iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 Issue: V Month of publication: May 2024

DOI: https://doi.org/10.22214/ijraset.2024.62718

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue V May 2024- Available at www.ijraset.com

Multipurpose Autonomous Navigation Robot (M.A.N.R)

Sanket Bhole[1], Nirmal Gharpure[2], Vrushali Mohite[3], Tanishq Shinde[4], Prof. G. S. Wayal[5]
[1, 2, 3, 4]Students, [5]Assistant Professor, Department of Computer Engineering, Padmabhooshan Vasantdada Patil Institute of Technology, Pune, India

Abstract: The "Multipurpose Navigation Robot" project proposes the development of a highly versatile and adaptive robotic system capable of seamlessly navigating through diverse real-world environments such as restaurants, hospitals, and warehouses. The project centers around a modular design, featuring a flexible base chassis responsible for efficient and obstacle-free movement across various terrains and settings. The core innovation lies in the incorporation of easily attachable and detachable modules, enabling the robot to cater to specific tasks in different industries.
Keywords: Arduino, Raspberry pi, PWM, PID controller, Odometry, A-star algorithm, Path planning, Robot GUI, Task Scheduling

I. INTRODUCTION

The primary objective of the project is to design and construct an intelligent robot capable of serving multiple purposes in diverse work environments. The driving force behind the Multipurpose Autonomous Navigation Robot project lies in the recognition of a crucial gap in the robotics landscape. Traditional robots struggle to adapt to the dynamic challenges posed by diverse environments such as restaurants, hospitals, and warehouses. This project is motivated by the vision of creating a versatile and adaptable robotic solution. In the restaurant setting, the robot will function as a serving bot, facilitating smooth and efficient customer service. In warehouses, the robot will transform into a robust package-moving bot, streamlining the logistics and distribution process. Furthermore, in healthcare environments, the robot will take on the role of a healthcare assistant, providing valuable support to medical staff and patients alike.

The successful realization of the Multipurpose Navigation Robot holds the promise of revolutionizing industries by offering a cost-effective and multi-functional robotic solution. This project serves as a stepping stone towards a future where robots can be dynamically deployed to serve multiple purposes across various work environments, enhancing operational efficiency, reducing human workload, and ultimately contributing to the advancement of automation and robotics in society.

II. PROBLEM STATEMENT

The project goal is to develop a highly adaptable "Multipurpose Autonomous Navigation Robot" with modular attachments, ensuring autonomous navigation, safety compliance, and optimal task performance. The aim is to provide industries a scalable, cost-effective, and innovative robotic solution for diverse environments.

III.LITERATURE SURVEY

1) "Intelligent Warehouse Management System", Mohamed Dhouioui; Tarek Frikha

This paper presents the design and implementation of an intelligent warehouse management system. The main emphasis is on three software components: An Xamarian IOT application that acts as the exchange interface with end users, a web application that communicates with a database and ensures the persistence and communication between the different components of the system, and a robot that moves products in the warehouse according to storage and shipping requests.

2) "Path Planning of Restaurant Service Robot Based on Astar Algorithms with Updated Weights", Ruijun Yang; Liang Cheng

This paper introduces an improved A-star algorithm for optimal path selection for autonomous navigation robots in restaurants. This uses a real-time gridded restaurant congestion map, aiming at the shortest weighted path, and based on the degree of channel congestion to change the weight of the restaurant channel in real-time.

3) "Research and Implementation of Autonomous Navigation for Mobile Robots Based on SLAM Algorithm under ROS", Jianwei Zhao; Shengyi Liu; Jinyu Li

This paper aims at the problem of low mapping accuracy, slow path planning efficiency, and high radar frequency requirements in the process of mobile robot mapping and navigation in an indoor environment. This paper proposes a four-wheel drive adaptive robot positioning and navigation system based on ROS.

4) "Development of a wireless communication platform for multiple-mobile robots using ROS ", Pipit Anggraeni; Mariem Mrabet; Michael Defoort; Mohamed Djemai

The paper discusses the development of a wireless communication platform for coordinating multiple mobile robots using the Robot Operating System (ROS). The authors present the MiniLab Enova mobile robot as the focal point and detail the implementation of a multi-master system using ROS to manage a wireless communication network among multiple robots.

5) "ZigBee based Small-World Home Area Networking for Decentralized Monitoring and Control of Smart Appliances", Rakesh Das; Jitendra Nath Bera

The paper presents a novel approach to decentralized monitoring and control of smart electric appliances within homes, utilizing ZigBee mesh topology for home area networking (HAN). All communication nodes within the household are interconnected via ZigBee, with the operational status of individual smart appliances displayed on an in-home display (IHD) or smartphone via Wi-Fi internet connectivity

IV. METHODOLOGIES

A. A-Star Algorithm

The A* (A-star) algorithm is a widely used pathfinding algorithm in robotics and computer science for finding the shortest path between two points on a graph or grid. It's particularly effective for path planning in robotics because it not only guarantees finding the shortest path but also does so efficiently by intelligently searching the most promising paths first. As the environment or working area may be dynamically changing, the algorithm or the rules must be devised to ensure an optimistic collision-free path. A* algorithm is a heuristic function-based algorithm for proper path planning. It calculates heuristic function's value at each node on the work area and involves the checking of too many adjacent nodes for finding the optimal solution with zero probability of collision. Hence, it takes much processing time and decreases the work speed.

$$f(n) = g(n) + h(n)$$

n is the next node on the path, g(n) is the cost of the path from the start node to n, and h(n) is a heuristic function that estimates the cost of the cheapest path from n to the goal.

B. Odometry

Odometry is a key aspect of our project's autonomous navigation system, responsible for tracking the robot's movement and estimating its position within the environment. Odometry is the use of data from sensors to estimate change in position of bot over time. For example, if a robot is traveling in a straight line and if it knows the diameter of its wheels, then by counting the number of wheel revolutions it can determine how far it has travelled. In our case, we will be using optical rotary encoder to get the environment input while the robot is moving and feed it into the microcontroller to calculate the position of robot with respect to the environment.

Generalized wheel kinematic model is used to estimate the velocities of wheels for localisation.

$$\omega = \frac{1}{r\cos\gamma}\left[\sin(\alpha+\beta+\gamma) - \cos(\alpha+\beta+\gamma) - l\cos(\beta+\gamma)\right]\begin{bmatrix}\dot{x}_R \\ \dot{y}_R \\ \dot{\theta}_R\end{bmatrix}$$

C. Robot Structure

1) Microcontrollers

Microcontrollers are often called the brain of the robot. They collect information from input devices such as sensors, switches, and others, and then execute programs that control output devices such as motors and LEDs. The output signals from the microcontroller are given to motors (wheels, legs, etc.) or light or any other actuator, making the robot walk or move. The best microcontroller is the one that does what you need at the least possible cost of power, size, and money. Thus the microcontrollers used in our projects are Arduino UNO, Arduino Mega, Raspberry Pi.

2) Motor Driver

We use motor drivers to give high power to the motor by using a small voltage signal from a microcontroller or a control system. If the microprocessor transmits a HIGH input to the motor driver, The driver will rotate the motor in one direction keeping the one pin as HIGH and one pin as LOW. Motor Driver used in our projects are Cytron Motor Driver for 10A current(MD 10C).

3) Power Supply

Power supplies play an important role in the proper operation of industrial robotics. Most industrial robots will be powered by a battery source, either chargeable or non-rechargeable. The power supply will help deliver power to different components, like a motor drive or inverter circuit within the robotic circuit. Our robot is equipped with 12V DC Battery which provide the power supply to motor driver and all the other electrical components to operate. Also we provide step-down voltage of 5V to our microcontroller for its operation.

4) Chassis

A two-wheeled robot with a dead wheel in front is used along with maintaining its modular design. A modular upper body offers significant flexibility and versatility for various applications such as warehouse automation, hospital logistics, and restaurant services. This modular design allows for easy customization and adaptation of the robot's functionality to meet specific requirements in different environments

V. IMPLEMENTATION

A. Integration of Methodologies

In our project, the A* algorithm, LiDAR, and odometry work together synergistically to enable the robot to navigate autonomously in various environments. Here's how these components interact:

1) Environment Mapping with LiDar
- The LiDAR sensor scans the robot's surroundings and creates a detailed map of the environment, including obstacles, walls, and other features.
- This map is used as the basis for path planning by the A* algorithm.

2) Path Planning with A* Algorithm
- The A* algorithm uses the map created by the LiDAR sensor to plan an optimal path from the robot's current position to its goal. This map is used as the basis for path planning by the A* algorithm.
- It takes into account the location of obstacles and navigable areas to determine the most efficient route.

3) Localisation with Odometry
- Odometry data from the wheel encoders is used to track the robot's movement and estimate its current position.
- This position estimate is used by the A* algorithm to determine the robot's starting point for path planning.

4) Dynamic Obstacle Avoidance
- As the robot moves along its planned path, the LiDAR sensor continues to scan its surroundings
- If a new obstacle is detected, the A* algorithm can re-plan the path in real-time to avoid the obstacle, using the updated LiDAR map and odometry data.

5) Feedback Loop
- The robot's movement is a continuous feedback loop between odometry, LiDAR, and the A* algorithm.
- Odometry data is used to update the robot's position, LiDAR data is used to update the map and detect obstacles, and the A* algorithm uses this updated information to plan the next move.

B. Implementation if UI/UX

The User Interface (UI) and User Experience (UX) play a critical role in ensuring the effective operation and interaction of the Multipurpose Autonomous Navigation Robot. This section outlines the design and implementation of the UI/UX components tailored to the diverse operational environments of warehouses, hospitals, and restaurants.

1) GUI Design
- The Graphical User Interface (GUI) is designed to provide an intuitive and user-friendly platform for commanding the robot. The design principles emphasize clarity, simplicity, and adaptability to accommodate various user preferences and operational requirements

2) Environment Selection
- Upon launching the GUI, users are presented with an environment selection panel. This panel allows users to choose the specific operational environment for the robot, such as warehouse, hospital, or restaurant. The selection process is facilitated through clearly labelled buttons or dropdown menus, ensuring ease of use.

3) Environment-Specific Actions:

Once the environment is selected, the GUI dynamically adjusts its interface to display environment-specific actions and functionalities.
- Warehouse Environment: If the warehouse environment is selected, the GUI presents options related to crate handling, inventory management, and navigation through aisles.
- Hospital Environment: In the hospital setting, the GUI showcases functionalities such as medication delivery to patients, transportation of medical supplies, and navigation to different wards or rooms.
- Restaurant Environment: For restaurant operations, the GUI displays options for food delivery, table service, and navigation through dining areas.

4) Command Inputs
- Users can input commands or set waypoints for the robot's navigation through the designated input fields or interactive map interfaces. The GUI provides clear feedback on the accepted commands and planned routes, enhancing user confidence and control over the robot's actions.

5) Real-Time Feedback
- During operation, the GUI continuously provides real-time feedback on the robot's status, including its current location, planned trajectory, and any encountered obstacles or challenges. This feedback loop enables users to monitor the robot's progress and make informed decisions as needed.

6) Customization Options
- The GUI offers customization options to cater to the preferences and requirements of different users and operational scenarios. Users can adjust settings such as navigation speed, obstacle avoidance sensitivity, and display preferences to optimize the robot's performance for specific tasks and environments.

C. Odometry

1) Calculation x, y, θ

We can use the following pseudocode to calculate the position of the robot with respect to the environment.

- We can use the following pseudocode to calculate the position of the robot with respect to the environment.
  $double\ dtheta\ =\ cm\_per\_tick\ *\ ((dn2 - dn1)\ /\ (LENGTH))$
  $double\ dx\ =\ cm_{per_{tick}}\ *\ ((d + dn2)\ /\ 2.0)$
  $double\ d\ =\ cm_{per_{tick}}\ *\ (dn3\ +\ ((dn2 - dn1)\ /\ 2.0))$
- Small movement of the robot gets added to the field coordinate system:
  $pos.x\ +=\ dx\ *\ Math.cos(pos.h)\ -\ dy\ *\ Math.sin(pos.h);$
  $pos.y\ +=\ dx\ *\ Math.sin(pos.h)\ +\ dy\ *\ Math.cos(pos.h);$
  $pos.h\ +=\ dtheta\ /\ 2;$

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue V May 2024- Available at www.ijraset.com

2) Speed of wheel velocity

We can use the following generalized wheel kinematic model to calculate individual wheel velocities.

$$\boldsymbol{\omega} = \frac{1}{r\cos\gamma}[\sin(\alpha+\beta+\gamma) - \cos(\alpha+\beta+\gamma) - l\cos(\beta+\gamma)]\begin{bmatrix}\dot{x}_R \\ \dot{y}_R \\ \dot{\theta}_R\end{bmatrix}$$

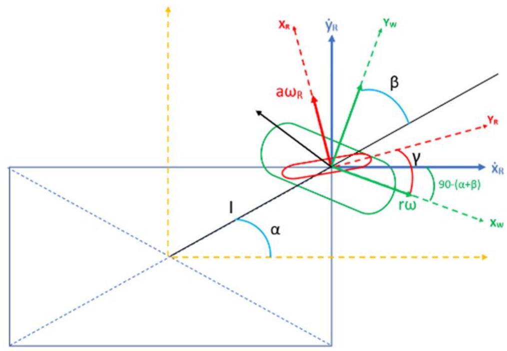

Fig. 1 Kinematic Model of Differential Drive

D. Algorithm of A-Star

1) Initialization
- Create open and closed lists to keep track of nodes.
- Add the starting position of the robot to the open list.

2) Loop until the open list is empty:
- Find the node with the lowest combined cost (total cost) in the open list. This node represents the current position of the robot.
- Remove the current position node from the open list and mark it as visited by adding it to the closed list.

3) Check if the current position is the goal position:
- If yes, the robot has reached its destination. Construct the path by tracing back from the goal position to the starting position using the parent pointers.

4) Generate possible movements for the robot
- Consider all adjacent positions that the robot can move to, taking into account the environment (e.g., obstacles, boundaries).
- Calculate the cost of moving from the starting position to the current position (g-value) and the estimated cost of moving from the current position to the goal position (h-value).
- Calculate the total cost of each possible movement (f-value = g-value + h-value).
- If a position is already in the open list with a lower g-value, skip it.
- Otherwise, add the position to the open list for further evaluation.

5) Repeat the loop until the open list is empty.

6) If the open list is empty and the goal position has not been found, there is no feasible path for the robot to reach its destination

VI. CONCLUSION

The development of a multipurpose autonomous navigation robot marks a significant milestone in robotics and automation. The multipurpose autonomous navigation robot promises to enhance efficiency, safety, and productivity across diverse applications. By leveraging advanced sensors, artificial intelligence, and adaptive algorithms, these robots can navigate complex environments with ease, perform tasks autonomously, and adapt to dynamic surroundings. As we continue to refine and expand the capabilities of these robots, we move closer to a future where intelligent machines seamlessly collaborate with humans, unlocking new opportunities and transforming the way we live and work.

VII. FUTURE WORK

As we look to the future, there are several areas of potential improvement and expansion for multipurpose autonomous navigation robots. Autonomous navigation robots can play a central role in the factories of the future, working alongside human workers to streamline production processes, perform repetitive tasks, and optimize logistics within manufacturing facilities.

Future innovations may include robots equipped with specialized sensors for patient monitoring, telepresence capabilities for remote consultations, and the ability to navigate complex healthcare environments with precision and care. Autonomous navigation robots can contribute to the development of smarter and more sustainable cities ,Home and personal assistance, Outdoor Exploration and Disaster Response, Education and Research.

Overall, future work on multipurpose autonomous navigation robots should focus on advancing the state-of-the-art in navigation, perception, collaboration, interaction, and reliability to enable these robots to operate effectively and autonomously in a wide range of environments and applications. As technology continues to evolve and mature, autonomous navigation robots will play an increasingly integral role in shaping the future of work, healthcare, transportation, urban development, and beyond.

REFERENCES

[1] Jagruti Chaudhari, Asmita Desai, and S. Gavarskar, "Line Following Robot Using Arduino for Hospitals", 2nd International Conference on Intelligent Communication and Computational Techniques (ICCT), September 2019, pp. 330-332.
[2] Ifte Khairul Alam Bhuiyan, "LiDAR Sensor for Autonomous Vehicle ", Tampere University, September 2017.
[3] Bria1n Cèsar-Tondreau, Garrett Warnell, Ethan Stump, Kevin Kochersberger, and Nicholas R. Waytowich, "Improving autonomous robotic navigation using imitation learning", Frontiers in Robotics and AI, June 2021, pp. 1-10.
[4] Alif Ridzuan Khairuddin, Mohamad Shukor Talib, and Habibollah Haron, "Review on Simultaneous Localization and Mapping (SLAM) ", IEEE International Conference on Control System, Computing and Engineering, November 2015, pp. 85-90.
[5] Faiza Gul, Wan Rahiman, and Syed Sahal Nazli Alhady, "A comprehensive study for robot navigation techniques ", Cogent Engineering, 2019.
[6] Dian Rachmawati, and Lysander Gustin, "Analysis of Dijkstra's Algorithm and A* Algorithm in Shortest Path Problem", Journal of Physics: Conference Series, 2019.
[7] M. Rhifky Wayahdi, Subhan Hafiz Nanda Ginting, and Dinur Syahputra, "Greedy, A-Star, and Dijkstra's Algorithms in Finding Shortest Path", International Journal of Advances in Data and Information Systems, February 2021, pp. 45-52.
[8] Kenta Takaya, Toshinori Asai, Valeri Kroumov, and Florentin Smarandache, "Simulation Environment for Mobile Robots Testing Using ROS and Gazebo ", 20th International Conference on System Theory, Control and Computing (ICSTCC), October 2016.
[9] Jianwei Zhao, Shengyi Liu, and Jinyu Li, "Research and Implementation of Autonomous Navigation for Mobile Robots Based on SLAM Algorithm under ROS ", Sensors 2022, May 2022.
[10] Mohamed Dhouioui, and Tarek Frikha, "Intelligent Warehouse Management System", 2020 IEEE International Conference on Design & Test of Integrated Micro & Nano-Systems (DTS), June 2020.
[11] *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification*, IEEE Std. 802.11, 1997.