



Design and Implementation of a Dual-Mode (Autonomous and Manual) Industrial Robotic Transporter

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ABSTRACT

The use of autonomous mobile robots in an industry is getting increasingly prevalent as the demand to automate human industrial tasks develops. Robots can be employed in the industry to transfer various heavy things, which are frequently repeated tasks that take a long time to accomplish when employees perform these tasks on their own, especially in industrial settings with a large ground area. The design and implementation of an industrial robotic transporter of 150 kg that can work in two modes (manual and line follower) were explored in this study. The development of a robotic transporter was examined in terms of its mechanics and operating principles in this study. Furthermore, the built robotic transporter was analyzed, and the results revealed that as the cargo increases, the robotic transporter takes longer to navigate a sharp corner than a curved corner. Furthermore, when compared to the concrete environment, the robotic transporter takes 33.3 percent longer to move on the interlock environment and 15.42 percent longer to move on the tiles environment. The targeted advantages of this robotic transporter include but are not limited to the following, the ability to transport a load that is above 40% average weight of an adult (average weight of an adult is estimated at 70 kg by the World Health Organization), reduction of stress and other health challenges of the worker, and reduction of other workshop hazards.

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INTRODUCTION

In the early development of robots, robotics applications were restricted to industrial and manufacturing processes and they were generically called industrial robots, however, with the advancement in technology in the last five decades, the use of robots has become an integral part of all facets of every life. In recent times, robots are no longer confined to factory assembly lines for repetitive tasks but are now employed in places closer to humans, thereby interacting in the everyday environment and making daily life smarter (Kumar et al., 2014).

Mobile robots are designed to assist humans in a variety of environments either by performing the task itself or by assisting in accomplishing the task efficiently through the reduction of human efforts. Generally, mobile robots assist humans by performing a job that is dull, dirty, dangerous, redundant or

repetitive. Autonomous robots are being increasingly deployed for extended periods in a variety of environments, including homes, industries, offices, stores etc. and are expected to be versatile, capable of performing multiple diverse tasks thereby decreasing the workload and improving human lifestyle (Allawi et al., 2015). The use of autonomous mobile robots in an industry is trending as the need to automate human industrial activities arises. Robots in the industries can be applied to perform transportation of some heavy materials, which in some cases are repetitive tasks that consume a lot of time when the workers have to perform this function on their own, particularly in industrial settings with a large ground area. In comparison with the manual truck or a forklift, the major advantage of a robotic transporter lies in the lesser requirement of human efforts, and the lower cost of maintenance, although the initial



developmental cost can be higher (Yamauchi, 2008).

The performance of a robot relies greatly on the effectiveness of the navigation techniques adopted. The mobile robot must be able to provide the answers to the three navigation questions of the present location, destination, and process of getting to the destination. The navigation task is challenging due to several complex problems such as limitation of computational power, are difficulties in detecting and recognizing objects, difficulties in avoiding collisions with objects and the difficulties involved in using the information provided by the environment (Negenborn, 2003). In this study, an industrial robotic transporter was designed with a black line-follower navigation system and the ability to transport a maximum weight of 150kg of industrial materials. The focus was placed on the transportation of industrial materials such as workshop toolbox and other machine components from one point of the industry to another due to the cervical, thoracic, lumbar and coccydynia disorders that are common among the workers involved in this task. According to the Occupational Safety and Health Association (OSHA), workers should not lift or transport manually objects that are more than approximately 40% of their weight (Tamene et al., 2020).

LITERATURE REVIEW

In previous years, a lot of time and energy has been spent developing systems to enable autonomous robots to follow obvious paths using vision systems. Unsurprisingly, most of these researches were aimed at the modification or design of full-size road vehicles that can be driven on roads without manual management. The research of using small robots for autonomous driving usually follows one of the following two methods. In the first method, a mathematical model of the vehicle and its environment is generated, tested in simulation, and then applied to a robot built specifically to solve the problem. In the second method, a combination of a graphics service system and a kinematic model is used. Similarly, robots are usually designed around solution technologies. Due to the size of these robots, the available processing methods are quite limited, so simpler models and technologies (such as the vision part) are used

to reduce the processing load (Islam et al., 2021). Robots are widely used in the healthcare supply chain, from drug testing and manufacturing to logistics, and finally to patient treatment and care. Robots improve the efficiency of drug production by performing monotonous tasks that require high-precision drug testing and medical analysis. Furthermore, the application of robots in patient movements, especially in surgical operations, is constantly expanding. These robots are increasingly used to assist medical staff with daily tasks ranging from weight lifting to rehabilitation and dressing (Dahl et al., 2014).

Considering some of the past works on robotic transporter, Ohashi et al. (2016) described the problem of using a group of small mobile robots to transport large heavy objects. In this study, to solve the problem of the robot overturning objects and trolley slipping when tilting objects, the outrigger device was used to prevent the problem of tilting, and the handcart locking device was used to prevent the problem of sliding. Furthermore, Sonal et al. (2017) carried out a study on the design and implementation of RGB colour line following robot. The developed robot could differentiate between the red, green and blue colours and based on the instruction provided by the human operator, follows the specified line. The colour sensor system was built using coloured LED and LDR as the main component. The developed robot also could avoid collision and detect collision with obstacle sensor. In the same vein, Elawad et al., (2013) designed and implemented a robotic system to transport disabled people. The robot was navigated via the line-following with obstacle detection principle which is considered economical, simple and can be easily executed. The transporting wheelchair was developed from conventional manual wheelchairs used in hospitals, although adjustments were made, and components such as optical and ultrasonic sensors, two DC motors and L293D motor driver; and programmed with Atmega16L Microcontroller. The performance evaluation of the developed health transport showed that it was able to follow a predetermined line path and detect obstacles within an acceptable range.

METHODOLOGY

To develop an optimum design of an autonomous industrial transporter, several factors need to be considered such as the structure, mechanics, control, power source, and weight capability. In this study, the design considerations were a minimum function requirement of 1 kg, and a maximum of 150 kg, an environmental expectation of smooth floor so that the black absorbing layer on the hot junctions transforms the incoming radiation into heat, the cost-effectiveness of the system, and safety requirement.

MECHANICS

Manual Mode

Under the driver mode (also known as the manual mode) the robot cannot operate on itself because it depends on the driver (human) to operate it. It is considered to be one of the simplest modes of the robotic transporter wherein by manually controlling the drive units, the robotic transporter can be controlled based on the flow chart given in Figure 1. In this mode of operation, however, the robotic transporter is in a complete sensor-free mode, hence features such as obstacle avoidance is switched off.

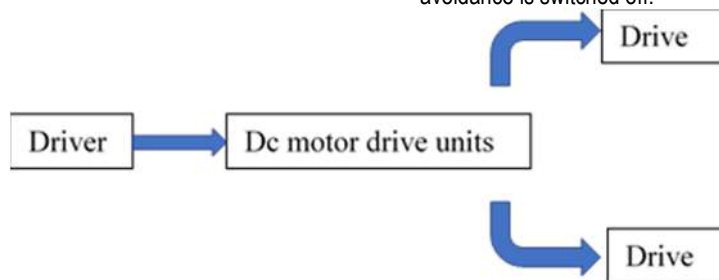


Figure 1: Flow chart of the robotic transporter under the manual mode of operation

Line Following Mode

Under the line following mode (also known as the automatic mode), the robotic transporter is placed on a fixed black path, and it follows the path by detecting the line. The direction of the robot's movement depends on the output of the two sensors. When the two sensors are on the path line, the robot moves forward. If the left sensor is far away from the line, the robot will move to the right. Similarly, if the right sensor is far away from the path, the robot will move to the left. Whenever the robot is driving on the black line, infrared rays are

constantly absorbed by the black surface, and no light is reflected, so the output is very high. Whenever the robot moves out to a white surface, it will begin to reflect infrared rays and reduce the output. Therefore, according to the output of the infrared sensor, the microcontroller instructs the motor to change direction as given in the flow chart of the line following mode in Figure 2. The sensing system consisted of sensing systems such as optical sensors, ultrasonic sensors, microcontrollers, and processors.

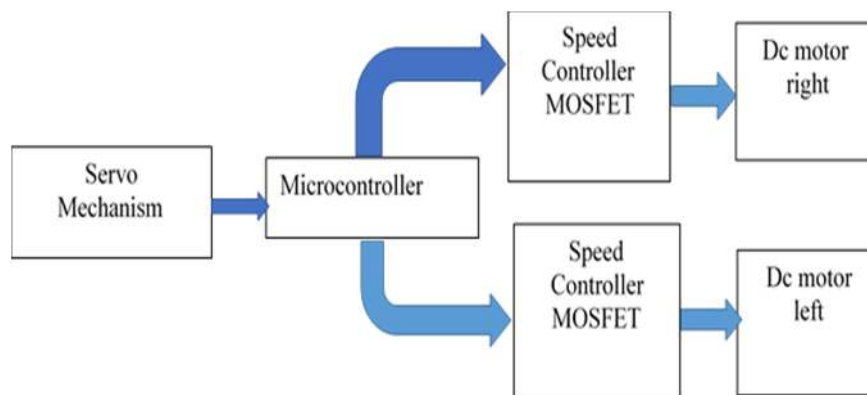
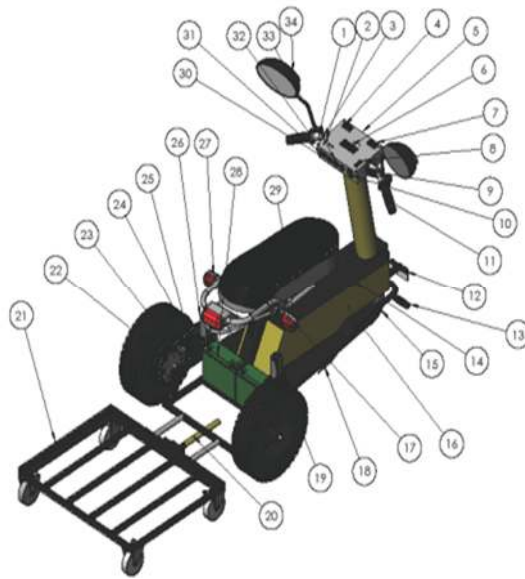


Figure 2: Flow chart of the robotic transporter under the manual mode of operation

Working Principle

The schematic of the developed industrial robotic transporter and the list of the parts is given in Figure 3. Two DC motors were used to drive the robotic transporter, with each one connected to the rear wheels, while the front castor wheel was idle. Through the

development of a chain-drive system, the output shaft of the DC motors was connected to the wheels. Upon detecting a black line, the rear wheels will be directed either to right or left, otherwise, the wheels will be stopped.



Part Number	Part Name	Part Number	Part Name
1	Left handle	18	Right hand sensors
2	Left hand direction button	19	Right hand DC motor
3	Horn switch	20	Payload hook
4	Left hand speed controller indicator	21	Pay-load
5	Control box	22	Left hand tire
6	Voltage and current indicator	23	Driven sprocket
7	Right hand speed controller indicator	24	Chain
8	Forward, stop, revers	25	Driving sprocket
9	Right hand direction button	26	Left hand DC motor
10	Ignition key	27	Left hand rear signal
11	Right handle	28	12V Battery
12	Front ultrasonic sensors	29	Seat
13	Foot rest	30	Rear lamp switch
14	Chassis	31	Line follower switch
15	Caster Tyre	32	Head lamp switch
16	Microcontroller and other electrical components housing	33	Charging port
17	Right hand rear signal	34	Left-hand side mirror

Figure 3: Robotic Transporter

The line following mode was carried out with the help of optical sensors. Using the optical features of black and white hues, the line following algorithm follows a path based on a black and white surface (or vice versa) visibility. One transmitter (IR LED) and one receiver are found in each of the two optical sensor cells (phototransistor). Phototransistors are well-known for their rapid response across a broad spectrum of light. A voltage divider circuit was used to provide the output of the line following the circuit to the microcontroller. To provide optimal sensing, the sensors were connected beneath the robotic carrier.

The ultrasonic sensors are used to identify obstacles. The front of the robotic transporter was fitted with a set of ultrasonic sensors that also served as a transceiver. Ultrasonic waves are delivered into the space ahead, the reflecting waves are received, and

voltage measurements are sent to the microcontroller. By comparing the receiver voltage output to a threshold value, the presence of a barrier can be established. Furthermore, the robotic transporter was powered by two-12V lithium-ion batteries each with a rating of 100Ah. A circuit was to deliver constant voltage to the main circuit of the controlling system and a switch and indicator LED light was used to measure and ensure that the circuit was power-up or not.

RESULTS AND DISCUSSION

Figure 4 shows the experimental setup for the performance evaluation of the industrial robotic transporter at two different cornering conditions (curved and sharp corners) when in the line follower mode with a set speed of 41 m/s.



Figure 4: (a) Speed regulated to 41 m/s, (b) Robot on Sharp Corner, (c) Robot on Curved Corner (d) Robot with 150 kg on a sharp corner

Figure 5 shows the results obtained from the coming design of the robotic transporter with a comparison with the sharp

and curved lines under the line follower mode with varying loads from 10kg to 150kg.

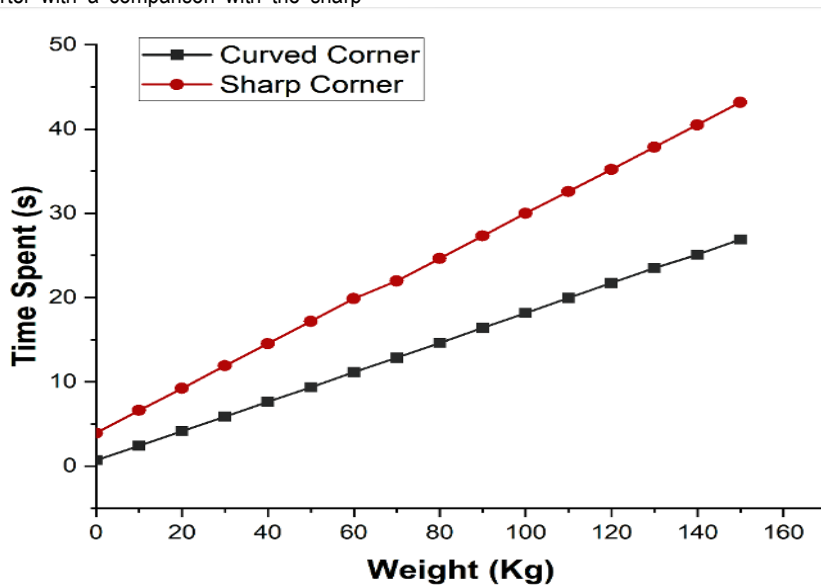


Figure 5: Corning design of the robotic transporter with an increase in payload on the robotic transporter

From the result obtained, it was observed that there is a distinctive difference between the curved corner movement of the

robotic transporter and the sharp corner, although there is a similar trend of increase in time with an increase in the payload as

expected. The obtained result showed that the curved corner tends to require lesser time for the robotic transporter to navigate than the curved corner. Furthermore, the result showed that with an increase in payload, it takes a longer time for the robotic transporter to navigate the sharp corner in comparison with the curved corner. At the payload of 150kg, the sharp corner navigation requires 60% more time than the curved corner navigation. The obtained result is in agreement with the findings of Dertien et al. (2011) who developed an inspection robot for small diameter gas

distribution mains and discovered that sharp corner navigations required some complexities and, in some cases, constraints are required for smooth movement of the robotic transporter through such navigation.

Similarly, the effect of various working environments on the working performance of the industrial robotic transporter was evaluated by considering the three most common flooring types in an industrial setting: interlock, tiles and concrete. Figure 6 shows the experimental setup of this evaluation.

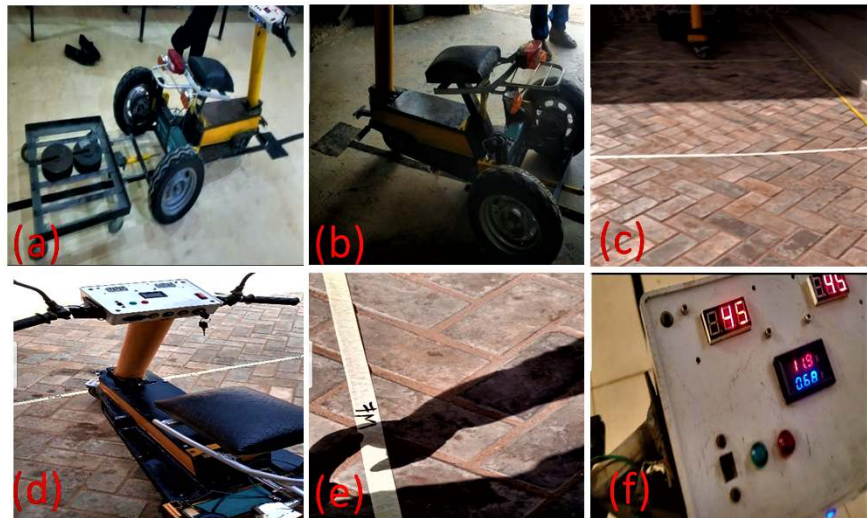


Figure 6: (a) Robotic transporter on tiles, (b) Robotic transporter on Concrete, (c) Robotic transporter on Interlock, (d-e) 7m mark (f) Speed of 45 m/s.

Figure 7 shows the results obtained from the time variance of the robotic

transporter in different environments varying load from 10kg to 150kg.

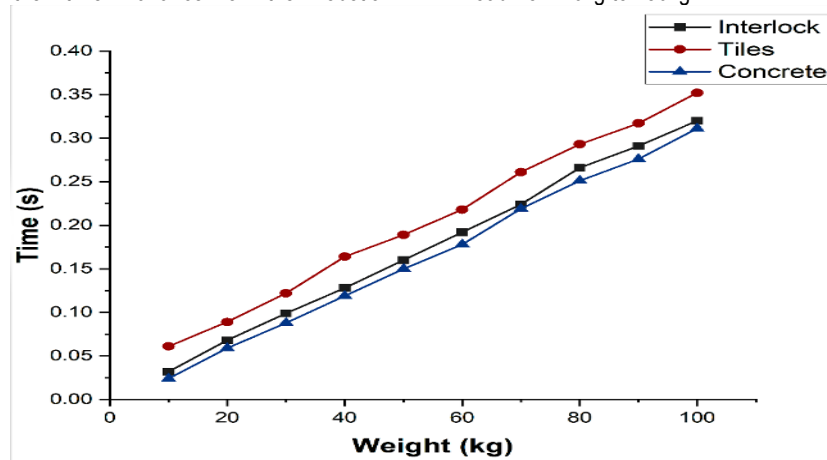


Figure 7: Time variance of the robotic transporter in different environments



From the result obtained, it was observed that there is a distinctive difference between the time variance of the different environments of interlock, tiles and concrete, although there is a similar trend of increase in time with an increase in the payload as expected. The obtained result showed that the robotic transporter tends to require lesser time on the concrete than the interlock environment, which requires less time than on the tiles environment. At the payload of 10kg, the robotic transporter requires 33.3% more time to move on the interlock environment in comparison with the concrete environment and 15.42% more time to move on the tiles environment. The reason for this trend of result is attributed to the grip characteristics of the different environments with respect to the road surfaces. As for the characteristics of a conventional rubber tire, a superior adhesion feature is favourable to a smooth road surface. This is because a high hysteresis is good for a rough road surface, and superior wear-resistance and high tear energy are advantageous for a road surface (Oh and Lee, 2014).

CONCLUSION

In this study, the design and implementation of an industrial robotic transporter that can operate in dual-mode (manual mode, and line follower mode) have been considered. As the demand to automate human industrial operations grows, the employment of autonomous mobile robots in an industry is becoming more popular. In the industry, robots can be used to transport various heavy objects, which are often repeated operations that take a long time to complete when employees must do this duty on their own, especially in industrial settings with a big ground area. In this study, the development of a robotic transporter was considered in terms of its mechanics and working principles. Furthermore, the developed robotic transporter was evaluated and the result showed that with an increase in payload, it takes a longer time for the robotic transporter to navigate a sharp corner in comparison with the curved corner. Furthermore, the robotic transporter requires 33.3% more time to move on the interlock environment in comparison with the concrete environment and 15.42% more time to move on the tiles environment.

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