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Path Planning and Obstacle Avoidance using ROS

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Abstract:- The project presents an implementation of a prototype for the autonomous vehicles with the Robot Operating System (ROS). The system utilizes turtlebot 3 for the navigation purpose. The aim of this work is to integrate the obstacle avoiding algorithm with path planning techniques to create a system that is able to navigate in given static environments. The software prototyping tool used is Robot Operating System.

Robots and their applications evolved swiftly over decades, proving to be a great achievement in human history. Robotics are improving people's lives by assisting them in resolving challenges they face on a daily basis. As a result, they have a greater impact on our lives. The influence of robot use on our lives is undeniably beneficial in terms of saving time and effort. Robotics' constant advancement has created several growth potentials in industries, education, utility facilities, and health care.

Keywords:- *Turtlebot 3, ROS, Gazebo, RVi, Autorace.*

I. INTRODUCTION

The Robot Operating System (ROS), a framework for developing robot applications, allows programmers to piece together a large system by connecting existing solutions to small problems. The main aspect of ROS is the way the programme operates and interacts, which allows users to create complicated software without having to understand how specific hardware works. ROS gives access to a network of processes (nodes) to communicate with a central hub. Nodes can run on many devices and communicate with the hub in a variety of ways. Doing this on a real robot would be expensive, and it would waste time setting up the robot every time. As a result, robotic simulations are used. Gazebo is the most commonly used ROS simulator. It has a strong community, is open source, and is simpler to deploy robots on. ROS was created with certain use cases in mind. Many things have changed since then, including a resurgence in AI research and an increase in the number of use cases. Even though ROS handles these issues admirably, robotics is growing more popular among the general public.

In the near future, robots will continue to revolutionize our lives beyond our wildest dreams, and they will continue to play a significant role in human existence and behavior. It creates effective learning, production, control, and usage while also providing modern facilities for our lives.

II. ALGORITHMS

A. *Gaussian Potential field algorithm*

Potential field-based methods use an artificial potential field consisting of an attractive field and a repulsive field. The attractive field attracts the vehicle toward the goal while the repulsive field repels the vehicle from obstacles. Based on the position vector of each obstacle the obstacles are detected and avoided. Obstacle avoidance is one of the essential technologies in local path planning and one of the critical technologies that guarantees human and vehicle safety.

B. *Dijkstra's algorithm*

Dijkstra's algorithm is an algorithm we can use to find shortest distances or minimum costs depending on what is represented in a graph. Dijkstra's algorithm is very similar to Prim's minimum spanning tree. Like Prim's Minimum spanning tree, we generate a shortest path tree with a given source as a root. We maintain two sets, one set contains vertices included in the shortest-path tree, other set includes vertices not yet included in the shortest-path tree. At every step of the algorithm, we find a vertex that is in the other set and has a minimum distance from the source.

III. LITERATURE REVIEW

"Automatic Vehicle Navigation using Dijkstra's Algorithm": Dijkstra's method is used to formulate the shortest path algorithm in this study. The classic Dijkstra method can only discover the shortest path using the AS/RS system's rectangular environment map, and it skips over additional pathways with the same distance. An updated Dijkstra algorithm is used to address the path-planning problem in rectangular contexts, which identifies all equidistant shortest pathways[1]. This enables a car to drive itself around a network of interconnected roadways, taking the cheapest path.

"Functional System Architectures towards Fully Automated Driving" The paper covers how to determine the vehicle's performance using the Functional System Architecture. This study focuses on the creation of a system architecture that is in line with the Robust Sense objectives across Europe. Rather than comparing individual algorithms for perception, prediction, and planning, this paper emphasizes robustness and reliability by focusing on autonomous vehicle architectural design and its impact on degraded operation modes in the case of sensor failures, misdetections, and unexpected changes in traffic flow[2]. There are two sorts of architectures: centralized and distributed architectures. Both topologies use redundant sensor arrays as a shared feature.

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"LOAM: Lidar Odometry and Mapping in Real-time" In this article, range measurements from a 2-axis lidar travelling in 6-DOF are employed as a real-time approach for odometry and mapping. Odometry algorithms estimate velocity from lidar data, correct distortion in the point cloud, and then integrate and register the point cloud into a map using a mapping technique[3]. The method is low-drift and computationally simple because it does not require high precision range or inertial measurements. SLAM can be performed by separating the problem into two halves and employing two algorithms to optimize a large number of parameters at the same time. One approach uses high-frequency odometry with limited fidelity to determine the lidar's velocity.

"Path-planning of Automated Guided Vehicle based on Improved Dijkstra Algorithm" This paper introduces a new algorithm that finds shortcuts in a rectangular area accessible to it all equal distance distances. By adding a run time planning test method, the right way for both short distance and time can be determined[4]. The algorithm was developed using Visual C ++, and simulation results show that it works and is possible. Determining methods in Default Storage and Recovery Programs (AS / RS). Using the adjacency matrix and spatial coordinates in two dimensions, the environment map is described. Automated guided vehicles will be more efficient with this algorithm as it is applied to AS/RS. With the study, AS/RS system path planning will be supported, as well as other applications with multiple equidistant shortest paths.

"Autonomous Obstacle Avoidance Vehicle using LIDAR and an Embedded System" The car just has one LIDAR sensor, allowing it to navigate in low-light conditions safely. Raspberry Pi and LIDAR sensor are the two main hardware components. of this application[5]. A Light Detection and Ranging module (LIDAR) were utilized to detect obstacles. In LIDAR, pulses of pulsed light are continuously sent into every direction (360*) and measured with a sensor based on the wavelength and time at which the reflected pulses are received. The distance from the nearest obstacle is determined by the wavelength and time of the signals received. It is powered by an OpenCV Raspberry Pi 3 board. Using current Wi-Fi infrastructure, the car is capable of locating itself in the environment and safely driving from a starting point to a destination point.

"A Study of Improved Global Path Planning Algorithm for Parking Robot Based on ROS" This paper focuses to prepare a global path for the parking robots. The concept of global path planning is used for the parking purpose. This method improved the efficiency of the robots that helps in parking[6]. Also, this algorithm was compared with other algorithms on simulation platforms like ROS and found that this algorithm used has given good results than the others. The concept of BP neural networks was also considered as one of the main factors while testing.

"Path Planning Using State Lattice For Autonomous Vehicle" Several categories of planning for autonomous vehicles are discussed in this paper, including path, trajectory, and motion. State lattice strategy is used to plan the path. As a result of this approach, the vehicle's geometry and kinematics are incorporated into the path set, which is called a motion primitive and a rotation matrix is used to describe the novelty[7]. State lattice refers to the set of motion primitives arranged in a particular way. Motion primitives are saved in structural arrays and later used to construct a map's viable path. A path planning technique based on state grids is provided in general. When determining the path, a pre-computed path set also saves time. To validate the technique, different situations are considered.

"Research on Obstacle Avoidance Path Planning Algorithm for Six-axis Robot" In this paper, it deals with the problem of the six-axis robot possibly colliding with an obstacle in the working space[8]. This problem is addressed by using a method known as artificial potential fields. Collision detection algorithm plans the manipulator's path to be collision-free. A six-axis manipulator simulation system using MFC programming and OpenGL is developed to verify the algorithm.

"Static Obstacles Avoidance in Autonomous Ground Vehicle using Fuzzy Logic Controller" For an autonomous vehicle to be used in real time navigation technology is probably an important requirement[9]. A fuzzy logic-based controller is used in this paper to control an autonomous vehicle for the challenging task of avoiding obstacles, which is one of the soft computing techniques. Two inputs and one output are considered in the fuzzy logic controller. The distances from left and right sensors are inputs, while the rotation angle is an output. Fuzzy logic controllers with Graphical User Interface [GUI] were designed based on 36 rule bases, and they provide information on the direction in which the vehicle is moving.

O. Khatib: This work provides a unique obstacle avoidance strategy for manipulators and mobile robots based on the concept of artificial potential fields[10]. In order to apply the potential field approach to robot manipulators, we use the operational space formulation. Formally, this formation focuses on controlling the motion of the end effectors and avoiding obstacles in the operation space of the manipulator end effector. Its base tool is the equation of motion of the manipulator end effectors in the operation space.

"Stereo vision obstacle avoidance using depth and elevation maps" The goal of this study is to present a single-sensor obstacle avoidance approach for mobile autonomous robots employing a stereo camera[11]. To avoid obstacles, a robot must be able to determine the distance to its surrounding objects. Stereo vision is the most popular method for extracting depth information from visual images, but its disadvantage is that it requires very powerful hardware. A depth map concept uses images to align to obtain information about the depth of an object. A elevation map concept is used to take into account nearby objects to overcome the disparity map problem. As a result, the robot's view is represented as a 3D point cloud. Threshold Estimation Method is used for obstacle avoidance. To estimate the distance between objects, this algorithm uses

Disparity maps robotically. ExaBot is used for this experiment.

"UAV Obstacle Avoidance Using Potential Field under Dynamic Environment" This paper implements an obstacle avoidance approach that may be applied to the Parrot AR Drone 2.0. Attractive potential functions and repulsive potential functions are the two types of potential functions. The quadcopter was attracted to the desired position by the attractive potential function and repelled the collision by the repulsive potential function in order to keep it away from the obstacles. They simulated quadcopter performance with static impediments, dynamic obstacles from other quadcopters, and five quadcopters flying in the same field at the same time to complete this study. A pair of quadcopters have been tested with Krogh's repulsive potential. In this simulation, the potential function of Krogh was investigated for dynamic obstacles[12]. Under ROS (Robot Operating System), the Gazebo Simulator is used for simulation. They were able to simulate the Parrot AR Drone 2.0 as closely as possible using the TUM simulator ROS module. To achieve the goal of quadcopters, they have utilized the Khatib's attractive potential feature.

"Navigation of Autonomous Mobile Robots - Invited Paper" Through this paper we explored navigation stacks, mappings and localizations, sensor fusions, collision avoidance and trajectory tracking[13]. Indoor and outdoor navigation are the two different types of navigation for autonomous vehicles. It is difficult for the navigation path to be prepared for the unstructured environment. Using mapping and other concepts, we are able to overcome this challenge. Maps are created by converting information in a map's form. If the map is static, it will continue to have the same characteristics over time. There are most likely to be dynamic maps that move with the vehicle as it moves. As a result, the robot must construct the map of any moving environment. Using local and global mapping techniques is one way to accomplish this. When the robot has obtained information about the environment around him, he can move accordingly. It is also capable of localizing it

"Navigation and Obstacle Avoidance System in Unknown Environment" We learned about the concept of unmanned aerial vehicles in this work (UAVS), commonly referred to as drones, that are very versatile, capable of monitoring, rescuing and conducting searches from the skies. Commercial organizations, researchers, and individuals have become interested in drones because of this, resulting in an increase in drones every day. As the number of airborne vehicles increases, collisions may occur between them and navigation systems could be interfered with. Earlier studies of obstacle avoidance systems focused on path planning for static environments or known environments, but only a small number studied dynamic environments or unknown environment[14]. By using lightweight LIDAR (Light Detection and Ranging) sensors, the authors have devised an obstacle avoidance system that uses these sensors to detect obstacles and react accordingly.

"Efficient Visual Obstacle Avoidance for Robotic Mower Yao" This paper provides a novel technique of robotic mower lawn obstacle avoidance and motion control using the Gabor texture-based classification method and drivable regions search. After getting real-time image streams of grass scenes, they used Gabor filters to extract robust texture features. The robotic mower was tested under complex scenes utilizing the Robot Operating System (ROS) built on compressed features[15]. Robotic lawnmowers have made remarkable advancements over the past decade thanks to the massive demand. For security and efficiency reasons, robotic mowers need to be capable of detecting and avoiding obstacles while operating. At present, collision sensors are mostly used to avoid obstacles, seasons, and light conditions on robotic mowers.

"Design and Implementation of UAV Obstacle Avoidance System" An ultrasonic-based method of obstacle avoidance is presented in this paper. The obstacle avoidance flight of the multi-rotor UAV can be achieved by increasing the number of ultrasonic waves so that they form a circle based on the traditional ultrasonic obstacle avoidance scheme, fusing the information from multiple ultrasonic sensors, and adjusting the channel value of the tele controller based on the distance between the UAV and the obstacle[16]. At the same level, the motors are on the front, the back, the left, and the right side of the body. The four-rotor UAV must increase or decrease its power output simultaneously in order to avoid obstacles, so that the lift force of the UAV exceeds or decreases its speed. In order to achieve front-back and left-right motions on an aero plane in the horizontal plane, some force must be applied.

"Fusing LIDAR sensor and RGB camera for object detection in autonomous vehicle with fuzzy logic approach" In this study, Velodyne HDL-64E 3D-LIDAR scanners and RGB video cameras were used as the sensors. Lidar scanners acquire three- dimensional data of the environment in the form of a sparse point cloud[17]. Lidar sensors can be used for a variety of purposes, such as object detection, semantic segmentation, and obstacle detection. This study proposes a method for fusing two sensors using fuzzy logic inference. The camera image and the LIDAR point cloud have been pre- processed prior to implementing our proposed framework, such as rectification and synchronization.

IV. PROBLEM STATEMENT

Designing robots in real time is not always possible. It takes a lot of time and human effort. Moreover, it is very much costly to implement the design in real time. This problem can be overcome by means of using ROS which allows the users to check for the possibilities of their robotic system design.

Making use of this available resources we can design a system design for the field of autonomous vehicles, ware house management, agriculture and so on. We know that a machine never gets bored with its tasks. Path planning and obstacle avoidance approach can be used in automobile field for the betterment of road transport.

V. METHODOLOGY

An autonomous car which is also known to us as Self driving cars are becoming more popular these days. They are designed in such a way that makes the work of the driver very easy. This is made possible by considering all the static and dynamic environmental factors. We focussed on developing a ROS prototype with, Gazebo simulator will be used for simulating the bot in desired environment and the Rviz visualizer will be used for visualizing the environment. Firstly, the perception will be done which means collecting the environment data from the sensors. Following perception mapping will be done based on that bot will be localized with respect to the framed map.

Path planning will lead to give ready to go environment for bot Navigation stack will function with move base package in this whole flow. The main purpose of this project is to develop a prototype that can be used for the autonomous vehicles and other fields like agriculture and ware house management for the supply of goods purposes.

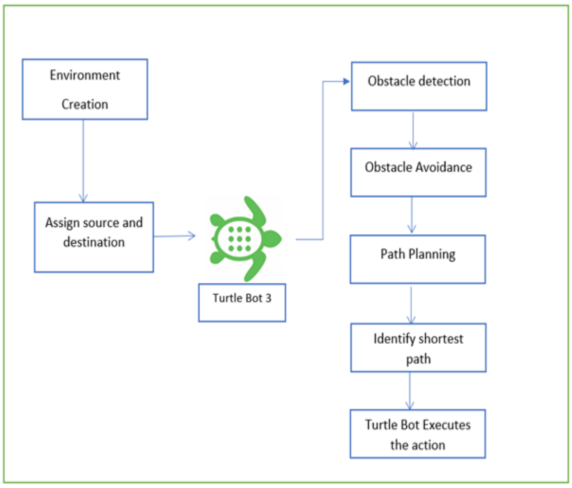

Fig. 1: Block diagram

The Turtlebot3 is used as the bot for the purpose of this project. There are two types of turtlebot3 available for usage in ROS namely, the turtlebot3 burger and turtlebot3 waffle. They got their names as they resemble, a burger and a waffle respectively. Either of these can be used for this purpose. But we are making use of the turtlebot3 waffle for the navigation purpose. Firstly, the environment is created by using the perception mapping, in which the turtle bot 3 is used as the virtual bot for the simulation purpose. The starting and destination places are set in the environment containing many obstacles.

The Gaussian Potential Field algorithm is used for the obstacle avoidance. The turtle Bot 3 will get trained using this algorithm. Also, for path planning, the Dijkstra's algorithm is used to find the shortest path that bot can make use to reach the destination. This entire simulation can be done using the navigation stack, which forms the base for this project along with the Robot Operating System Software.

VI. RESULTS

Deployed the turtlebot3 and some obstacle into the gazebo environment. Using the various options available in the Gazebo platform, we explored the ways in which the prototype could be implemented. We started exploring it with the various options that were available with us.

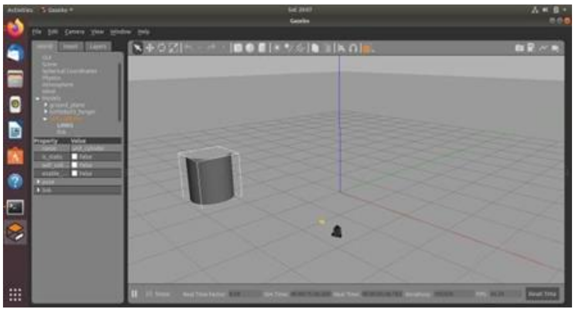

Fig 2: Gazebo simulator with Turtle Bot3 and obstacle

The gazebo simulator provides various size of obstacles which are of cylindrical, circular and others shapes. By making use of this as obstacles for the turtlebot 3, we designed the environments.

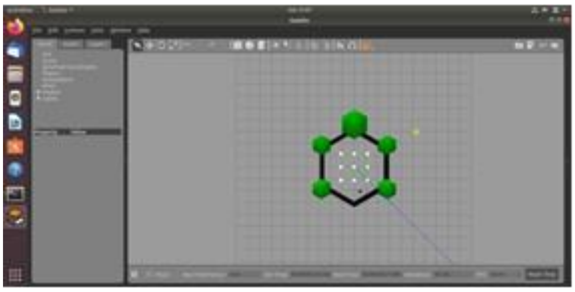

Fig 3: Hexagonal Gazebo environment with multiple obstacles and Turtlebot3

As the obstacles and the turtlebot 3 are deployed into the environment, we trained the Turtlebot3 in the gazebo environment, by making it move frontwards, backwards, and also on either side i.e. left and right.

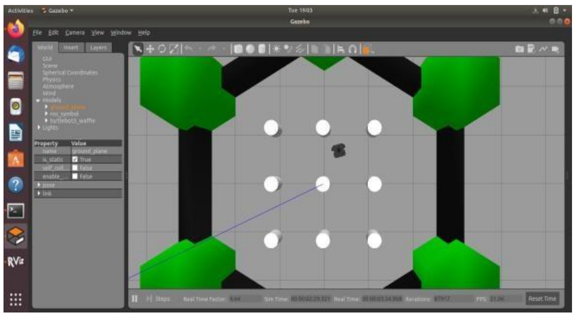

Fig. 4: Tutlebot3 moving in Gazebo environment

The RViz visualizer is visualizing the environment from the perspective of the turtlebot3 waffle, as it moves along the environment. Visualizing the map is done using RViz. As the turtle Bot is made to move through the hexagonal gazebo environment, the RViz will do the perception mapping for the same. Once the bot completes exploring the complete environment, the visualized map will look as shown below:

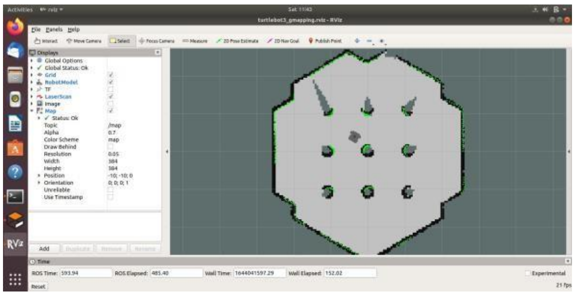

Fig 5: Completely visualized map

The SLAM (Simultaneous Localization And Mapping) generates the entire map simultaneously as the turtlebot3 moves around the space in the gazebo environment.

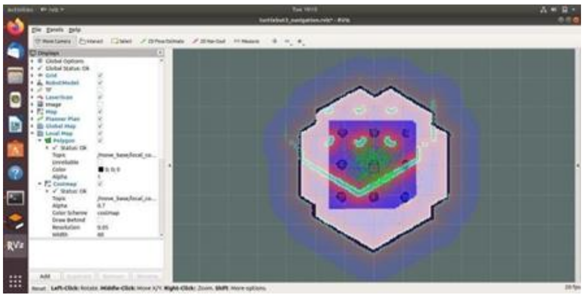

Fig 6: Visualized environment with mapping

As soon as the turtlebot 3 get trained and able to visualize the environment, we can train the model. We have trained the turtlebot 3 with Dijkstra's algorithm for finding the shortest path to navigate to the desired destination without colliding with the obstacles.

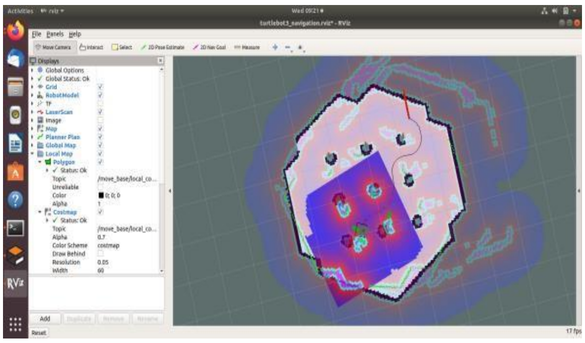

Fig 7: Navigating through the shortestpath using Dijkstra's algorithm

By using the 2D navigation tool application given in the Gazebo platform, we can set the destination for the turtlebot to move. without any collision. This 2D navigation tool also point the red color arrow mark as the destination is given and the bot will move to the destination. Also, in this the turtlebot moves in between the obstacles to reach the destination. The obstacles are visualized in the color of green and the boundaries of the environment are in black color as shown in the figure 8. On similar basis, the turtlebot 3 is made to get trained with the environment that is created and the classroom is made localized to the turtlebot 3 by moving it all around the new environment.

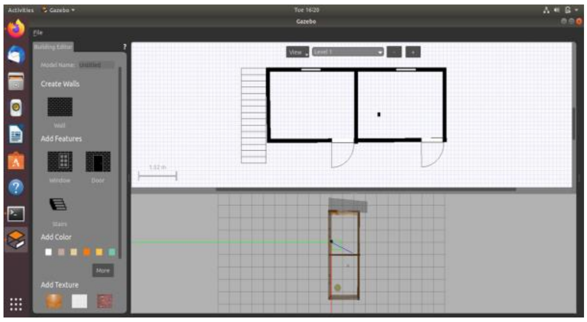

Fig 8: Developed an environment with classroom setup using Build Editor

VII. CONCLUSION

The Gazebo simulator provides various options for the user to use as obstacles in any environments and also the user can design their own environment and train the turtle Bot 3 with that particular environmentand as it visualizes the complete environment, then we can make it move from source point to destination without colliding with the obstacles. By making the best use of the available platforms, we can make sure that whether the systems can be implemented properly for the benefit of human beings.

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