous discharge and 3C (54A) discharge for a few seconds. The nominal capacity of the battery pack is 18000mah. The battery pack has an in-built BMS which prevents the battery from over charging above 29.2Vand also prevents it from over discharging below 22.5 volts. LiFePO4 cells offer much longer lifetime and more number of working cycles as compared to a Lead Acid or a Li-ion cell [15].

f) Motor driver:

This Motor Controller is 24V-250W and includes attachments for the motor, accelerator, brake, battery, battery charging, brake light, power lock. DC Motors are popularly known as scooter motors or general application motors. It is extremely durable and reliable. It's commonly found in 24V scooters or even small kiddies carts and it's also been a proven motor in robotics.

D. Circuit overview

The basic line follower has about 2 IR sensors connected to the Arduino. This motor driver is then connected to the Arduino uno. The motors are connected to the L298N motor, and this motor driver is connected to the Arduino. A 3 cell Li battery is supplied to the Arduino which then provides the power supply to the entire components.

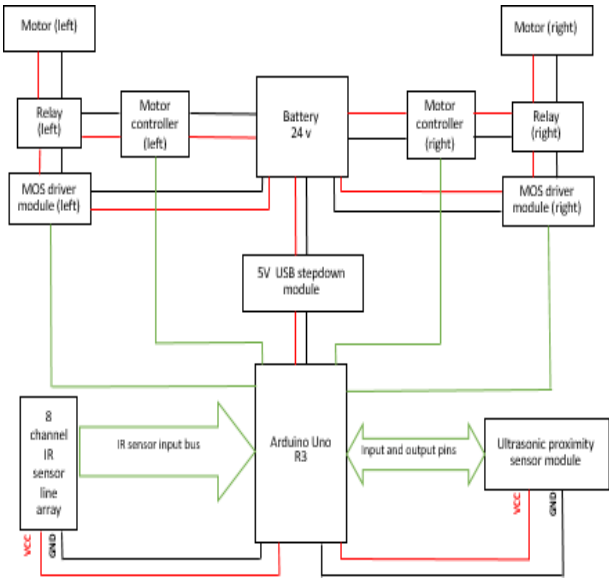

Fig. 9. Circuit layout

The ultrasonic sensor, the RFID sensors, and the 8 array IR sensors are taken as inputs for the microcontroller. The motor controller and the MOS driver are connected to the relay. The relay is to switch the motors rotation since the available motor can only rotate in one direction. This relay is directly connected to the motors hence switching its rotation depending upon the function.

The ultrasonic sensor is to check if there are any obstacles in front of the bot, and stopping its collision if the proximity is below 50 cm. The RFID sensor is used to turn on and turn off the line follower by inserting the unique identification of the tags. This is to improve the security of the line follower robot.

III. Results and Discussion

The proposed automatic trolley has a lot of potential in supply chain, and material handling operations and can be used in industries to carry and automate transportation with a high safety margin. The trolley can also be used to carry hazardous equipment and material and has a variety of applications in the chemical industry. However, the following things are to be noted. The width of the path should be at least 45mm so that it can cover minimum 2 sensors. It should also be noted that the load carrying capacity of the trolley is about 150 kgs.

The following functions are integrated into the trolley to make it an efficient transporter.

a) Path detection

The trolley is an advanced proportional line follower, with embedded system for IR sensors for path detection and movement, code is defined for line follower and a pre-planned route layout is implemented to the required workspace (here Library).

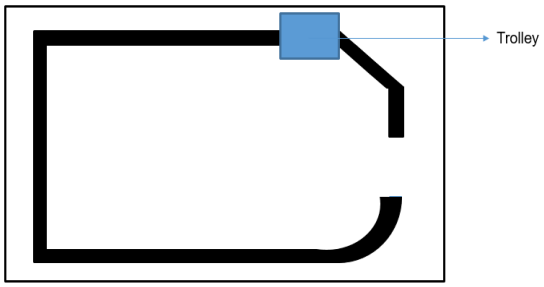

Fig. 10. Test track for the advanced line follower

The robot begins its function with the click of the start/stop button. The IR sensors can detect any one of the 2 signals HIGH or LOW (1 or 0) and the inputs received from the sensors are fed into the motors with through the circuit. When the two middle most sensors detect the black surface and rest of the array detect white surface the robot is programmed to move forward. The robot is placed on a pre-planned route designed for our advanced line follower as shown.

Fig. 11. Line follower path

The black outlines in the exterior is to help the trolley to move in a straight path as the six outer sensors need to detect white to move and as it approached a junction this same sensor setup will help aid the steering.

When the left-most sensors detect black that is when the trolley is supposed to turn left, the output from the sensors is received by the Arduino board and it enables differential turning (one of the motors rotates in the opposite direction). Similarly, it turns right when the rightmost sensors detect the black surface.

a) Object detection

In order to avoid collision between the trolley and the obstacles, an ultrasonic distance sensor is placed in front of the trolley. This sensor sends out a pulse and receives it in a matter of microseconds, and calculates the distance between the trolley and the obstacle. If the obstacle is less than a meter, then the trolley will stop for 3 seconds minimum until the obstacle is out of the sensor's periphery.

b) Accessibility

To secure access and avoid unwanted usage of the trolley, the start/stop function of the trolley can be controlled only by authorized library personal with the help of RF-id. Radio-frequency identification uses electromagnetic fields to automatically identify and track tags attached to objects. An RFID system consists of a tiny radio transponder, a radio receiver and transmitter.

IV. Conclusion

The trolley is not limited to one scenario (Library), the same model can be adapted at multiple Industrial and commercial workspace where hands free transportation can also encourage safety of the workers (e.g. Warehouses, chemical plants etc.). This paper reports the design and fabrication of an automated trolley that has both industrial and commercial application. The trolley navigates itself using advanced line follower mechanism with the help of IR sensors and use ultrasonic sensors for obstacle detection. By receiving the start/stop command, the trolley operates on DC geared motor to traverse distances with heavy payload. This paper also proposes a cost efficient design of trolley with budget friendly yet high performance components making it easily implementable at day to day workspaces.

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