Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 06, June-2023

Ditto: The delivery robot

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***ABSTARCT*—E-commerce and package deliveries are expanding quickly, and numerous start-ups have already started testing autonomous delivery robots to bring goods and groceries to customers (ADRs). The fast advancement of robot technology has made food delivery robots a focus of both domestic and international studies. In this study, a food delivery robot was developed based on the integration of Lidar and machine vision, which combined the information of Lidar and machine vision in time and location. Particularly, their data may be unified in time due to the synchronization of Lidar and machine vision in working frequency. Additionally, certain pertinent data can be unified in space by the equivalent conversion of the radar coordinate system, the world coordinate system, the picture coordinate system, and the pixel coordinate system. In this report, the robotic food delivery system makes use of the server for data processing and data transfer. The originality of this study is the integration machine vision to provide the robot with precise environmental awareness. According to the experimental findings, combining data from several sensors can significantly increase the robot's efficiency at delivering meals by lowering coordinate cumulative errors and the likelihood of "Suspended animation" during operation. The robot also features accurate obstacle avoidance, path planning, and autonomous navigation capabilities**

Keywords— E-commerce, Package deliveries, Autonomous delivery robots (ADRs), Food delivery robots, Lidar, Machine vision, Integration, Time and location, Data unification, Synchronization, Working frequency, Radar coordinate system, World coordinate system, Picture coordinate system, Pixel coordinate system, Robotic food delivery system, Server, Data processing, Data transfer, Environmental awareness, Experimental findings, Sensors, Efficiency, Coordinate cumulative errors, "Suspended animation", Obstacle avoidance, Path planning, Autonomous navigation capabilities.

I.INTRODUCTION

Autonomous robots are gaining widespread adoption in various industries, households, military operations, and disaster management globally. They serve as safer and more efficient alternatives for performing tasks that are challenging or time-consuming for humans. Examples include Roomba cleaning robots, delivery robots, and autonomous vehicles capable of navigating physical spaces without human guidance. Achieving complete autonomy necessitates a robot's comprehensive awareness of its surroundings and the ability to take action based on inputs from multiple modules. This requires data gathering from sensors, environmental perception, precise self-location, and optimal planning to accomplish objectives. Real-time integration of instructions from these modules and their transmission to a control node are essential for actual movement in the real world. Accurate and effective integration of all modules is crucial for an autonomous robot to function, as flaws in any module could jeopardize the safety of nearby individuals. This paper provides an overview of delivery robots, highlighting their features, applications, and potential benefits, including the utilization of advanced technologies like artificial intelligence, machine learning, and sensors. Ground-based autonomous vehicles and aerial drones are discussed as they offer distinct advantages and challenges. Major companies and logistics providers' adoption of delivery robots further underlines their potential to revolutionize the delivery industry. By leveraging advanced technologies, delivery robots can navigate complex environments, ensure goods' safety, optimize delivery routes, reduce carbon emissions, and alleviate traffic congestion, aligning with the growing focus on sustainability.

II. CHALLENGES AND PROBLEMS

Outdoor navigation for robot systems presents several challenges that need to be overcome for the robots to navigate autonomously in outdoor environments. Some of the significant challenges include complex terrain with uneven surfaces and varying slopes, uncertainty and variability due to unpredictable weather conditions and obstacles, limitations of sensors in outdoor environments such as GPS signal disruption and low visibility, power constraints requiring a reliable power source, communication challenges with limited range and signal interference, safety concerns in the presence of pedestrians, vehicles, and animals, and legal and regulatory hurdles involving permits, safety requirements, and liability issues. Overcoming these challenges requires careful planning, advanced technology, and a thorough understanding of the operating environment.

III. OBJECTIVES

- To use state of art GPS and IMU for improving the sensor accuracy and limitation
- To improve security concerns raised during delivery with the means of secure QR code based magnetic locker
- Autonomy infrastructure using only depth cameras, eliminating high cost LIDAR's. And using different forms of localization would help the robot understand its environment

IV. METHODOLOGY

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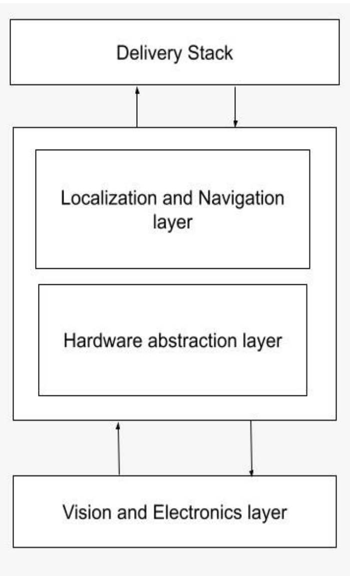
Delivery robots have emerged as a promising solution for efficient and convenient last-mile deliveries. These robots operate autonomously to navigate through various urban environments, but the extent of their autonomy varies across different levels. Level 2 autonomy represents a significant advancement in the capabilities of delivery robots, offering increased automation and improved performance. Level 2 autonomy in delivery robots refers to a stage where the robot can perform certain functions autonomously, but still requires human supervision and intervention in specific situations. At this level, the robot is capable of executing tasks such as obstacle detection, path planning, and navigation independently. It utilizes advanced technologies like sensors, machine learning algorithms, and computer vision to perceive its surroundings, analyze data, and make informed decisions. While the robot can operate autonomously in controlled environments or predefined routes, it relies on human oversight for critical decision-making or handling unexpected situations. Human supervisors monitor the robot's performance, intervene when necessary, and ensure its safety and compliance with regulations. This collaborative approach combines the efficiency and automation of the robot's capabilities with human judgment and intervention to address complex or unpredictable scenarios. Level 2 autonomy in delivery robots offers several benefits. It improves operational efficiency by automating routine tasks, reducing delivery times, and minimizing human errors. It also enhances safety by integrating human oversight to mitigate risks and handle exceptional circumstances. Additionally, Level 2 autonomy serves as an important stepping stone towards higher levels of autonomy, paving the way for future advancements in delivery robot technology. Ditto uses 4 layers for its control



The four major layers in Ditto comprises of:

1. Vision and Electronics layer: This layer consist of the sensors which are responsible for localization and navigation that is the camera. It also consists of raspberry pi 4B+ which acts like the brain of the computer.
2. Hardware abstraction layer: The data received from the camera is understood by the robot to perform object detection, depth analysis and road segmentation. This layer is also responsible for the operator to view the current settings of the robot environment and take control when it's necessary.
3. Localization and navigation layer: This layer is responsible to help robot understand, perceive and locate itself. Wheel odometry is achieved using encoders since the map is known for the operator, QR codes based navigation can be used. QR code based localization acts as a landmark detection for the operator to know exactly how far the robot is from the destination. Thereby navigation is either assisted by teleoperation or semi-autonomous.
4. Delivery stack: This layer merges all other previous layer, with in-house built secure locking mechanism which uses QR code based authentication. During the delivery process, after the robot reaches the location, the user is asked to show the QR code received to his mail while booking. If the QR code is successfully identified the lock opens with the help of rack and pinion mechanism. In case the delivery process is stopped, tampered with, or damaged, the operator will get notifications and alerts which will be helpful for preventing such malicious crimes.

V. HARDWARE AND SOFTWARE TOOL

a) Raspberry pi 4B+: The Raspberry Pi 4 Model B is a highly popular and versatile single-board computer that has garnered widespread acclaim among enthusiasts, hobbyists, and professionals. It boasts a Broadcom BCM2711 processor, offering substantial improvements in processing power, memory, and connectivity options compared to its predecessors. Featuring a quad-core ARM Cortex-A72 CPU clocked at 1.5GHz, the Raspberry Pi 4B delivers enhanced performance, catering to a broad range of applications. With support for up to 8GB of LPDDR4 RAM, the Raspberry Pi 4B facilitates seamless multitasking and efficient handling of resource-intensive tasks. It offers an array of connectivity options, including Gigabit Ethernet, dual-band Wi-Fi, Bluetooth 5.0, and multiple USB ports,

International Journal of Engineering Research & Technology (IJERT)
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ensuring flexible integration with various devices and peripherals. Additionally, its micro HDMI port enables dual 4K display support, making it well-suited for multimedia and digital signage applications. Thanks to its compact size, low power consumption, and extensive community support, the Raspberry Pi 4B has become a favored platform for projects spanning from home automation and robotics to media centers and IoT applications. Its open-source nature, coupled with a wide range of software libraries and development tools, renders it an accessible and cost-effective solution for beginners and experienced users alike. By empowering innovation and fostering creativity, the Raspberry Pi 4B continues to fuel the growth of the maker culture and DIY communities on a global scale.

b) OAK-D LITE: The OAK-D Lite is a state-of-the-art depth-sensing camera developed by Luxonis, specifically designed to provide accurate depth perception and object detection capabilities for a wide range of applications. This research paper explores the capabilities and potential of the OAK-D Lite as a versatile tool for real-time AI inference at the edge. Equipped with the powerful Myriad X vision processing unit (VPU) from Intel, the OAK-D Lite enables efficient and high-speed AI inference directly on the device, without the need for cloud connectivity. Through its stereo cameras and advanced depth-sensing algorithms, the OAK-D Lite delivers precise depth perception, allowing for robust 3D mapping and object recognition. The paper investigates the integration of popular neural networks and AI frameworks with the OAK-D Lite and showcases its suitability for tasks such as person detection, gesture recognition, and object tracking. Moreover, the OAK-D Lite's compact form factor and easy integration via USB provide flexibility in deployment across various projects and platforms. The research paper aims to provide an in-depth analysis of the OAK-D Lite's features, performance, and potential applications, highlighting its significance in the fields of computer vision, robotics, augmented reality, and edge computing.

c) FUSION 360: Fusion 360 is a comprehensive and feature-rich computer-aided design (CAD) and computer-aided manufacturing (CAM) software developed by Autodesk. This research paper provides an overview of Fusion 360, its capabilities, and its significance in collaborative product development. Fusion 360 offers a unified platform for design, simulation, documentation, and manufacturing, facilitating seamless collaboration between multidisciplinary teams. The paper explores Fusion 360's intuitive user interface, parametric modeling capabilities, and cloud-based collaboration features, emphasizing its role in enhancing productivity and streamlining the product development process. Additionally, the integration of CAM functionalities allows for the generation of toolpaths and the seamless transition from design to manufacturing. The paper delves into Fusion 360's simulation capabilities, including stress analysis and thermal simulations, enabling engineers to validate designs before prototyping. Furthermore, the research paper highlights Fusion 360's extensive library of standard parts and its compatibility with 3D printing technologies, positioning it as a versatile tool for rapid prototyping. Through an in-depth analysis, this research paper aims to showcase Fusion 360 as a comprehensive software solution for collaborative design and manufacturing, driving innovation and efficiency in various industries. We used Fusion 360 to design our robot and do a lot of theortical tests such as temperature conditions of the material. Stress test and many more.

d) ROS or Robot operating system: ROS (Robot Operating System) is a widely adopted open-source framework for robot software development and collaboration. This research paper provides an overview of ROS, its key features, and its significance in the field of robotics. ROS offers a flexible and modular architecture that enables developers to create and integrate software components for various robotic systems. The paper explores ROS's core concepts, including its messaging system, package management, and computation graph, highlighting its ability to facilitate communication and coordination among different software modules. Moreover, the paper discusses ROS's support for a wide range of hardware platforms and its compatibility with popular programming languages, allowing for seamless integration with diverse robotic systems. The research paper also emphasizes ROS's role in enabling collaborative development by providing a centralized repository for sharing robot software libraries, algorithms, and tools. Through an analysis of real-world use cases, this research paper demonstrates how ROS has become a fundamental framework for developing advanced robot capabilities, such as perception, navigation, manipulation, and human-robot interaction. Overall, this paper aims to showcase the versatility and significance of ROS in advancing the field of robotics through its collaborative and modular approach to software development.

International Journal of Engineering Research & Technology (IJERT)
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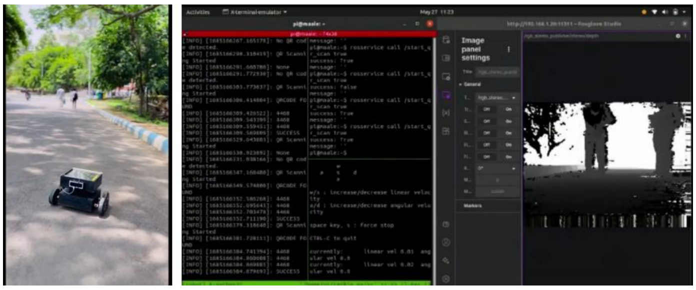
e) Gazebo: Gazebo is a powerful open-source simulation environment widely utilized in the field of robotics research and development. This research paper provides an overview of Gazebo, its key features, and its significance in simulating and testing robotic systems. Gazebo offers a comprehensive set of tools and functionalities for simulating complex environments, sensors, and robots. The paper explores Gazebo's physics engine, realistic rendering capabilities, and sensor simulation, highlighting its ability to create realistic virtual environments for testing and validating robot behaviors. Furthermore, Gazebo provides a modular and extensible architecture that allows developers to customize and integrate additional components as per their specific requirements. The paper also discusses Gazebo's support for various robot models, sensors, and actuators, enabling researchers to replicate real-world scenarios and evaluate the performance of their algorithms. Additionally, Gazebo supports the integration of popular robotic middleware, such as ROS, further enhancing its compatibility and flexibility in robotic software development. Through an analysis of case studies and research applications, this paper showcases the importance of Gazebo as a reliable and efficient simulation environment for accelerating the development and testing of robotics.

VI. IMPLEMENTATION

Delivery stack of Ditto encompasses multiple layers working in conjunction to achieve the robot's goal. The vision and electronics layer utilize the navigation and localization layer, incorporating hardware abstraction, to navigate and reach the desired destination for package delivery. Once Ditto arrives at its designated location, it successfully delivers the package as intended. To control the movement of the lock, Ditto employs a rack-and-pinion mechanism.The rack-and-pinion mechanism is a widely used mechanical arrangement for converting rotary motion into linear motion. It consists of two main components: a rack and a pinion gear. The rack, either flat or cylindrical, is equipped with teeth along its length. These teeth interlock with the teeth of the pinion gear, a small cylindrical gear with a central shaft. When the pinion gear rotates, it imparts linear motion to the rack in the desired direction. This interaction between the teeth enables the rotational motion of the pinion to be translated into linear motion along the rack. The rack-and-pinion mechanism finds extensive application in various fields, including automotive steering systems, machine tools, robotics, and machinery requiring precise linear motion control.Ensuring package security is crucial for Ditto due to various reasons. Firstly, it prevents theft of valuable items during transportation, particularly in public spaces or unmonitored areas. By protecting packages, groceries, or sensitive documents from tampering or damage, their contents remain intact, including fragile or perishable goods. Additionally, maintaining package security helps uphold customer trust and satisfaction. Customers expect their items to be delivered securely and without any disruptions. Prioritizing package security contributes to building positive customer relationships. Moreover, compliance with legal regulations and liability considerations necessitates package security, especially for confidential documents, medical supplies, or hazardous materials. Adhering to these measures ensures responsible delivery practices. Package security goes beyond physical protection. Delivery robots may handle sensitive data related to the delivery process, such as customer addresses or payment information. To preserve the privacy and confidentiality of customer information, robust cybersecurity measures are essential. Implementing stringent cybersecurity practices helps prevent unauthorized access and breaches, ensuring the integrity of customer data.In summary,

ensuring package security is vital for delivery robots like Ditto. It prevents theft, protects against tampering or damage, maintains customer trust, complies with legal requirements, and safeguards sensitive data. By addressing these security aspects, delivery robots can carry out their tasks responsibly and reliably, providing a secure and efficient delivery service.



VII. RESULTS

The evaluation of Ditto, a level 2 autonomous delivery bot, has yielded highly promising outcomes, showcasing its exceptional performance and potential. One of the key strengths of Ditto lies in its implementation of a QR code-based localization technique, which enables precise and efficient navigation within its surroundings. By leveraging this technique, Ditto accurately determines its position, facilitating seamless movement during delivery operations. The integration of a depth camera further enhances Ditto's capabilities, particularly in road segmentation and object detection. The depth camera empowers the bot to accurately identify road boundaries, ensuring smooth and reliable navigation across diverse environments. Moreover, its advanced object detection functionality enables Ditto to detect obstacles along its path, mitigating the risk of collisions and ensuring safe delivery operations. A noteworthy feature of Ditto is its QR code-based locking mechanism, which provides a secure solution for item transportation. This locking system utilizes a robust rack and pinion mechanism, ensuring the reliability and durability of the mechanism. The design ensures that the locking stack remains securely closed until the designated QR code is scanned, offering a high level of

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protection for the delivered items. The implementation of this mechanism strengthens Ditto's ability to fulfill its delivery objectives effectively and efficiently, instilling confidence in both users and recipients of its services. The evaluation results underscore the immense potential of Ditto as a dependable and autonomous delivery bot, highlighting its proficiency in navigating diverse environments, detecting obstacles, and ensuring the secure transportation of items through its innovative QR code-based locking system.In summary, the evaluation of Ditto demonstrates its exceptional performance and potential as a level 2 autonomous delivery bot. Its utilization of a QR code-based localization technique, combined with a depth camera and advanced object detection capabilities, enables precise navigation and obstacle avoidance. Additionally, Ditto's QR code-based locking mechanism ensures secure item transportation, further enhancing its reliability and effectiveness. These features position Ditto as a highly promising solution for autonomous delivery, with the ability to navigate diverse environments, detect obstacles, and securely transport items.

VIII. CONCLUSION AND FUTURE SCOPE

Ditto, an autonomous delivery robot operating at level 2, showcases the immense potential in the realm of package transportation. Its self-navigation capabilities and efficient operations offer a promising solution for the future of delivery services. However, the development and implementation of delivery robots like Ditto also open up avenues for further advancements and enhancements in this field. In conclusion, Ditto serves as a prime example of how delivery robots can revolutionize the transportation of packages. With its autonomy and robust safety features, it ensures secure and efficient delivery operations, leading to increased productivity and customer satisfaction. Looking forward, the future scope for delivery robots, including Ditto, is vast. Ongoing research and development endeavors are focused on enhancing their navigation abilities to seamlessly adapt to complex urban environments. This involves refining obstacle avoidance mechanisms, precise localization techniques, and optimizing path planning algorithms to improve reliability and efficiency. Additionally, the integration of robotics and Internet of Things (IoT) technologies provides opportunities for advanced package tracking and monitoring. Real-time updates on delivery status, temperature control for perishable items, and secure package handling mechanisms can be integrated into future iterations of delivery robots. Moreover, collaboration between delivery robots and existing transportation networks holds potential for optimized last-mile delivery solutions. By coordinating with traditional delivery vehicles or leveraging public transportation systems, efficiency can be improved while reducing road congestion. In summary, Ditto represents a significant advancement in autonomous delivery robots, highlighting their potential to transform package transportation. Continued research and development efforts will refine their capabilities, enabling seamless navigation, improved safety, and enhanced environmental interaction. The future of delivery robots holds great promise, with advancements in AI, IoT integration, and collaboration with existing transportation infrastructure shaping the future of the logistics industry.

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