Journal of
Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.7628846

DESIGN AND OPTIMIZATION OF PATH PLANNING BOT BASED ON ROS

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Abstract: SLAM (simultaneous localization and mapping) is a technique for automated vehicles that enables simultaneous map building and vehicle localization. The vehicle is able to map out uncharted terrain owing to SLAM algorithms. Engineers use the map information to carry out tasks such as path planning and obstacle avoidance. An autonomous machine needs the ability for planning the motion of a high level command. For Example – If a task is given to explore a particular area, the bot have to plan accordingly to complete the required task. To achieve thislevel of accomplishment, the path works on an algorithm that solves SLAM and path planning problems.
The machine is designed in such a way that it will work as a grass cutter will complete the task in the given frame. The grass cuttingmachine creates its own path in the frame and detects obstacle coming in the path. In this way the Slam robot is utilized in the application of agricultural field. In the current work, we have designed a 3-D model of Slam robot and its various components like LIDAR Camera, Jetson Nano, Lithium-Ion Battery, Motor and Body design of machine. This model is capable of performing grass cutting operation using cutting blade and collection of waste in a sack attached to the machine. This machine works on automation based on path planning algorithms using ROS, this eliminates human interference. Various kinds of research paper were reviewed to compare different kinds of mechanisms and various components were analyzed for the final model created.
Keywords: SLAM, LIDAR, Jetson Nano, Lithium Ion Battery

1 Introduction
1.1 LIDAR SENSOR:
LIDAR 3D scanning technology was developed around 1960s, this technology was used for the detection of submarines from a fighting jet or an aircraft. These days LIDAR sensor is highly popular, it is used in different types of machines. They are used in cars for the auto driver functionality. This sensor creates a 3D image of the surroundings of the car which help the control system of the car to predict the future obstacle and change direction and speed accordingly. LIDAR sensor is also used in the mobile phones like iphone, etc for augmented reality (AR) features. Augmented reality is used to create filter, games and is used in designing purposes also. LIDAR sensor comes with an amazing range of height of 100 km altitude. So this sensor can be used in many other applications because of the height range of the sensor.

1.2 Jetson Nano:

The Jetson Nano is a tiny, powerful computer designed for use with low-level edge AI appliances and applications. (As shown in figure 1).

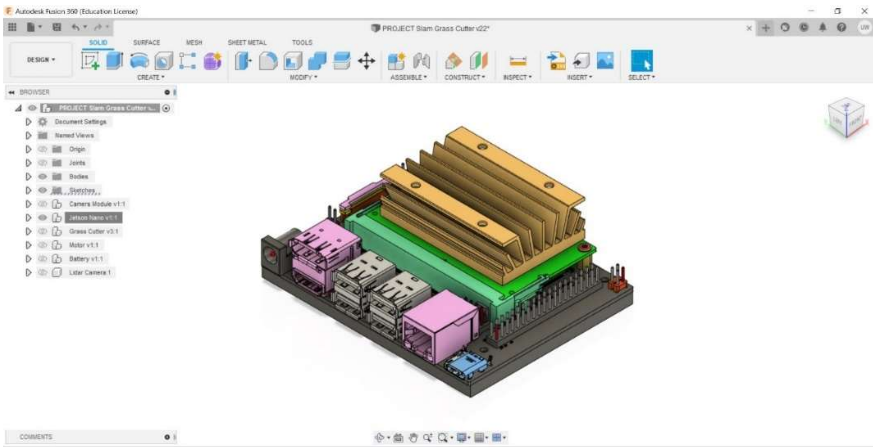

Fig. 1. Jetson Nano is the microcontroller used for programming algorithm in the machine.

Numerous libraries for deep learning, computer vision, graphics, multimedia, etc. are incorporated into it.

1.3 Lithium-Ion Battery:

Anode, cathode, electrolyte, separator, and two current collectors make up a battery (anode and cathode).

Both the anode as well as the cathode must capture lithium. The electrolyte passing through the separator transports the positively charged lithium ions from the anode to the cathode and vice versa. Electrons are created by the motion of lithium ions which gives the change to the positive charge collector(As shown in figure 2).

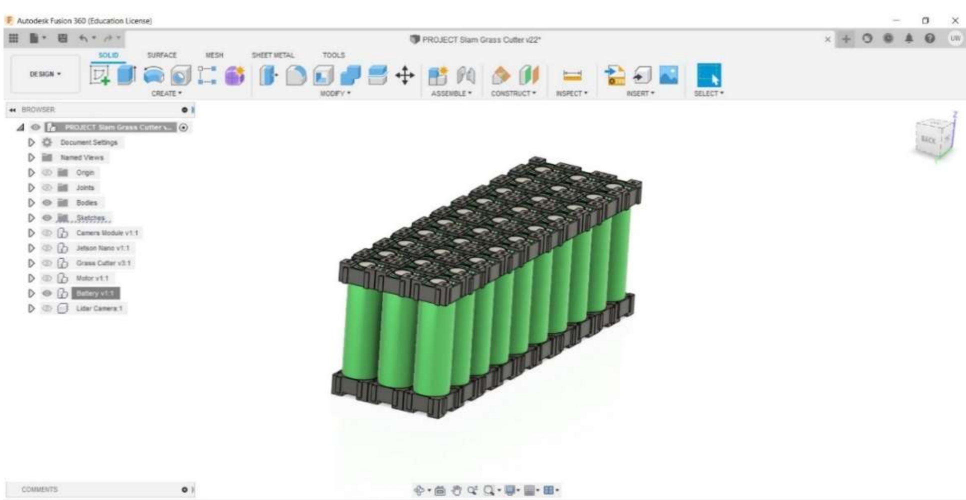

Fig. 2. Lithium Ion Battery is the power source which generates energy to move the machine.

Electricity is transferred from the power supply to the negative current collector in the current collector.The separator prevents the movement of electrons within the battery.

1.4 Motor:

Motor used in the model is used for purpose of rotating the grass cutting blades and servo motor is used for wheels moment(As shown in figure 3).

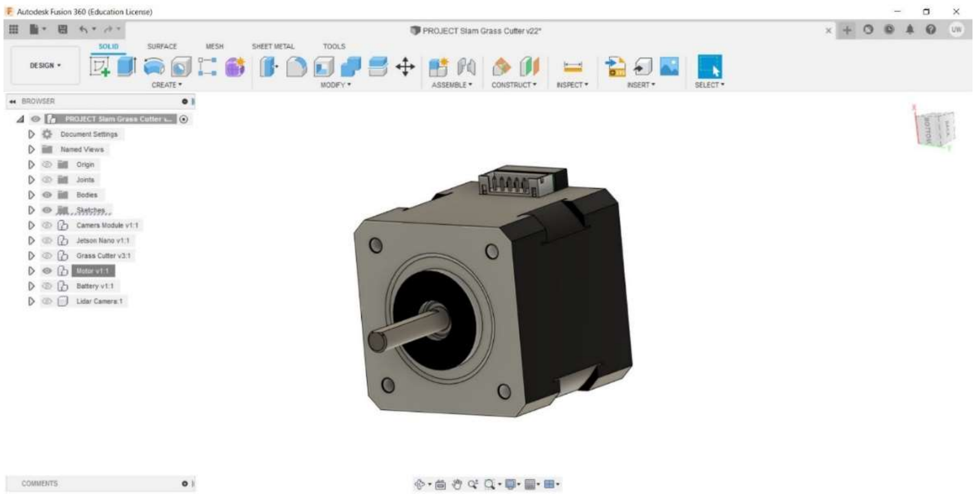

Fig. 3. Servo Motor for rotating the cutting blades.

A motor is made with the help of magnets and copper wire. Magnets are pasted on the inner surface of the motor cover and the insulated copper wire is wounded on the spindle. When current flows across the wire, the wire acts like an electro magnet. The electromagnet repels the magnet and the spindle starts moving. A capacitor is used to start a motor in a particular direction. Different kind of motors are available in market, some are brush less and works on direct current or some on alternating current.

1.5 ROS: Robotics of system is an open source project whichprovides a framework to your robot. It has become an integral part of robots today, and has massively impacted the Robotics Arena. ROS is extremely fascinating to study, but is not easy or beginner friendly.

ROS Theory is an attempt to document the basics of ROS. This documentation will take you through a number of examples to better understand the concepts, and is neatly demonstrated by code and pictures of my terminal.

1.6 Gazebo: Gazebo is a 3D simulator software platform which is used to simulate robot. It offers robot the skill to efficiently and sufficiently simulate robot in various types of complex indoor and outdoor environment.

Figure 4 shows the output of gazebo simulator which displays the boundaries and obstacles as shown in the given environment.

It provides the best sensor and interface applications for both users and programs.

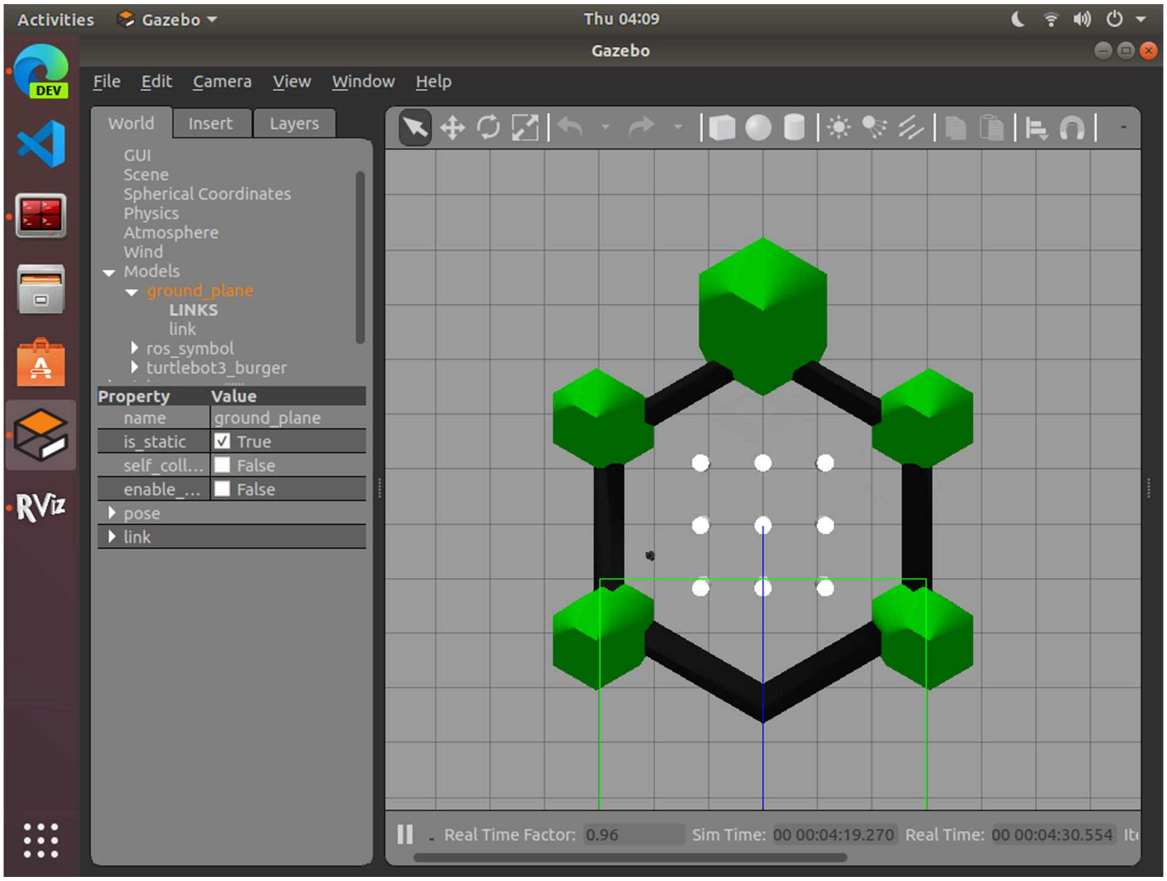

Fig. 4. Gazebo 3-D Simulator Environment.

2Literature Review

According to Zhi et al., the Control System is the most crucial component of the Slam Robot since it determines the performance in movement as well as elements like stability and precision.Here we explored various G-Mapping methods, Navigation and path planning used for the project. The information from the laser scan and the already-created map can be used to realise localization, navigation, and autonomous robot movement.[1]

Takayaet al. created project where Gazebo and ROS software were used for 2-D and 3-D mapping including the simulation.
For further knowledge we can use gazebo and ROS for cresting environment for path planning.[2]

Shen et al. perform 3 experiments on Slam robot for simulation in this project. The purpose of the paper is building different environments for obstacle avoiding purpose.
The article concludes that g-mapping performs best in environments with small scenes. Hector-slam, however, is better suited to environments with long corridors. [3]

Menget al. aim at the issue of the traditional g-mapping algorithm. This algorithm's accuracy is poor and it lacks a loopback. It is suggested as a solution to strengthen the closed loop detecting link. Various procedures have been experimented on the slam robot.
Algorithms for laser mapping and Monte Carlo adaptive positioning were chosen for improved performance.[4]

For the ROS / Gazebo environment, Khazetdinov&Zakiev et al. have been working on a model of a warehouse created totally in compliance with GOST rules and global best practises.Its applicability and computing performance are compared to those of the current solutions.
The ROS navigation system has been used to validate models.They proposed prefabricated warehouse models that can be assembled in a variety of ways.[5]

Ling et al. develop a multipurpose configuration of a mobile manipulator that can carry out numerous tasks, such as object grasping, navigation and positioning, manipulator control, object pose estimation, and indoor planar environment recognition.
A single robot machine employed in sophisticated assembly and logistics sorting can perform a variety of functions. [6]

An open-source motion planning method that is implemented in the ROS platform is presented by Mirzae, Karimi, and others.For the rescue robots, the proposed planner creates a semiautonomous algorithm.
The Gazebo-simulated results validate the efficient performance of the presented algorithms which we can use further.[7]

LIDAR is used as the detecting sensor and a self-made wire-controlled chassis is used as the mobile platform in the AMR that Feng et al. develop using the ROS operating system.To quickly track the environment and target points, AMR combines the cartography algorithm and move base path planning method.
We can utilise AMR because it can quickly and accurately construct the world map without deviating while travelling, and its mapping accuracy is comparatively steady.[8]

Megalingamet al sought to create a vision-based autonomous manipulation system for assistive devices like wheelchairs, service robots, and rescue robots, among other things.
It also covers the procedure for converting the coordinate systems of the manipulator and camera.
Using the ROS framework, we can create a thorough system integration between vision and a robotic arm.[9]

Wang et al. integrate various positional sensors utilising the Robot Operation System (ROS) as the foundation.
Providing accurate positioning by fusing data from technologies including Light Detection and Ranging (LIDAR), Inertial Measurement Unit (IMU), odometer, and Ultra-wideband (UWB).

We can do SLAM (simultaneous localization and mapping) that is more refined and satisfies the requirements of intelligent robots in the application field.[10]

A two-wheeled self-balancing robot can handle great efficiency and adaptability, according to research by Santoso et al.
On simulations in the GAZEBO application, the research generates virtual robots, virtual maps, and virtual sensors that can be seen in RVIZ.
In addition to producing speed data that is provided to GAZEBO simulations and balancing robots in the actual world using the ROS platform, usage of the map development and navigation system was observed.
To make an autonomous robot, features of high efficiency, flexibility, and a reliable navigation system should be fulfilled. A reliable navigation system can be reached by using the ROS (robot operating system) platform with gazebo software.[11]

The robotic operating system presented by Alborzi et al. uses a Parrot AR for robot navigation and autonomous simultaneous localization and mapping (SLAM). A laser scanner and an inertial measurement unit are features of the quadrotor drone 2.0.
For a future project, we can employ the navigation system as well as Slam.[12]

A model and the Gazebo simulation of an autonomous robotic system that palpates any soft surface are presented by Shafikov et al.The system makes use of a modified KUKA IIWA LBR manipulator model that is furnished with a new force sensor plugin and a spherical indenter.
The system collects information from a virtual Kinect camera and computes points for palpation based on an acquired point cloud in order to perform a palpation method.
To improve the gazebo simulator's ability to detect areas more precisely, we can apply the needed software.[13]

A hybrid path planning method was presented by Chen et al., combining a new, enhanced adaptive window methodology with safe global path planning.The enhanced adaptive window technique, which was based on the idea of a safe path, greatly increases obstacle avoidance accuracy.
This study demonstrates how hybrid path planning may be used to securely control a mobile robot in a changing environment. [14]

The goal of the bot in the paper by Zhang et al. is to discover the safest, shortest route possible through the objective environments.
By combining the strengths of the ant colony, Dijkstra, and heuristic algorithms, a heuristic bidirectional ant colony algorithm is given, which allows us to determine the skeleton topology's shortest path.
By using coordinate transformation, we may convert the path planning into an n-dimensional quadrate viable region and solve it using the particle swarm optimization technique.[15]

Fritsche et al., evaluated how well they worked for robotic mapping, introduced two radar-based scanning techniques.
Both approaches will be contrasted, and outcomes will be assessed.For the finest results of the path planning robot, all methodologies and theories are contrasted.
Both the methods for occupancy grid mapping can be used for projects in future reference.[16]

Xu et al. concentrated on creating motion control systems for robot cars using DSP technology. They proposed an integrated-separated PI control algorithm that ensures control accuracy and enhances real-time control.We may make use of the motion control system's efficient architecture for the robot car. [17]

According to Köseolu et al., the hardware architecture and electronic communication protocols are both taken into account while presenting the framework of an autonomous mobile robot (AMR) modified for robot operating system (ROS).The design of the robot served as the foundation for the entire paper.
The result obtained from this paper can be used in various activities of robot functionality.[18]

Lera et al. went over the benefits and drawbacks of using 3D simulators.They are utilised to test the autonomy of mobile robots in enclosed spaces.We looked at the definition of sensing, navigation, and manipulation mistakes and how these might affect the robot's actual performance.[19]

In order to support applications involving unmanned aerial vehicles (UAVs), Li et al. discuss a 3D texture mapping in Visual Simultaneous Localization and Mapping (VSLAM).
We can evaluate how well our 3D mapping approach worked.[20]

A unique algorithm for simultaneous localization and mapping was published by Karlsson et al. as the Visual Simultaneous Localization and Mapping (vSLAM) algorithm (SLAM).
The method, which is based on vision and odometry, allows for low-cost navigation in crowded and congested surroundings.SLAM is able to recover swiftly from significant perturbations.[21]

Hexacopter and mobile robot UGV (unmanned ground vehicle) combination was simulated by Nugraha et al.
The gazebo simulator, which is built on the robot operating system, is used to simulate cooperative robots (ROS).
Camera gazebo simulation can be used to steer an unmanned aerial vehicle (UAV) in the direction of the desired motion.[22]

A crawler UGV's track-terrain interaction was approximated by Gabdullin et al.It models and simulates the Russian crawler robot in ROS/Gazebo and uses the Rvizprogramme to display its motion.

In any Gazebo environment, we can utilise gazebo software to operate a bot in a heterogeneous robot group navigation. [23]

For usage with Ackermann steering simulations, Shimchik et al. employed the ROS-based software from which Gazebo generated virtual golf course topography and golf cart models.The golf cart model was moved from one hole on the 3D virtual golf course to another to verify the simulation and algorithm.
To accomplish localization, calculate the best trajectory, and detect dynamic impediments with real-time route adjustments, one can employ an artificial environment.[24]

A path planning method based on splines was developed by Magid et al. The desired path is short, smooth, and avoids obstructions.
A series of splines defined by an ever-increasing number of knots is used to represent the path in order to prevent an extremely challenging optimization over all of its locations.
In order to plan a path while avoiding barriers for any required application ,one might be able to use some methods.[25]

According to Magid et al., the fundamental objective of the algorithm is to keep the robot as stable as possible at every point along its journey; under rare circumstances, we need the robot to become unbalanced and abruptly alter its 3D orientation.
On the gazebo platform, we create numerous algorithms to stabilise the robot's motion.Rescue robots can be used to enhance the capabilities and safety of human rescue teams by employing these techniques.[26]

A new proximity-based navigation system is presented by Maria Fazio et al., which uses Beacon’s data to determine the user's position.The edge computing infrastructure processes the optimal route for interior navigation, and the user receives service through smartphone.
We can benefit from Bluetooth Low Energy, an upcoming IOT-based short-range wireless communication technology (BLE).[27]

In order to organise IOT application composition and data processing across heterogeneous computer infrastructure, LongxiangGao et al. developed a new IOT programming paradigm.The newest IOT technology, sensors, actuators, and cloud computing should all be utilised while developing new technology.[28]

Robots and robot cells were used to demonstrate a system by Mahbuba et al. at the factory level.The robot then identifies the fundamental components that are necessary to realise such capability in a fog-based system.
Resource virtualization, memory interference control, real-time communication, system scalability, dependability, and safety can all be used for further research.[29]

In order to investigate the mobile robot's navigation utilising a visual SLAM platform, Peng Ji et al. demonstrated the integration of a robot with cloud computing.For the creation of a virtual environment, the platform is built on the OpenStack management platform.[30]

Using 3D LIDAR, Mendoza et al. developed an object-level SLAM system for driverless vehicles. The outcome demonstrates that the SLAM method may create useful maps to arrive at precise estimations.[31]

Shen et al. developed indoor mapping for a setting using g-mapping and LIDAR.The outcome shows that employing mobile SLAM may produce a high precision map while saving money. [32]

The algorithm that confirms the service platform's ability to successfully offload the robot's tasks to the cloud is something we can employ.Additionally, it decreases hardware performance for the robot's needs.

3 Methodology

We have created a grass cutting machine using Auto Cad Fusion 360 software which is used for grass cutting operation in agricultural field. We have simulated the bot on gazebo platform which is dynamic simulator. The bot is SLAM machine which works on autonomous purpose using g-mapping algorithm on ROS. The machine creates and simulates its own map using the path planning algorithm.

3-D Model

In the project we have created a Slam grass cutting robot.

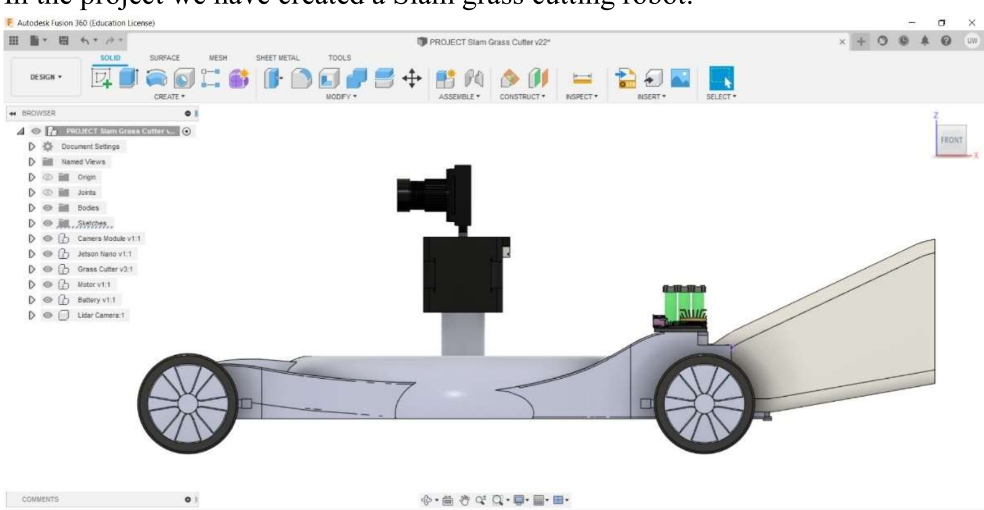

Fig. 5. Grass Cutting Model (Side View)

The purpose of the bot is to create path using the path planning algorithm. We use the ROS and gazebo software for the coding part of the project (As shown in figure 5-6).

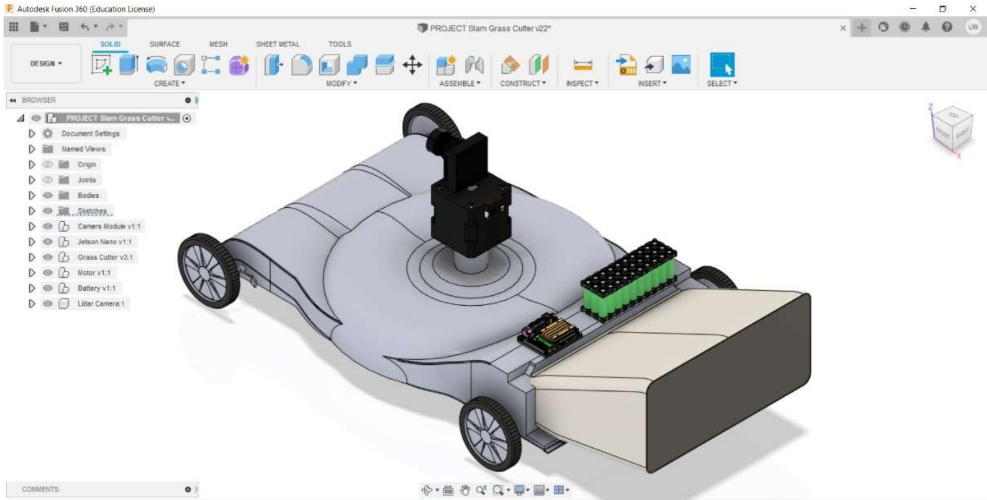

Fig. 6. Isometric View has been displayed for the model.

For the working model we created a 3-D model on AutoCAD Fusion 360 software.
The model consists of Lithium-ion battery, Jetson Nano, LIDAR camera, Motor and the body design

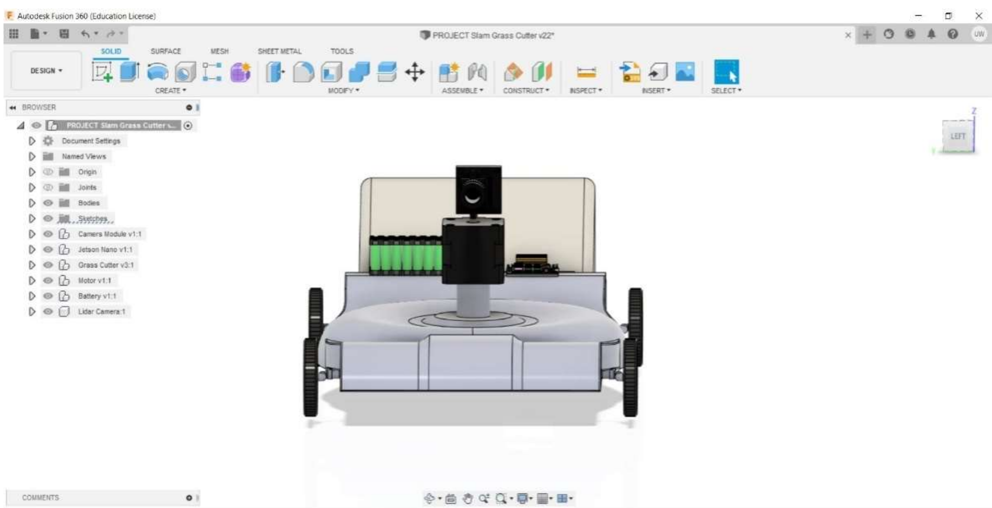

Fig. 7. Front View has been displayed for the model.

The model works on automation purpose, no human intervention is required in the working of machine (As shown in figure 7).

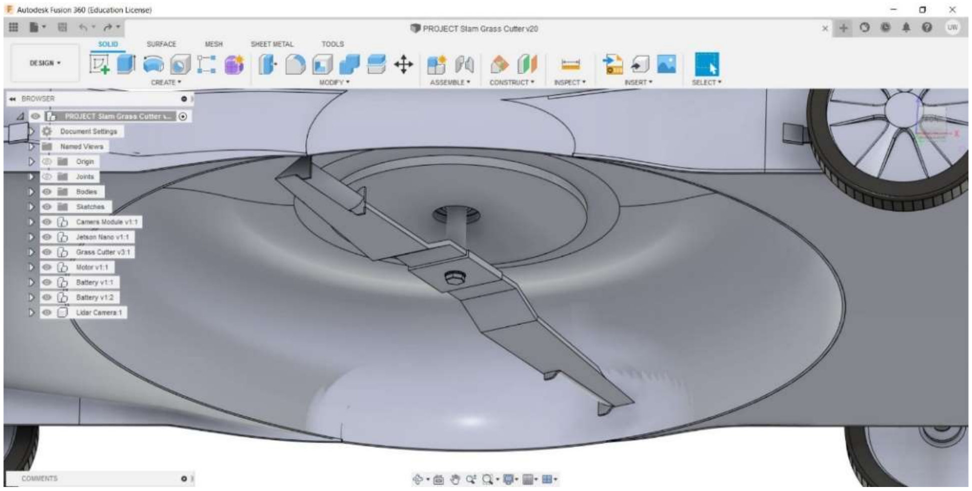

Fig. 8. Cutting Bladeof grass cutting machine.

This part of machine consists of the cutting blades which are used cut the grass according to the simulated path (As shown in figure 8).

4 Result and Discussion

We have used this bot for the application of agricultural field where the Grass Cutting machine acts as a Slam robot.

In the given field or outdoor surrounding it creates a path for a particular range. The Slam robot simulates its path and then it moves in it accordingly as per the given velocity and range. The Bot works on automation which a part of the new revolution of Industry4.0. The field is considered to be a random agricultural field where obstacles are placed as the poles. The slam bot cuts the grass in the area it simulates in the Gazebo Simulator.

4.1 Gazebo Environment

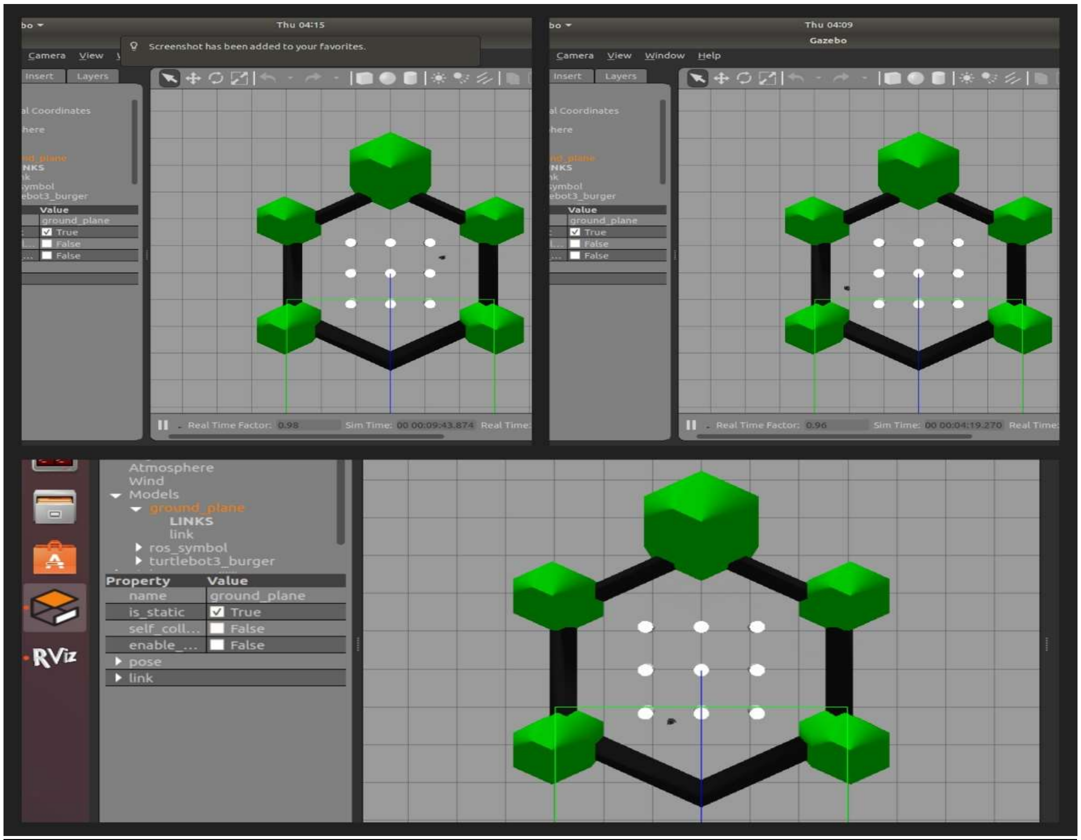

Fig. 9. Gazebo Environmentsimulating 3-different dynamic positions of bot.

In the gazebo 3-D simulator we created our environment using bot. All the properties of the environment are set according to the value of surrounding required by the bot(As shown in figure 9).

The boundaries are created in this environment in the form of a hexagon, obstacles are places in the path of the bot.

The bot covers every position in the environment in order to generate the path after visualizing the area captured while travelling the entire range.

4.2G-Mapping and path planning on ROS

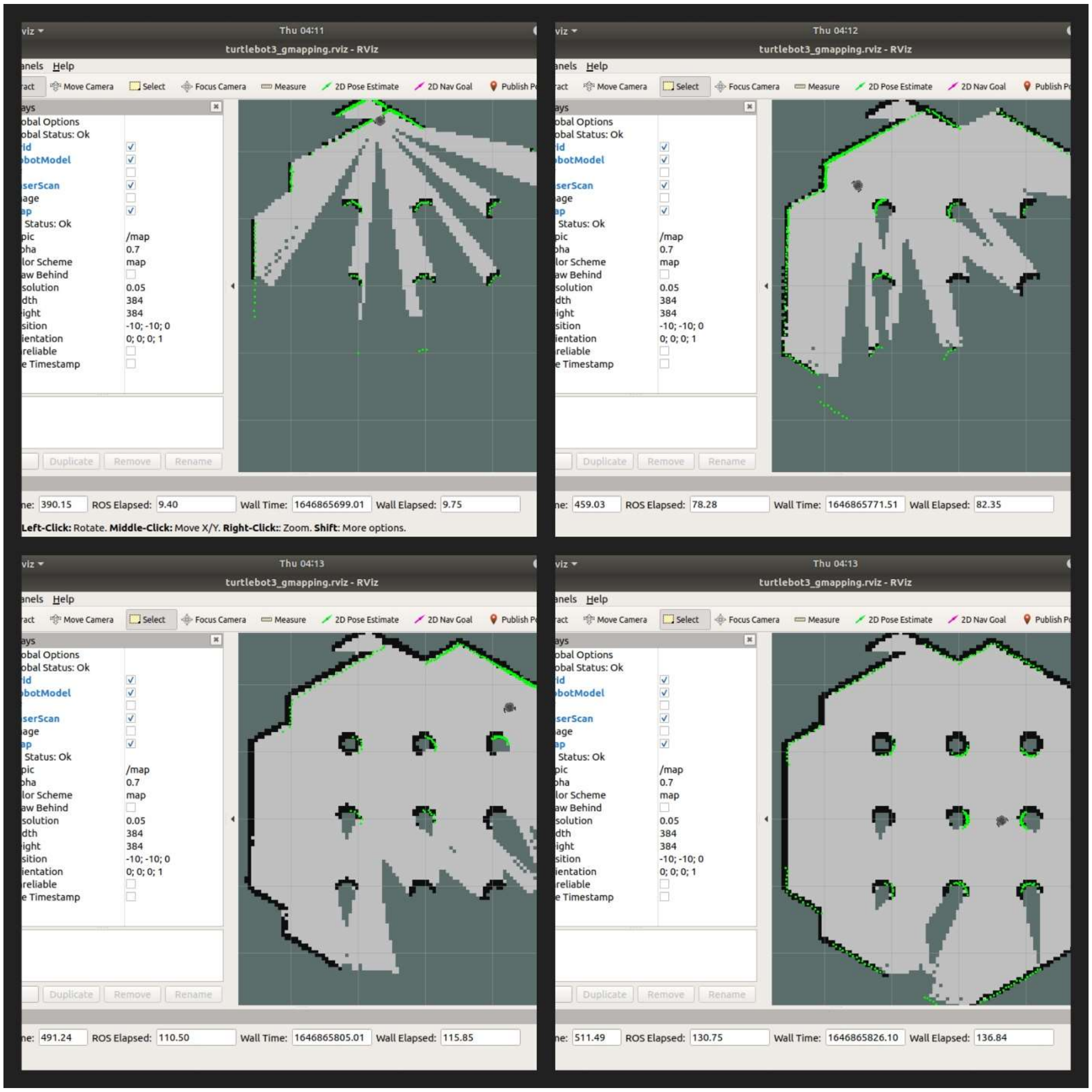

Fig. 10. G-mapping algorithm creating a 2d map for the bot.

The g-mapping package provides laser-based SLAM (Simultaneous Localization and Mapping), as a ROS node. It is known as slam g-mapping.

Slam is simultaneous localization and mapping is a method used in autonomous vehicles to map and simulate their path in any type of environment. Here slam g-mapping is used where we can observe the bot create its path by itself for particular range where it can predict the path on it.

All the obstacles are predicted and the outer layer depicts the boundary of the field. The green part in the figure explains about the path which falls under the range of LIDAR sensor(As shown in figure 10-11).

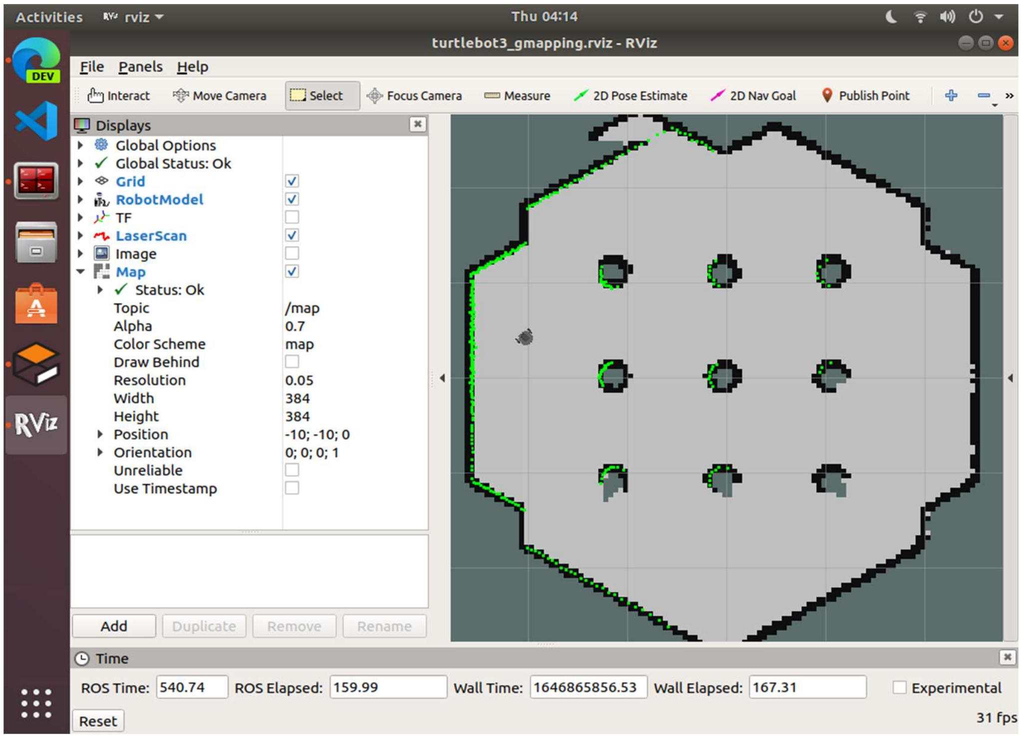

Fig. 21. Tracing of Complete path on 2-D Path Map using g-mapping algorithm.

4.3 <u>Laser scanning path (LIDAR Sensor)</u>

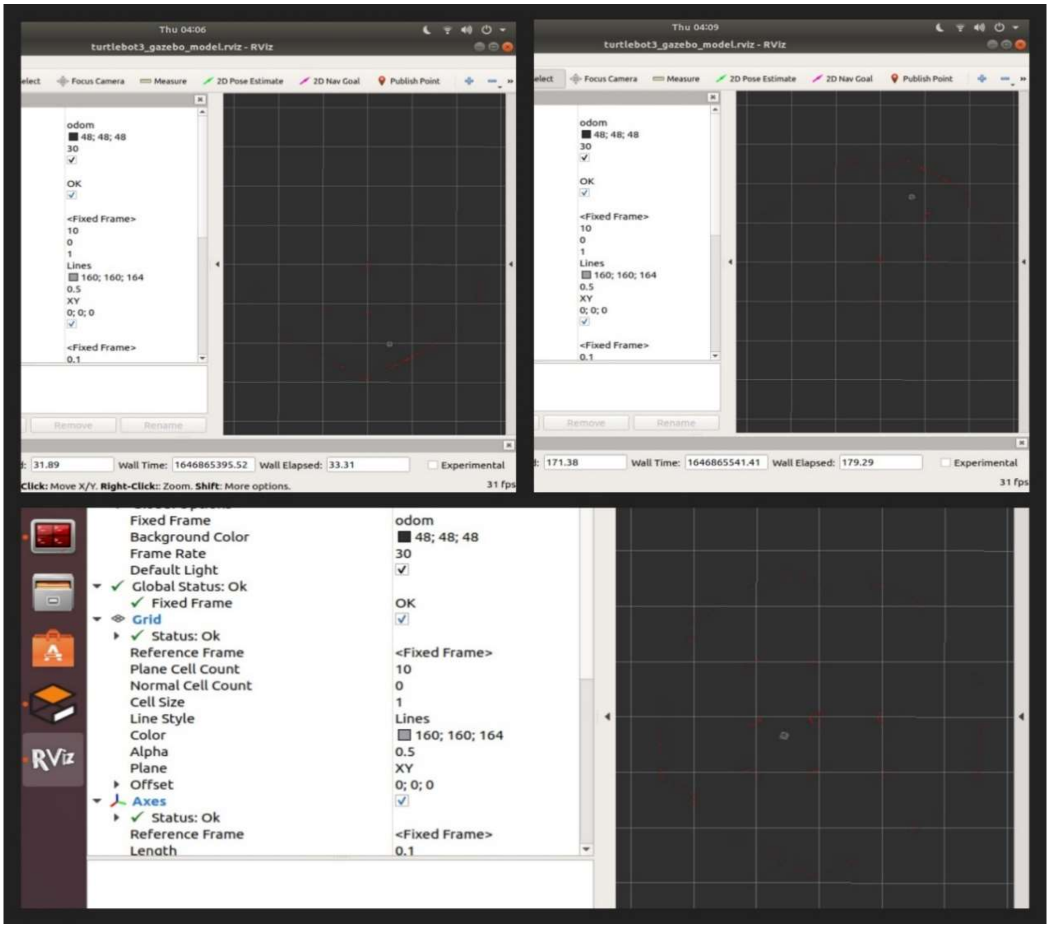

Fig. 32.LIDARusing laser sensor to generate a 3D map of its environment using Rviz software.

The LIDAR Sensor provides the full range capacity. When the bot uses LIDAR Sensor to sense and scan full path, on the XY plane the LIDAR sensor provides the boundary in the form of red dotted rays.These are used to create a fixed frame under which we can perform any operation using the bot.

In the end results were obtained after completing the G-mapping algorithm on the gazebo 3-D simulator successfully.
LIDAR 3-D Map was generated smoothly, for all the 3 positions we have simulated and tested the bot on ROS.

5 Conclusion

In the project we have created a 3-D model of a Slam grass cutting machine based on ROS. The Slam bot has been programmed in such a way that it programs itself according to the environment for the working of a grass cutter. We have studied different kinds of path planning algorithm for performing simulation by the bot in the gazebo environment.

The model consists of a LIDAR camera, Jetson Nano, Motor and Lithium-Ion battery as a source of power. Rest of the body has a chassis design consisting of four wheels and servo motor.

We have simulated bot using g-mapping algorithm which has been performed by the bot on the gazebo software using ROS (Robot Operating System) platform. We have used the gazebo software on ROS platform for comparing different simulations the bot is simulated and tested using path planning algorithms. Gazebo software has been used to simulate path for various environments. The bot has been used as a model to create path. On the Rviz tool, LIDAR sensor will detect path by red scattered rays creating boundaries. The model works on automation purpose, no human intervention is required in the working of machine and it consists of the cutting blades which cut the grass according to the simulated path as planned by the software.

Application of this bot is a grass cutting machine in the agricultural field. Where the bot will be able to create and simulate its own path by detecting obstacles and boundaries. The bot will be using its own algorithm to simulate the machine and complete the purpose of its application. The whole machine works on automation eliminating the labor cost.

Future plans to use this bot can be targeted in various kinds of applications such as solar panel cleaning, road cleaning, etc.

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