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MECHANICAL AND SOFTWARE DESIGN OF THE WAREHOUSE ROBOT

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ABSTRACT

In this study, a mobile robot design will be used to carry goods in warehouses will be made. This robot will provide quick access to product in big warehouse where the different types of products. The robot will move autonomously. Tasks to be performed and the route will be reported to the robot by the computer. In robot design focuses on two points. One of them is the mechanical design. The mechanical design are made for flexible mobility, product handling and detect obstacles. The other is a software design. The software provide the robot to operate autonomously and to fulfill the tasks assigned. For this purpose, route tracking, obstacle detection, power management and computer communication is done.

This study covers the mechanical and software design of a warehouse robot. In a mechanical design result in the robot's weight, lifting capacity was calculated. Route tracking is done using artificial intelligence based software.

INTRODUCTION

The number of mobile robot used in a variety of jobs is each day increasing. Different companies, for performing various operations made a special mobile robot designs. [1-3]

E-commerce website offers different products to users. Product must be in stock to deliver products to customers quickly[4-6]. In the large warehouses is spent a lot of time for the collection of customer orders. Fast and accurate product collection can easily be done with a mobile robot [7-10]. For this, the software and hardware features must be configured in a good way. Some software features are path planning, shortest path, communication, task management etc. Mechanical features are flexible mobility, lifting and transport, etc. All the combinations of these properties consist of warehouses robots which is a mechatronic system[11, 12].

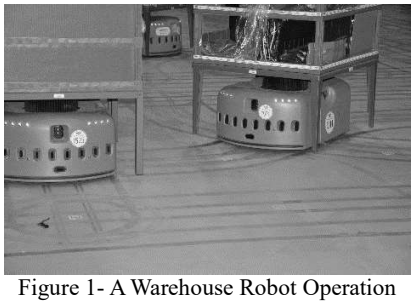

Figure 1- A Warehouse Robot Operation

In this study, a mobile robot design that can carry will be made. Mechanical and software design has been made to be moved to the desired position of the different products in warehouses.

MOBILE ROBOT DESIGNED

Mobile robot design will be discussed in three categories. These are mechanical design, electronic design and software.

Mechanical Design

Mobile robot is a mechatronic system that can move in the desired plane. Some types can move on ground, air or water. In this study, the design of a mobile robot that moves on the ground is made[12, 13]. A strong robot is planned. So four motors are used for mobility. Same way, to lift racks designed for robots a mechanism which has four motors is planned. Reduction is used by all DC motors[14, 15]. This allows a more powerful robot is designed. Differential drive system is used for mobility[16]. Movement will be achieved by varying the motor speed and direction. Motors can be moved independently. In addition to the motor in the system are as follows; electronic circuit, sensors (to detect environment), communication module and battery. Full placement of this equipment is the design of mobile robots.

Mechanical design of the robots will be examined in two parts. These mechanism are for lifting and for moving.

Lifting Mechanism

Robot lifting mechanism is as shown in Figure 2. Four reduction gear dc motor is used for lifting. The arm which is 45 mm length is attached to motor shaft. Lifting will be provided by the angular movement of the arm. The arm will move freely in the horizontal axis. This will be done for proper bedding.

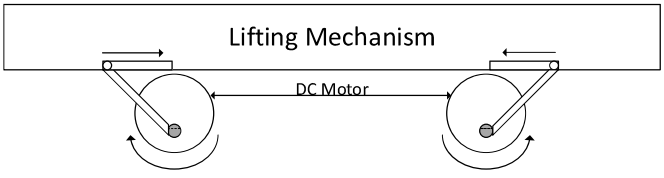

Figure 2- Lifting Mechanism

Placement of motors and arms is as shown in Figure 3.

The lifting mechanism dimensions of the robot is 300mmx300mm. Geared DC motor has a diameter of 36 mm. Motors is available in 6 mm “D” shaft. Motors are working with 12V. Speed is 6rpm. 7,845 Nm torque can be obtained at motors[17].

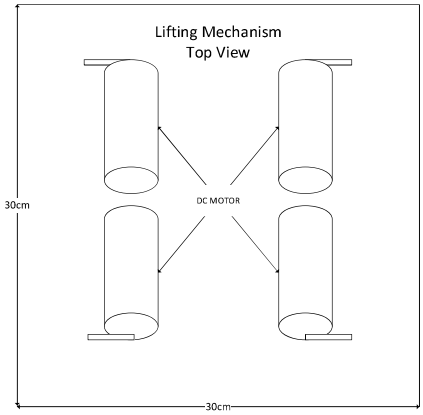

Figure 3- Lifting Mechanism Top View

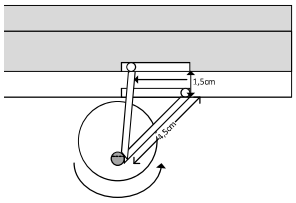

Figure 4- The Operation of The Lifting Mechanism

$$T = F\,x\,r\,x\,\sin\theta \qquad (1)$$

T = Torque;
F = Force
θ = The angle at which the force acts,

In the above formula, the θ angle is taken 90° to calculate the minimum lifting force. With about 30 degrees to move the motor 16mm lift will be provided (figure 4). Maximum lifting distance is 23 mm. Lift height is to detect by a sensor to the desired distance.

T=1111 ozf in (7,845Nm)

$$F = \frac{T}{r\,x\,\sin\theta}$$

* θ = Selected 90° for minimum force

And then

F= 174,333 N (Lifting Weight=17,77kg)

W=17,77 x 4=71.08kg

Drive Mechanism;

A driving mechanism is designed to be movable with its own weight and the weight of the load carrying. Differential drive is made for flexible mobility. Motor in either direction is movable separately. Rubber tires are used for contact with the ground. Tire's diameter is 50mm. Rolling resistance coefficient for use in hard surface is selected 0,015mm[18, 19]. The resistance of wheel rotation was found as in the following formula.

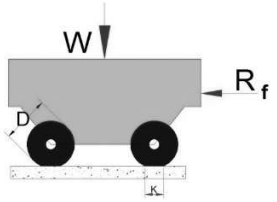

Figure 5- The Resistance of Wheel Rotation

$$R_f = \frac{w\ x\ f}{D/2} \quad (2)$$

R_f= force to overcome the resistance of wheel rotation;
w = . W (total weight) / Number of wheels
f = coefficient of resistance (mm)
D = Wheel diameter (mm)

$$R_f = \frac{174{,}33N\ x\ 0{,}015}{25} \quad (3)$$

$$R_f = 0{,}104N \quad (4)$$

Final force is calculated adding the load force and force to overcome the resistance of wheel rotation.

$$F_T = 174{,}33 + 0{,}104N \quad (5)$$

$$F_T = 174{,}43N \quad (6)$$

According to the diameter of the selected wheel, velocity value it is found as follows, if DC Motor speed is 100rpm.

Radius = 2,5cm
Perimeter = 15,7cm (100RPM)
Velocity = 15,7 m/min (0,261 m/s)

Motor force was calculated for this wheel diameter as follows. This is the minimum force to be selected.

$$T = 174{,}43N\ x\ 0{,}025 \quad (7)$$

$$T = 4{,}36\ Nm \quad (8)$$

Robot dimensions is shown as Figure 6, after all the equipment is placed.

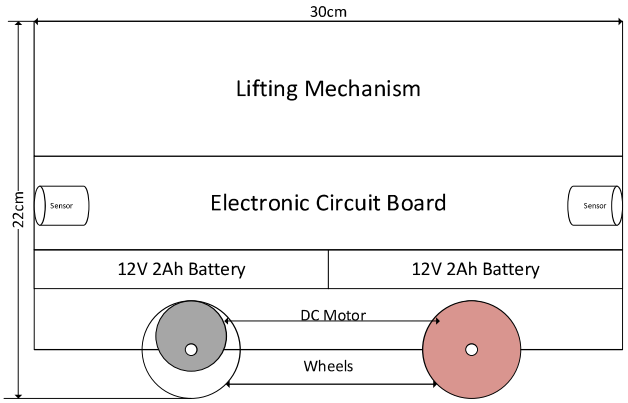

Figure 6 - Designed Warehouse Robots Dimension

Electronic Design

An electronic circuit is designed for autonomous movement. Electronic circuit performs these functions such as; motor control, sensor readings and computer communications. Electronic circuit block diagram is as shown in Figure 7. Arduino mega is used for control and monitoring. Autonomous movement in the system, according to the environment and location information received from the sensors is achieved by making route planning. Tasks are provided with wireless data by computer. According to the given task by determining trajectory of motion. In addition, the robot power management is well maintained. All these operations are done with the software developed on the microcontroller.

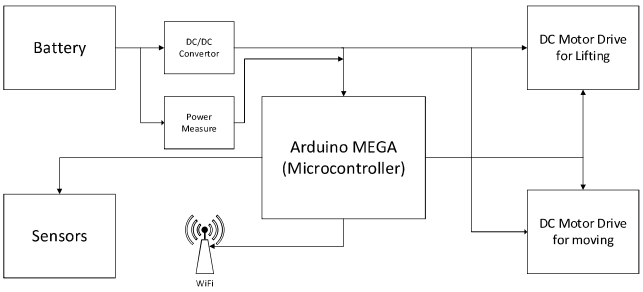

Figure 7 – Electronic Circuit Blok Diagram

Software Design

The most important part for the operation of mobile robot is software. Basic operation is as shown in Fig. By processing the signals from the electronic circuit outputs are controlled. Software has been developed on the Arduino platform. It is open source and free software. For this reason, it provides flexibility in many aspects.

While robot moves from one point to another, A star algorithm, based on artificial intelligence is used for the fastest route planning.

A* (A Star);

Search progress is in progress by selecting the lowest cost node. New costs are calculated in the next node, and the list is updated[20-22].

The operation is as in the following formula

$$f(n)=g(n)+h(n) \quad (10)$$

Here

f (n); Calculations made heuristic function

g (n); the known cost of getting from the initial node to n; this value is tracked by the algorithm

h (n); heuristic estimate of the cost to get from n to any goal node.

First visited a minimum cost node while searching. After moved to the other nodes. If all distance between nodes is known, results can be accessed in the shortest way. Such information in this study is not known. Therefore node preferences and a definitive conclusion about the fastest goal may not reach.

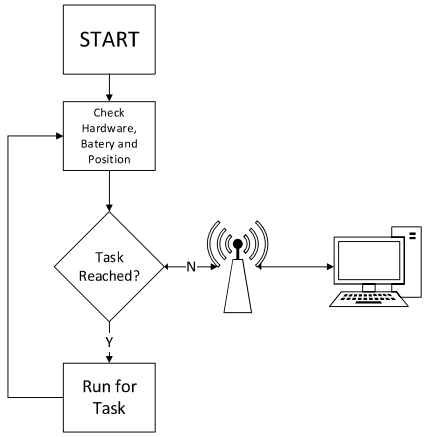

Figure 8 – Software Algorithm

RESULTS AND DISCUSSION

A mobile robot design used to transport parts in large warehouse is made. This will allow to reach quickly parts. A mechanism is designed to lift the load 71kg. A mechanism is designed to lift the load 71kg. Design result, four 12V, 6rpm 7,845Nm DC motors for lifting mechanism are selected. To support this load, four 100 rpm, 12V 4,36Nm DC motors are selected. The speed of the mobile robot is 26.1 cm/s.

Speed can be increased by selecting a higher speed motors. But Motor torque must be at least 4,36Nm. Values were calculated according to the parts to be used on robots.

In addition to mechanical design, electronic circuit is designed for autonomous operation and communication. Likewise a software is developed for the microcontroller. Software controls the DC motors by processing data received from sensors. Whereby the movement and transport is provided. Task information is provided by the computer. A * algorithm is used to get quickly to the given coordinates.

CONCLUSION

This paper presents the warehouse mobile robot design. The design is discussed in three parts. These are mechanical electronic and software design. In mechanical design, load and motor parameters were found. In this study, developed robot can carry the load of 174N. The required motor torque is calculated.

More than one of these robots is available in large warehouses to achieve to product. Many e-commerce companies have started to use such robots. This study was conducted fundamental work of a robot design. Design changes can be made for different weight and size.

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