SMART SHOPPING ROBOT FOR SUPERMARKETS USING DIJKSTRA'S ALGORITHM

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Abstract : The growing trend and requirement of robots assisting humans in their surroundings have been explored considerably. Recently, the area of autonomous mobile robots increased the demand for various types of applications such as enhancing the physical mobility of elders, assisting in the transportation of products, and providing precise information for the user in a more intelligent manner. Moreover, some studies have addressed the idea of developing intelligent shopping robots. These robots are designed and developed to interact with customers. This paper presents an intelligent shopping robot. The main features of the robot are that it will display product information, estimated time required to collect the products, and it will collect all the products which are ordered. This intelligent shopping robot gives priority to improve space utilization, increase energy conservation, effective time management and the automation of existing supermarkets without an additional expensive renovation.

***IndexTerms* - Pick and Place, Line Following, Mobile Robot, Path Planning, Wireless Communication.**

I. INTRODUCTION

Over the last few years, robots have evolved in different technological fields like medical, construction, production, agriculture, surveillance, communication, etc. The obstacles in the everyday context are getting more complicated, so to make these situations effortless robotic assistance can be employed. Even though e-commerce has a major impact on the current trend of shopping, still people tend to purchase directly from the shops. In light of the above-mentioned information, shopping assisting robots are appropriate companions to the customers. Service robots should have the ability to move and interact with their environment, but mainly with their users, common people, in a friendly way.

This paper presents a novel method for product reference and identification by keeping a unique count of the nodes in the black lines. The count is generated with the help of the Infrared (IR) sensors. The cost of taking different routes is given in a cost matrix and the directions in the direction matrix. Dijkstra's algorithm is implemented with the help of these matrices. These matrices help in mapping out the whole arena which helps in the navigation and localization of the robot. Image processing is not required in this method as the items in the supermarket are identified with the help of nodes. This eliminates the need for high-end microcontrollers, Random Access Memory (RAM) requirements and cameras for capturing images.

II. LITERATURE SURVEY

In various mobile robot applications, the robot enters an unknown environment and relying solely on sensor information, it forms up an environment map that can be used for collision-free navigation and localization. Conventional ultrasonic sensors measure distance using time of flight. The detected object may be located anywhere along the perimeter of the sonar sensor's beam pattern. Therefore, as in [1], the distance information that ultrasonic sensor provides is considerably accurate in depth, but not in azimuth.

[2 - 5] focused on modeling of the ultrasonic sensors to get precise range information. Laser scanner provides high-resolution information, however, it arouses a high cost, sometimes more than the mobile base itself. Mobile robot builds the environment map for navigation and localization from the range sensor information as in [8]. With reliable range data, the environment map is built using occupance grids [10]. Therefore, the accuracy of the map depends on the accuracy of the range sensor information, so do the navigation and localization. Different from the ultrasonic sensor, the IR sensor emits a very narrow beam and measures the distance either from the offset of the reflected beam or the intensity of the reflected light.

III. SENSOR INFORMATION

The obstacle detection sensor used in this work is SHARP GP2Y0A21YK0F sensor. Instead of measuring the amount of the reflected light, this type of sensor measures the offset distance of the point on the photo-resistive strip where the reflected light hits. Therefore, it has much less influence on the color of the reflective objects and reflectivity. Most of the analog output IR range sensors have the following characteristics between the distance and the output analog voltage as shown in Fig. 1.

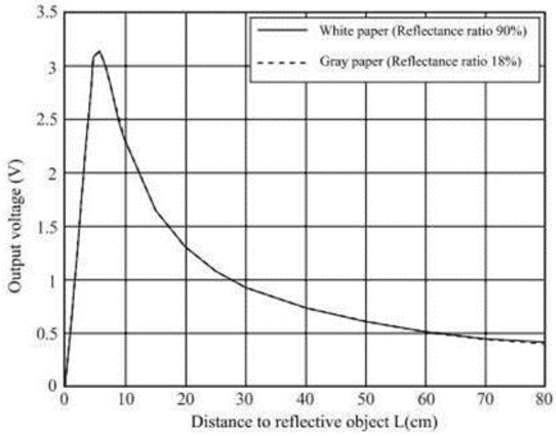

Fig. 1. Sharp Sensor Characteristics

IV. SYSTEM DESCRIPTION

In this paper, we propose the design and implementation of a complete shopping assistance robot that permits people during their shopping process with the added value of complete connectivity with supermarket resources with a friendly user- interface. Our prototype is comprised of three major components: an interface, a mobile robot, and local infrastructure. There is an interface consisting of a list of products for the customer to interact with the robot. The order which is a list of required products can be given to the robot through this interface by the customer. Once the order is placed, the payment for the products is done. After payment the order list is given to the robot. Payment is done in the beginning to eliminate spurious orders. Then the robot starts its intended function and collects the items from the racks. When the collection of the products is done, it will transfer the items to the delivery section. The customer can access the products in the delivery section

V. SCENARIO DESCRIPTION

The major parts of the robot are - a robotic arm, a movable chassis, and a collecting basket. The supermarket is currently designed like a square consisting of different nodes. A node represents one item in the supermarket.

There is very less human effort involved in the purchasing process. The robot traverses the supermarket with the help of designated black lines. Therefore, space inside the supermarket can be utilized very efficiently. There is no need for an attractive ambiance, lighting inside the supermarket because humans are not entering the supermarket for shopping. Air conditioning (AC) systems are not required which helps in cutting down the energy consumption. The robots are well capable to pick the items even in the absence of light. Thereby we can reduce the overall energy consumption. Figure 2 describes the flow of the whole system.

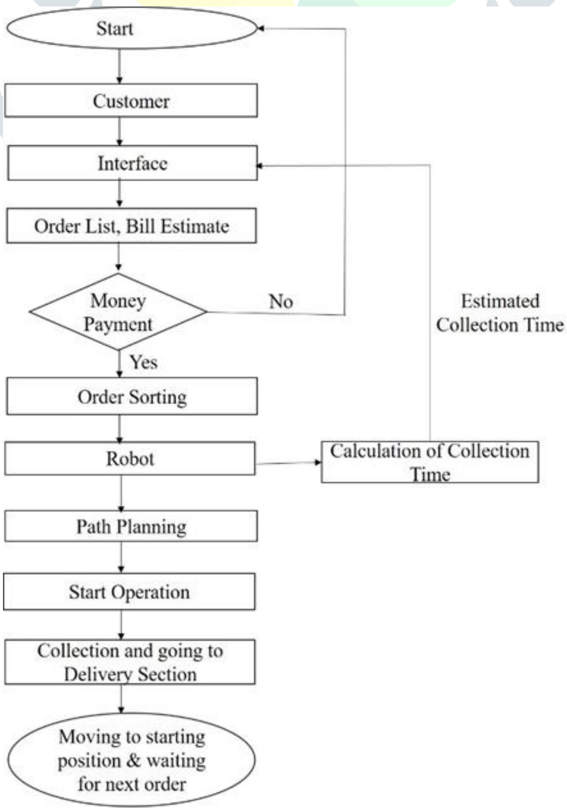

Fig. 2. Flowchart of the system

VI. SIMULATION

The simulation was performed in V-REP PRO EDU to make the code solid. The code from Microsoft Visual Studio 2017 gets mirrored onto V- REP PRO EDU to run the simulation.

6.1. Microsoft Visual Studio

Microsoft Visual Studio is an Integrated Development Environment (IDE) developed by Microsoft. It is used to develop computer programs, as well as websites, web apps, web services, and mobile apps. Visual Studio supports 36 different programming languages and allows the code editor and debugger to support nearly any programming language, provided a language-specific service exists.

6.2. V-REP (Virtual Robot Experimentation Platform)

The robot simulator V-REP (Virtual Robot Experimentation Platform), with integrated development environment, is based on a distributed control architecture: each object/model can be individually controlled through an embedded script, a plugin, a ROS or BlueZero node, a remote API client, or a custom solution. This makes V-REP very flexible and ideal for multi-robot applications. Controllers can be written in C/C++, Python, Java, Lua, Matlab or Octave.

6.3. Implementation

The path planning algorithm was implemented using a weight matrix and a direction matrix for the movement of the robot. PID line follower was coded for effective and smooth traversal of the robot on black lines. The nodes represent individual brand items in the supermarket. The simulation has a limitation of picking only one object at a time. It can pick another object only after placing the object which it has picked. The robot moves through the shortest path to the destination. If an obstacle is present, it will take the next available shortest path to the destination. The simulation starts from the start point, picks the object and places it at the goal point.

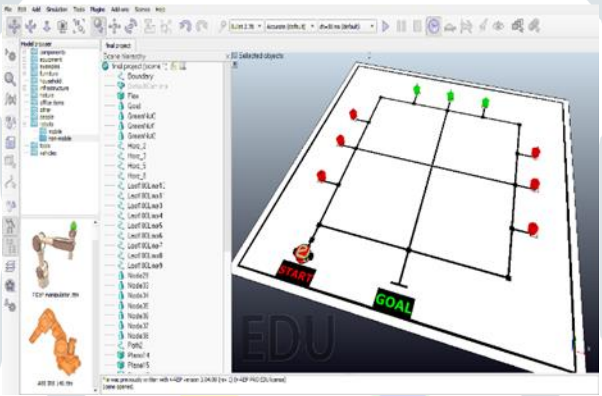

Fig. 3. Simulation Arena in V-REP PRO EDU

VII. PATH PLANNING

7.1. Dijkstra’s algorithm

Dijkstra’s algorithm finds the shortest path tree from a single source node, by building a set of nodes that have a minimum distance from the source. The algorithm creates a tree of shortest paths from the starting vertex, the source, to all other points in the graph. It can also be used for finding the shortest paths from a single node to a single destination node by stopping the algorithm once the shortest path to the destination node has been determined. For example, if the nodes of the graph represent cities and edge path

costs represent driving distances between pairs of cities connected by a direct road, Dijkstra's algorithm can be used to find the shortest route between one city and all other cities.

7.2. Implementation

Dijkstra's algorithm to map out the arena. Two arrays were created – one array signifies the distance between the various nodes present in the arena and the other array contains the information about the previous, present and future node and with this information, the direction of the robot is specified in the array.

Then a function named Dijkstra was created in which the cost matrix is created first. The cost matrix is nothing but the distance from one node to another. Then the predecessor, distance and the visited array are initialized. Then the function checks for a better path through the next node. While the robot is moving, it will take the shortest path to the item zones. If an obstacle is present it will take the next shorted path to the destination.

VIII. METHODOLOGY

8.1. Circuit Diagram

The cicuit diagram was done in Proteus. The components are an Arduino Mega, 4 Servo motors for the robotic arm, 2 DC motors, L298N motor driver, an IR array, a sharp sensor and LM7805 voltage regulator. The power supply was designed in such a way that it will satisfy for the on-load requirements and stall conditions of the motors.

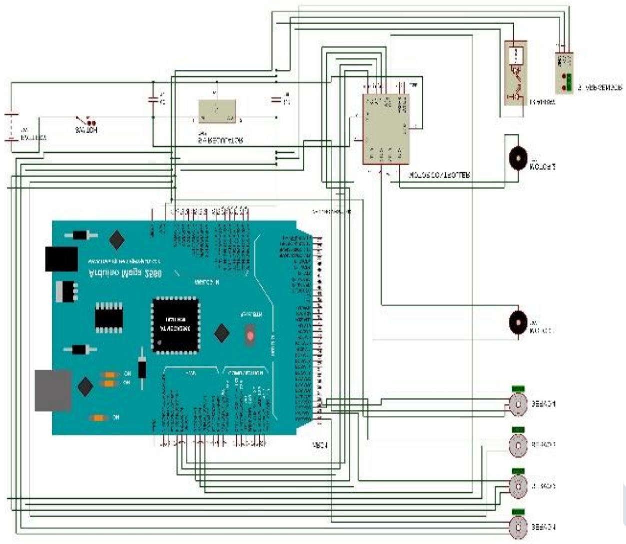

Fig. 4. Power and Control circuit developed in Proteus

8.2. Traction Control System

Traction control is an inevitable factor of mobile robots for optimum locomotion and for reducing the energy consumed by it. It mainly consists of two 200 rpm, 3.9 kg-cm Johnson Geared Motor. It is controlled by using the L298N 2A based motor driver module. Two Robocraze w- 70mm X 40mm gear motor robot wheel, tyres for 6mm shaft geared DC motor are used for locomotion. The wheels are arranged across the center of the chassis. To maintain the stability of the whole structure - 3 Robocraze Goli Caster wheels are used, two at the front and one at the rear side.

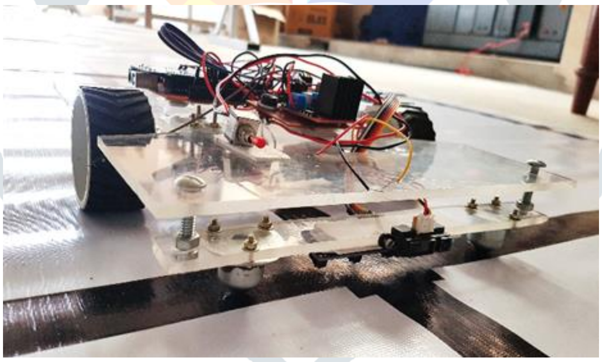

Fig. 5. Traction system implementation

8.3. Robotic Arm

This robotic arm has 4 degree of freedom which is made possible by attaching 4 MG90s metal gear servo motors. The material used for 3D printing is Poly Lactic Acid (PLA). It is a biodegradable polyester which is considerably strong. One is for the movement of the base, one is for the shoulder, one is for the elbow and one is for the gripper.

All the parts of the servo mechanism was designed in Solidworks software. The drawing files were exported to .stl files for 3D printing. The 3D printed robotic arm was affixed to the second acrylic layer. This second acrylic layer was mounted onto the first layer which is also made of acrylic. The design of the robotic arm is given in Fig. 6.

The base servo motor is restricted to a motion of 90 degrees. All the other servo motors have a motion of 180 degrees. The control signals of these servo motors were given from Arduino Mega's PWM ports. Plastic gear servo motors generate unwanted vibrations which reduces the stability of the robotic arm. Therefore, metal gear servo motors were used to reduce the mechanical vibrations which helps in achieving greater control of the pick and place mechanism of the robotic arm.

Fig. 6. Robotic Arm implementation

8.4. Arena Implementation

The arena for the mobile robot was done on a premium flex. The black lines for the arena were given C=100, Y=100, M=100, and K=100 for achieving perfect black print for exceptional reflectance for the IR array sensors.

When the robot receives the list of items by the customer through a wireless connection, it starts from the zeroth node and determines the shortest path by Dijkstra’s path planning algorithm. The time required for the purchasing is calculated using velocity and distance relation and the customer is notified so that they can make use of this time effectively. It traverses from the initial node to the desired node for fetching the products.

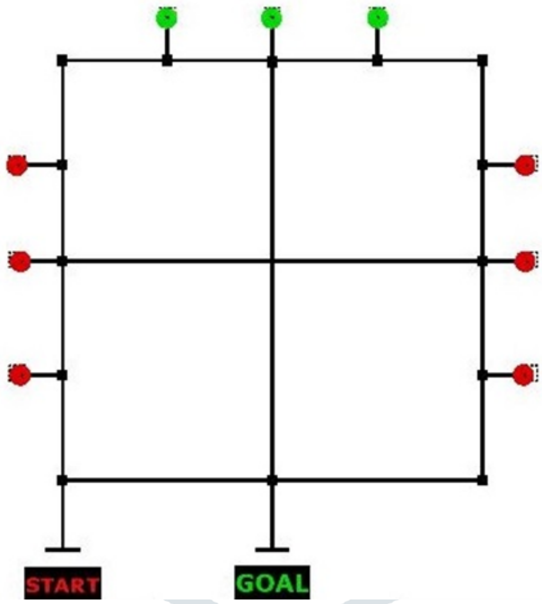

Fig. 7. Arena for the traversal of the robot

8.5. The line follower robotic assistant

IR reflectance sensors are often used to detect white and black surfaces. White surfaces generally reflect well, but black surfaces reflect poorly. An IR sensor consists of two diodes-one to send IR rays and the other to receive it. If the receiver receives the reflection ray, it means that the robot is on a white surface and if it cannot receive it, so the robot is on a black surface. The distance between the sensors and ground surface must be 5 or 6 mm. Here the dark line is of width 38 mm which is detected by one IR sensor while the nodes of the items are of size 60*60 mm detected by 3 IR sensors and the starting and delivering points is of size 40*100 mm detected by 5 IR sensors of the IR sensor array.

When the robot reaches the node of the arena, it stops and fetches the item details from the goal array. The robot picks it with the robotic arm and places it in the basket. By any case an obstacle is in the way, the sharp sensor will detect it and the robot chooses the next shortest path to reach the node. After collecting all the items ordered by the customer, the robot goes to the delivery section. The robot stops its traversal at the delivery section. The supermarket personnel can then take all the items from the robot and give it to the customer. The customer can collect the ordered items from the delivery section.

The robot works even in the absence of ambient light. Therefore the ambiance lighting used in the supermarkets for the appealing of the human eyes can be avoided.

CONCLUSION

This system is aimed at the automation of the existing supermarkets without an expensive renovation. There is less human effort involved in the purchasing process. The robot traverses the supermarket with the help of designated black lines. Therefore space inside the supermarket can be utilized very efficiently. There is no need for attractive lighting and centralized air conditioning system inside the supermarket because humans are not entering the supermarket for shopping. Thereby we can reduce the overall energy consumption. One more benefit is that, when the customer orders the items needed, the robot will return a message to the customer showing the estimated collection time of the items. The customer after ordering, can go for a different task and then come back to collect the items at the end of the estimated time. The customer can save the time he spends in the supermarket.

FUTURE SCOPE

The robot can be made futuristic by giving intelligence such that customer satisfaction can be enhanced. The interest of managers to use robots in shop management helped to increase the customers to their shops [6].

The integrated service can be enhanced by using an online platform for ordering and getting on with the products from the malls. With the development of drone technology, a fully autonomous shopping experience is developed. The customer can order the products online and the drones provide them with the required products from the market [7]. The live status of the collection of the items can be provided to the customers.

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