DESIGN, FABRICATION AND EVALUATION OF AN AUTONOMOUS GUIDED VEHICLE WITH A UNIT LOAD CARRIER

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ABSTRACT

This paper focuses on the techniques involved in the design, fabrication and evaluation of an improved material handling system for a typical industrial application. Generally, a successful attempt has been made in this present work to build an automated guided robot with a unit load carrying capability. This system is equipped with three wheels mechanical drive ability with a steerable standard wheel at the front, an Arduino UNO as the main microcontroller to react towards the data received from the push-button and infrared sensors to give fast and safe movement in a structured environment. The automated line follower robot was tested and allowed to run repeatedly as it was designed to operate and a mathematical model was used to describe the operation of the robot from a loading point to a specific destination. Thus, the robot cycle time is 2.05min/delivery from the loading point down to the offloading point after which it makes a U-turn at the reset point.

Keywords: Wheeled mobile robot, Automated, Sensor, Microcontroller, Fabrication

1. INTRODUCTION

Automation basically refers to the technology by which processes or procedures are executed or performed without human assistance (1). Automation has become the core of modern manufacturing so much that, no company is able to survive in a competitive market without automating its operations. In the field of automation, robots can be used as a master or a slave in doing the repeated tasks. A robot is a reprogrammable, multifunctional device designed to move materials, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks (2).

One of the key components of automation in a manufacturing process is the Material Handling System (3). A Material Handling system is responsible for loading, unloading, moving or generally transporting any type of materials (raw material, work in process, and finished good) within and out of manufacturing cells such as warehouses, machines and assembly lines. Moreover, Material Handling System (MHS) consists of different components (conveyors, automated guided vehicles (AGV), automated storage and retrieval system) which AGV is considered as the most flexible equipment of MHS. Furthermore, a typical Automated Guided Vehicle is a 'Line Follower Robot' which follows a path. The path can be visible like a black line on a white surface (or vice-versa) or it can be invisible like a magnetic field designed to be flexible and obstructive.

2. LITERATURE REVIEW

Mobile robots have played a vital role in moving material and product for more than 50 years. The first automated guided robot system was built and introduced in 1953 by Barrett Electronics of Northbrook (4). It was a modified towing tractor that was used to pull a trailer and follow an overhead wire in a grocery warehouse. By the late 1950's and early 1960's, towing automated guided robots were in operation in many types of factories and warehouses. Out of this technology came a new type of guided robot, which follows invisible UV markers on the floor instead of being towed by a chain (5). This system was deployed at the Willis Tower (formerly Sears Tower) in Chicago, Illinois to deliver mail throughout its offices. As a result of this, the introduction of a unit load robot in the mid-1970s fascinated inline transportation because of their ability to serve several functions. Since then, guided robots such as line follower, have evolved into complex material handling transport vehicles ranging from mail handling robots to highly automated automatic trailer, loading automated guided vehicles using laser and natural target navigation technologies. (6).

Ramshetty, (2014) designed an android based autonomous coloured line follower robot that can differentiate among various colors and choose a desired one to find its target.

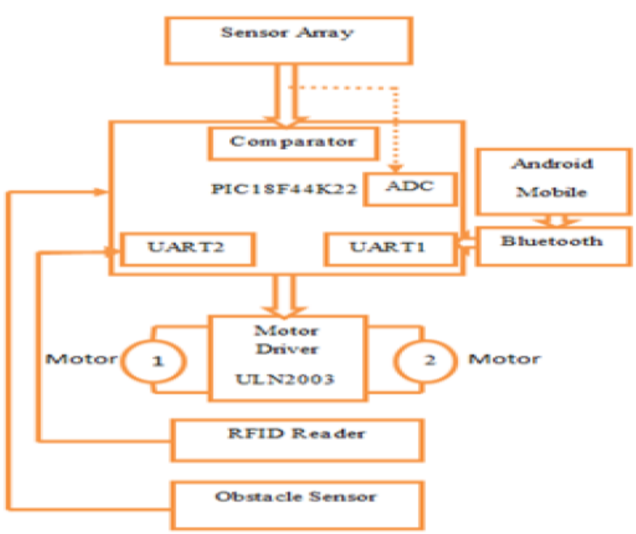

Figure 2.0: Block diagram of A Coloured Line Follower Robot.

From the android mobile, instructions are given to the robot that senses a line and adjusts itself accordingly towards the desired target by correcting the wrong moves using a simple feedback mechanism. The robot is capable of following different colours with congested curves as it receives the continuous data from the infrared sensors. This robot avoids collision and moreover, in cases where ambient light interferes with the sensors thereby disturbing the transition of data at that time, RFID (Radio Frequency Identification) readers detect the desired target by detecting RFID tag placed at the destination

Therefore, the concept of the android based colour line follower robot was practically implemented based on PIC Microcontroller, RFID reader and infrared sensors. The block diagram of the overall system is shown below.

Sandeep, Pavan, & Prasad, (2017) designed and implemented a basic prototype line follower robot with obstacle avoiding capabilities. This prototype of the robot follows a black line, detects obstacle and take necessary actions to avoid it. They integrated an Arduino motor shield and sensors are connected to the control system powered by a 12V battery. The design includes two modules; line following and obstacle detection so that, both modules and its algorithm are implemented individually and at final, both are combined in such a way that the robot performs specified task. Hence, they concluded that the robot can be used in hospitals industries; replace conventional conveyor belts and army applications.

3. PROBLEM STATEMENT

Nowadays, manufacturers seek to implement methods of automation appropriate for increasing productivity and shorter throughput times. Material handling systems using carts and trucks with human drivers has caused unreliability and inefficiency in the part of assembly line forming the weakest link. As a result of this, automating material handling processes using intelligent technology to maximize productivity and reduce operating cost, has proven to be the solution to unreliability and inefficiencies caused by human errors and labor, during repetitive and burdensome materials transportation.

4. SYSTEM OVERVIEW

The Autonomous guided robot was developed by an integrated design from the knowledge of mechanical, electrical & electronics, and computer engineering. Consequently, the following factors and preliminary calculations were carefully considered in the design of the robot.

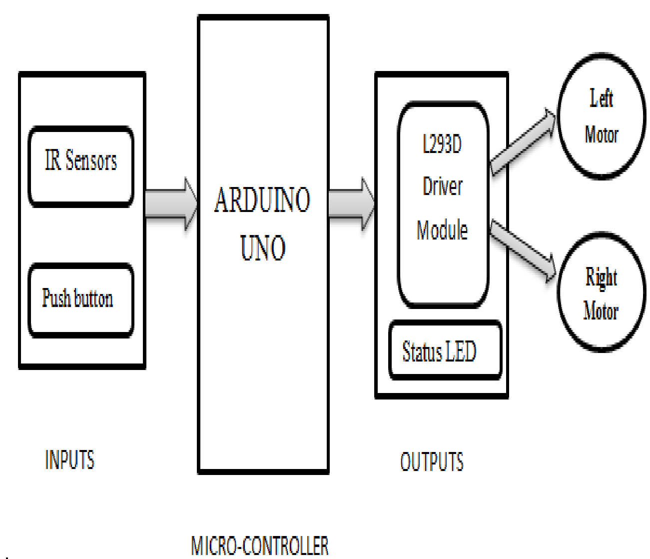

Figure 4.0: Block diagram of the Robot

Source: Self

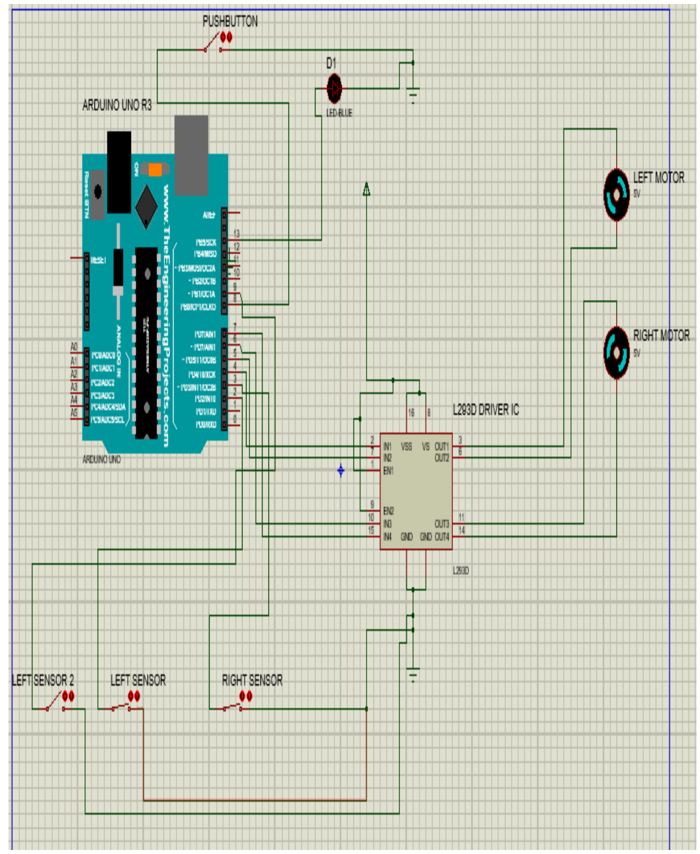

Figure 4.1: Circuit Simulation of the Robot

Source: Self

5. EVALUATION

5.1 Sensor Placement for Smooth Turning

In order to avoid the dilemma of sensor positioning, the equation below (proposed by Zafri.*et. al.* 2008) was utilized to determine the exact distance between the sensors.

$$w < |S_{RR} - S_{LL}| < \frac{w}{\tan\theta_c} \quad \text{……………........equ.3.1}$$

Where;

$|S_{RR} - S_{LL}|$ is the distance between the left most and right most sensor in mm,

w is the width of the line being detected in mm and θ_c is the critical entry angle of the robot.

Thus;

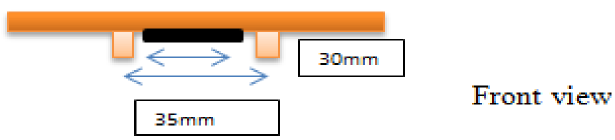

Figure 5.0: Front Schematic View of the Robot

Source: Self

The width of the line has been determined by measurement to be **30mm.**
Setting the distance between the two front sensors to be **35mm**, and rearranging inequality equation to calculate the critical entry angle:

$$w < |S_{RR} - S_{LL}| tan\theta_c$$

$$\theta_c < tan^{-1}\frac{w}{|S_{RR} - S_{LL}|}$$

$$\theta_c < tan^{-1}\frac{30}{35}$$

$$\theta_c < tan^{-1} 0.85714$$

$$\theta_c < 40.6^{\circ}$$

This yields θ_C to be 40.6 degrees.

This implies that, if the robot attempts to enter a curvy path at an angle above this value, it will not be able to follow the line. Therefore, reduction in the distance between the two sensors would result to greater critical entry angle during transition to curvy routes or paths and improved sensitivity to following the line thereby achieving better performance.

5.3 Result and Discussion

The automated line follower robot with a unit load carrier was tested and allowed to run repeatedly as it was designed to operate. Thus, the following parameters were obtained as a function of time. The below mathematical model can be used to describe the operation of the robot from a loading point to a specific destination. Moreover, assuming constant velocity throughout the environment and ignoring the effect of acceleration, deceleration and other speed difference. The time for a typical deliver cycle system is;

- Loading at the pickup station
- Travel time to the drop-off station
- Unloading at drop off station
- Empty travel time

$$T_e = T_1 + \frac{L_d}{v} + T_u + \frac{L_e}{v}$$

T_e = delivery cycle time (min/delivery)
T_1 = time to load (min) is 0.05min
L_d = distance travel from load to unload station is 0.25m
v = carrier velocity is 0.31m/s; ($v = \frac{\pi DN}{60}$) where N = 90 rpm and D = 65mm
T_u = time to unloading station is 0.17min
L_e = distance the robot travel until the start of the next delivery station is 320cm
Therefore, the delivery cycle time is

$$T_e = 0.05 + \frac{0.25}{0.31} + 0.17 + \frac{0.320}{0.31}$$

$$T_e = 0.05 + 0.80 + 0.17 + 1.03$$

$$\boldsymbol{T_e = 2.05\ min/delivery}$$

Thus, the robot delivery time per cycle is **2.05min/delivery**

6. CONCLUSION

The Robotic system designed in this research has been able to meet expectations in theory and practice. The goal of the project was to design an automated line follower that can deliver unit loads from a loading point to an offloading point by following a designed path strictly. Moreover, the essence of the work was to facilitate automation processes in the industry. Thus, the goals were achieved and a path has been provided for the robot to follow and the operation of the robot has been tested.

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