Design of a Smart Vacuum Cleaner with Indoor Localization

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Abstract—**Cleaning houses is very difficult for people in terms of time and labor. The fact that vacuum cleaners are wired and slow is not advantageous in terms of ease of use. For this reason, many robot vacuum cleaners that can replace traditional vacuum cleaners have started to appear on the market. In our project, we aimed to design and simulate a smart vacuum cleaner. The smart vacuum cleaner will work with a map by detecting the environment and obstacles around it.**

I. INTRODUCTION

Daily life, which is getting crowded today, has brought time savings to a very important point. Since people already do a lot of work during the day, they do not want to spend time cleaning after they come home. For this reason, technology has also developed in this direction. It has been inevitable to see robots in every aspect of our lives. Especially practical home robots are now seen in every area of our home. One of the areas where we see robots in our house is the cleaning category. The benefits of cleaning robots to humans are an undeniable fact.

In this study, a cleaning robot with a robot arm, which can be controlled remotely by devices with an android operating system, has been made. In this study, 3 DC servo motors with voltages of 5V are used. In the study, bluetooth technology was used to enable the robot to communicate with the device to be controlled. The preferred bluetooth module is the HC06 Bluetooth module. With the bluetooth device used, the robot can be controlled remotely by connecting with all devices that have an android operating system.

Relay was used first to control the motor. Because with the relay, large currents and powers can be controlled with small currents and powers. However, in the tests, there was a continuous disconnection and the robot did not work as desired. For this reason, L298 motor driver circuit has been used [1].

Path planning algorithms for autonomous vacuum cleaners are evaluated in this article. Because it is costly to use mapping technology, the idea of path planning where the robot can clean the entire area of the room was chosen instead. Although the robot has a round shape, it can clean edges and hard-to-reach areas. The robot proposed in the article is a battery-powered electronic device with two different sensors. The information obtained from the sensors is transmitted to the control unit, which is qualified as the robot's brain. The control unit also processes this information and generates control signals. These control signals are transmitted to wheel motor drivers.

Two modes, manual and autonomous, are included in the robot for use. Manual mode allows users to remotely control the robot and perform cleaning as desired. It is kind of like a remote controlled system. Autonomous mode, on the other hand, is when the robot calculates the route itself using path planning algorithms. Manual and autonomous mode cannot be used together [2].

In this article, it is aimed to make a cleaning robot that is low cost and can fulfill its purpose. A device has been selected to perform the cleaning process among the wireless charging vacuum cleaners on the market. The robot, which will have a circle shape, has been determined as 9 cm in height, taking into account the thickness of the carpet. Two symmetrical servo motors are placed in the center of the robot. With these servo motors, the robot will rotate around its own axis. If there is a situation such as being stuck in a point with this movement, the robot will easily get rid of that situation [3].

In this study, it is aimed to develop a robot vacuum cleaner suitable for use in offices and homes. The developed robot is controlled by ardiuno mega2560 microcontroller. While designing the smart vacuum cleaner, a robot that is comfortable to use has been designed considering its aesthetic appearance and total weight. 4 ultrasonic sensor systems were used in the study. These sensors are HC- SRO4 model ultrasonic sensors. This sensor offers distance detection between 2-400 cm. Arduino Mega microcontroller is used as it provides more memory space to store the codes [4].

The aim of this study is to enable the robot to map simultaneously without knowing the information about the environment in which it is located. In other words, by starting the robot in an unknown environment from a random point, it is aimed that the robot can simultaneously detect its location and draw a map of the environment. The robot is an autonomous robot and it is aimed to decide its destination itself.

In the developed study, it is aimed to use grid-based maps and topological maps together. Grid based maps are used as nodes of topological maps. In order to control the robot, the PIC16F877 microcontroller is used as the robot's brain. C language was used as the programming language.

PIC16F684 H-bridge circuit is used to provide speed control. 6 infrared Sharp GP2D12 sensors are used in order for the robot to detect objects around it. 8 microswitches are placed in the corners of the robot to detect it in case of a collision [5].

The current robot discussed in this article has an encoder sensor on its wheels. It is stated that an accurate measurement, mapping and position estimation in the direction of the sensor is provided by the gyroscope sensor. Optimal path planning is an important technology for navigating the area with minimal time to the algorithm of the global map. Optimum route planning has been oriented to ensure the maximum area of travel with minimum time. For this reason, the cells in the area are segmented optimally in time and all areas are provided to navigate with the same frequency and power because they do not overlap and create an optimal path [6].

In the article, the limits of controlling the robot by remote control at a certain interval were tried to be controlled by mobile phone by establishing a connection with DTMF (dual tone multi frequency) technology. In the article, obstacle detection was achieved by using an ultrasonic sensor called HCo4 for the robot to avoid obstacles. The robot also collected information from the room with the help of sensors. For the control of the robot's motion, a two-disc DC motor driven by the DC motor driver L293D is used. L293D is provided to run the motors according to the signals received from the microcontroller [7].

This article discusses the design and implementation of an intelligent autonomous floor cleaner robot with an Android-based controller. The design and implementation of an autonomous robot with both mopping and vacuuming functions is described. It is aimed to control the robot with an android application via Bluetooth. It was emphasized that the ultrasonic sensor and three infrared sensors are used to prevent the sensors from collision. These sensors are said to be connected to the use of a pre-programmed AT MEGA 2560 microcontroller so that it can manage the instructions. It is stated that a DC vacuum fan is used so that the smart robot can take the dirt into the dirt chamber to do the cleaning job. DC water pump is also used to realize the mop function [8].

The recommended method for the structure of the robot is explained as follows, when the robot is turned on, both motors must work normally and move forward. During the study period, the proximity (infrared) sensor calculates the distance between the robot and the surface, and this information is processed by Arduino, and if the distance between the robot and the obstacle is less than 3 cm, the motor direction of the left wheel is reversed and the right wheel motor operates normally. It has been said that this process will continue indefinitely and the motor driven IC (L293D) motors, which will provide the supply current where the robot continues to move without any obstacles, therefore this driver information will remain in the Arduino and the motor will continue to work as desired [9].

A study was carried out to detect the position of both the human and the Roomba robot, and to calculate and transmit the speed depending on the distance between the two positions using sensors and filters. A module has been developed that connects the environmental sensors used here to the robot's communication interface via RT-Middleware. With this module, human avoidance was achieved in 3 steps. First, positions were measured using environmental sensors. Secondly, the positions were estimated and as the third step, people avoidance was achieved depending on the distance of the predicted locations [10].

The point addressed in this article is the development of a low cost, autonomous robot prototype. There are structures such as ultrasonic sensor, Raspberry Pi, camera module as components in the study. Helping the robot by capturing images is provided in this way. The main purpose is to develop a prototype that can be used for experimental purposes in schools and research laboratories. It has been observed that there is a path planning technique algorithm to enable robots to work independently when they enter an area unknown to them. It has been observed that there are autonomous robots that use two algorithms such as SLAM and object detection to map an unknown area. In the studies, the structure of the robot that follows the line has also been examined. The robot has a web camera connected to MATLAB, DC motors and microprocessor PIC16F877. The image is captured by the camera and sent to MATLAB where the image processing is performed to determine the position of the line. This information is sent to the microcontroller that controls the speed and direction of the robot, and this follow-up process is carried out [11],[21].

This article discusses a common sensory navigation problem for autonomous cleaning robots in an unknown area. Here, a working robot system without any environmental map and self-localization is proposed. It is planned to create the building with three layers. In the lower layer, there are general equipment, i.e. ultrasonic sensors, infrared sensors, DC motors, vacuum, incremental encoders and similar structures. It is aimed to perform functions such as cleaning, target search and learning the environment with the sensory behavior layer containing various movement patterns on these sensors and task-based navigation in the upper layer [12].

The methodological structure of the smart dust cleaning system has been tried to be made by recognizing the two components. These components are: the interface between the robot carrier and the user. The main component of the robot is the Arduino Uno Atmega328 microcontroller, which is used to receive and control signals from DC motors with four-stage encoders through the H Bridge driver module. For the robot cleaner, infrared sensors are the structure that receive data as an input that determines whether the field conditions are applicable. This input data is taken to a program logic where the robot decides which direction to go and then these control signals go to the drive motors [13],[22].

II. METHOD

A. Case

Current vacuum cleaners, although efficient, are quite heavy so they require manpower to operate. However, nowadays, new generation smart robots that do not require human power in their use and provide ease of use are produced. These smart robots are more advantageous because they help cleaning without human power. Depending on the design goal, robotic vacuum cleaners are developed for offices, hotels, hospitals and homes. Our project is a smart vacuum cleaner design. A system simulation was designed by predicting the real world situation. In our project, it is aimed for a smart vacuum robot to guess the real world and sweep the room.

In the paper it is tried to simulate a mapping using the TurtleBot robot because it looks like the robot we designed over the Robot Operating System (ROS). TurtleBot: It is a low cost mobile robot kit with new generation modular, customizable, open source software. It can be simulated on Robot Operating System (ROS). Thus, the robot is controlled and simulated in three dimensions. ROS runs on the ubuntu operating system. TurtleBot is designed to work using ROS and Ubuntu only. We tried to perform this process on the virtual machine. It is a popular robot for research and education [14].

Gazebo: It is a simulation environment. In 2009, Gazeboya, ROS (Robot Operating System) was integrated, so Gazebo program has become a more preferred simulator program. ROS 6 works very well with gazebo simulation environment. It is an open source structure developed in Linux environment. For this reason, the Gazebo simulation environment helps to test the data structure that is turned into a ROS Package at the prototype stage in projects. In this study, TurtleBot simulation was made using Gazebo [15].

RViz: After the Turtlebot simulator is installed, the RViz installation is run and used in the terminal for three-dimensional visualization, ie mapping. In the presented study, the virtual robot is started using RViz [16][20].

SLAM Algorithm: The SLAM algorithm is used to use the mapping method, that is, to track the robot at the same time.

SLAM algorithm helps us with simultaneous localization and mapping function. The reason for simulating SLAM is to create a robot or to be able to keep track of its position in that environment while updating its map in an unknown environment. For this reason, the codes are run in the terminal. In the study, SLAM module was installed in a new terminal [17-19].

B. Case B

Second part of the project is an autonomous smart vacuum robot design. The smart vacuum robot is controlled by sensors based on measurements and control software provided. The smart vacuum robot predicts according to the situation of the real world and it has a system that moves on a structure. In the project, the measurements made with the sensors are based on and the robot control software is aimed to predict the real world and sweep the room.

In the design, E18-D80NK, GP2Y0A4150F sensors are preferred as infrared object detection sensors. It was also decided to place more sensors in front of the smart vacuum robot. Because of the obstacles in front of the smart vacuum robot and it has been seen that detecting objects is more important. It is aimed to use the Ardiuno UNO R3 CH340 Klon microcontroller card in the designed smart vacuum robot.

In order to examine the movements of the smart vacuum robot, it was decided to put a structure called double wheel tick on its wheels. The smart vacuum robot is a structure with differential movements in the direction of its wheels. When the two used wheels are at the same speed straight movement has occurred. It has been found that rotational movements occur when the wheels have different speeds. Thus, it is aimed to control the movements of the smart vacuum robot by controlling the rotation speeds of the wheels correctly.

Other materials of the smart vacuum robot are multipurpose mobile platform, infrared sensors, double motor driver board, double motor driver board with L298N voltage regulator, a DC Barrel Jack with terminal input and a jumper cable.

The control logic of the smart vacuum robot is defined with the following python classes; model/supervisor.py, models/supervisor_machine.py, model/controllers. The first class is the representation of the relationship between the simulated environment and the smart vacuum robot. The second class is that sensors interpret information to represent situations inside the smart vacuum robot. The third class represents the smart vacuum robot 's behavior according to the known state of the environment. With the Robot_supervisor_interface.py, a file that defines the API for the interactions with the smart vacuum robot 's sensors and motors has been arranged. read_prox_sensorr( ) read_wheel_encoderr( ) set_wheel_drive_rate(v_left, v_right). These interfaces are used internally with the robot object to move the wheels with data received from the sensors.

Various functions have been used to ensure that the smart vacuum robot 's movements are in accordance with the laws of physics, that it can think of hitting the obstacles and to provide new values for the robot sensors. Internal robot proximity sensors, apply_physics () will also provide the update as it will predict the environment during the simulation. The smart vacuum robot is a dynamic system. This robot's sensor reading and control signal interactions will constantly change. In order to control this, it is necessary to apply continuous control signals, measure the results and generate new control signals calculated in order to reach the target. It is very important for the designed smart vacuum robot to analyze and predict the state of the environment. The smart vacuum robot 's decisions will come about with these predictions. With the sensors to be used, the direction of the obstacles, the distance, the position of the smart vacuum robot must be estimated. The determination of the direction of the obstacles and the distance between them is tried to be achieved with the API function read_proximity_sensor( ). With these realizations, the smart vacuum robot design has been tried to make predictions about the environment.

III. PRESENTED PROJECT

A. Case A

The aim of the project is to design a smart vacuum cleaner that can determine the interior space. TurtleBot is an open source personal robot kit. The reason why the TurtleBot robot was preferred in the study is that the basic technology of TurtleBot is SLAM mapping and this feature makes it suitable for home service robots. SLAM algorithm helps us with simultaneous localization and mapping function. The reason for simulating SLAM is to create a robot or to be able to keep track of its position in the area while updating its map in an unknown environment.

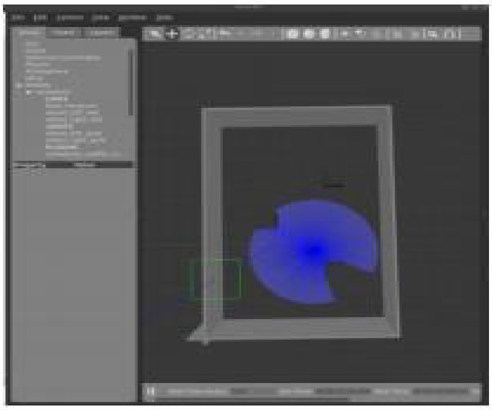

Fig. 1. The world created in the Gazebo environment

A world consisting of 3 obstacles was created with the edit-building editor feature in the Gazebo environment. The picture of the created world is given in Fig. 1 and Fig. 2.

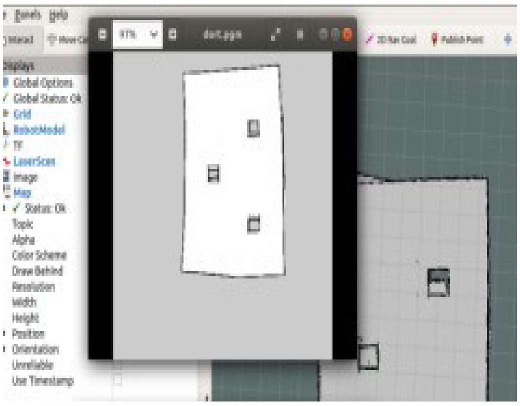

Fig. 2. mapping with moving of robot

After the world was created, Rviz was run to do the mapping process with the gmapping () method.

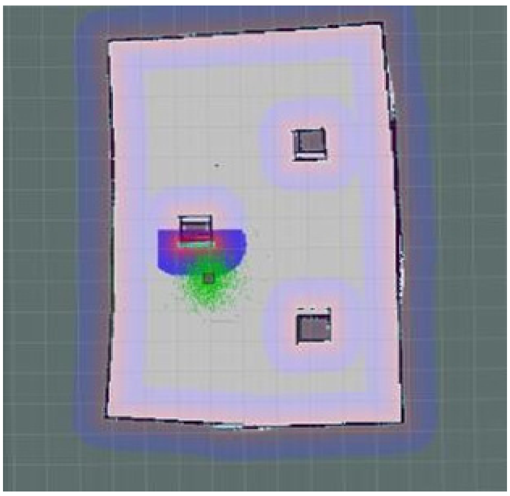

Fig. 3. Movement of the robot

Later, the robot was started to be moved randomly.

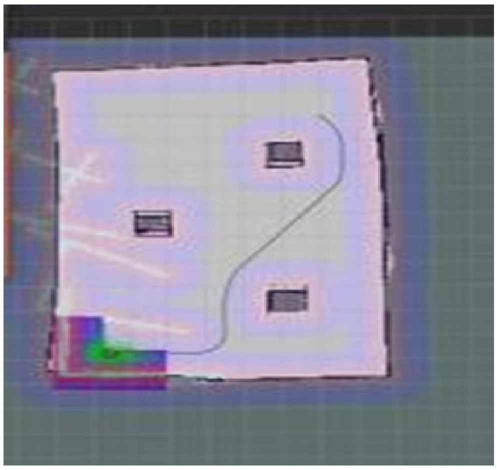

Fig. 4. The route the robot follows on its way to the target

In this article, a home service robot to be developed for the purpose of cleaning a room is mentioned and its path is shown in Fig. 4 and 5.

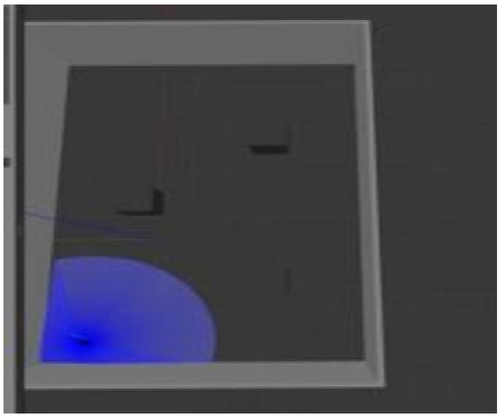

Fig. 5. The route the robot follows on its way to the target

After making sure that the mapping process was done properly, the created map was saved. The studies in ROS environment are shown in Fig. 2, 3 and 4, 5 and 6.

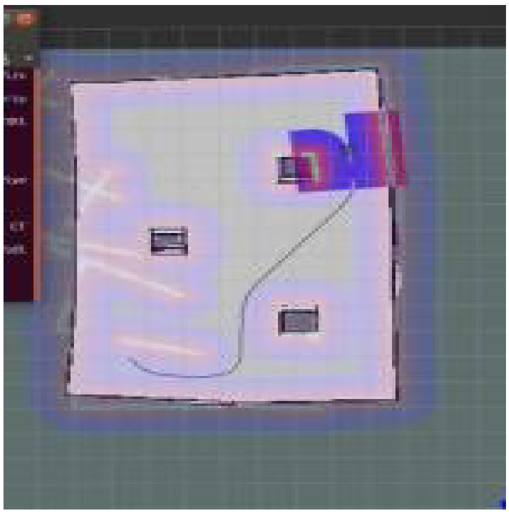

Fig. 6. Robot crossing obstacles on its way to the target

There will be a problem of perceiving structural shaped items such as chairs, tables, beds etc. as obstacles and avoiding them. Such situations are shown in Fig. 6 and 7.

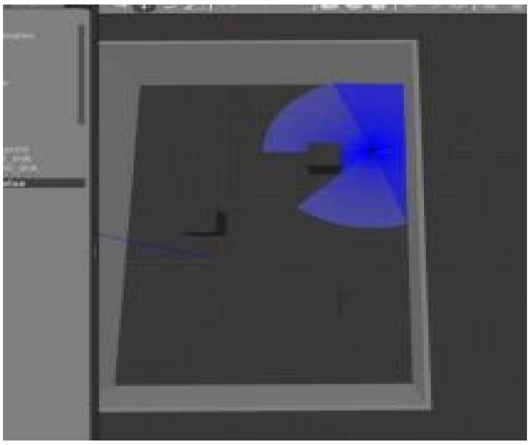

Fig. 7. Robot crossing obstacles on its way to the target

In this article, the structure of an automatic robot that can clean areas such as rooms, offices, shopping malls has been mentioned and its operation has been simulated.

IV. Conclusion

Indoor cleaning robots are helpers that we use frequently in our daily life and become a part of life. Old-style traditional products have been developed according to the needs of the users. Robot structures, which are more advanced today, did not make it possible to directly apply user needs when they were first developed. For this reason, in robotic technologies, the user has begun to be included in the design process according to their needs. In this article, optimal route planning is discussed. Thus, the analysis of the home environment is made and the path to be cleaned is determined, in this way, the interaction will be applied to the design.

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