Analysis and Review of Autonomous Mobile Robots for Indoor Hospital Environments

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***Abstract*—The speed of robotics innovation keeps growing with autonomous navigation serving as one of the leading forces in robotics development.. This paper introduces an autonomous robotic solution designed to optimize payload delivery within indoor hospital environments, addressing challenges posed by dynamic obstacles such as humans and static structures. Using Simultaneous Localization and Mapping (SLAM) with Light Detection and Ranging (LIDAR) sensor, the robot performs real-time mapping and localization, enabling precise navigation and destination marking within the hospital environment. Radio Frequency Identification (RFID) technology is integrated not only for destination identification but also as a security measure to ensure that only authorized medical staff can access the payload. A camera module is used for orientation upon reaching the destination, ensuring accurate docking and payload delivery alignment. Ultrasonic sensors, LIDAR, and motorized configurations help in smooth operation through effective obstacle detection and avoidance. Additionally, the system records destinations and monitors human activity which allows seamless navigation within the hospital. Traditional delivery tasks, often managed by human staff, tend to suffer inefficiencies due to fatigue, human errors, and breaks, which result in increased costs and reduced productivity. This robotic solution is capable of overcoming these limitations by automating mapping, navigation, and delivery processes. Users can interact with the system via a mobile app, allowing real-time path tracking, manual control, and autonomous navigation to specified destinations. Upon arrival, the robot performs the payload delivery after user verification using a sliding mechanism. By integrating advanced technologies, this solution enhances efficiency, reliability, and security, presenting an approach to improving productivity in healthcare.**

INDEX TERMS : SLAM, autonomous robot navigation, obstacle avoidance, real-time systems, stereo-vision.

I. Introduction

Hospitals and healthcare facilities confront many obstacles that have an impact on productivity, patient care, and overall operational success. There is the growing worry about not having enough workers, and it is applying pressure on the healthcare staff who are already swamped. Plus, handling the behind-the-scenes stuff, like getting medical gear, lab tests, and medications to the right spots on time, can be tricky and also eats up resources. These problems increase the costs, time for getting patients the help they need, and increases the odds of mistakes all of which tend to affect patient outcomes and smooth operations. On top of that, maintaining strict hygiene standards, especially in situations of global health crises like the COVID-19 pandemic, means figuring out ways to reduce human contact while still getting the work done.

Autonomous hospital robots bring a game-changer in managing healthcare logistics and giving patients a hand. They move around crowded hospitals without difficulty making sure the payload gets to where it needs to go and handle routine work with accuracy. Thanks to sensors like LiDAR and ultrasonic sensors, the robots are capable of finding their own way and use maps that update during operations. These metal helpers make hospital operations run smoothly and keep everyone safe. The best part? These medical robot don't get tired, so there are less delays and fewer mix-ups in critical healthcare systems.

The concept of self-operating hospital robots aims to do more than just automate tasks. It has a goal to build a smart system that works well with healthcare staff. These robots have a job to move supplies and other medical resources . They also interact with hospital workers through mobile screens that show real-time actions. By using SLAM methods, they can change how they work based on the environment in the hospital. This lets them find their way around, stay clear of things in their path, and pick the best routes.

Autonomous hospital robots offer great perks. They take on menial tasks that eat up a lot of time letting doctors and nurses pay more attention to the important work involving patient care. This ends up making work go faster and lets the health team feel better about their jobs as they're not stuck doing non-medical works. Additionally, these modern robots help keep hospitals safer as they cut down on the need for people to be in direct contact with each other, cutting the odds of spreading germs around. They're also able to function 24/7 ensuring the behind-the-scenes works at the hospital don't hit any difficulties, which means patients get better care and resources aren't wasted.

Thinking ahead mixing in AI-powered analytics and letting the robots do more in interacting and helping patients could improve hospital operations. It can result in healthcare that's quick to adapt, able to handle more patients, and work like a well-oiled machine.

II. LITERATURE REVIEW

Autonomous navigation is a core component of Robotic Medicine Delivery Systems Autonomous navigation is a central element of Robotic Medicine Delivery Systems (RMDS), which allows robots to navigate efficiently and safely in changing hospital settings. Autonomous navigation capability of robots is significant for tasks related to medicine delivery, patient monitoring, and logistics. A few works have looked into the use of SLAM algorithms for autonomous navigation indoors. SLAM is one of the most widely used techniques to allow robots to map their environment and localize themselves within the map at the same time.Singh et al. (2022) presented an adaptive SLAM approach using an Artificial Neural Network (ANN) with an adaptive squashing function that was better than the traditional methods in complex environments.Their paper proved that the suggested approach could navigate social spaces with moving obstacles while following social rules [6]. Liu et al. (2024) presented an extensive overview of indoor AMR sensing technologies, underlining the significance of LiDAR, vision-based systems, and multi-sensor fusion systems for SLAM applications [11]. Ngoc et al. (2023) contrasted various SLAM algorithms, such as GMapping, Cartographer SLAM, and SLAM Toolbox, in the context of a ROS2 implementation. The research indicated that SLAM Toolbox provided the best accuracy x and reliability for self-driving navigation in complex environments [10].

Path planning is yet another important element of autonomous navigation. Alatise and Hancke (2020) discussed different sensor fusion methods and navigation algorithms for mobile robots with a focus on the significance of obstacle detection and avoidance in dynamic environments. They mentioned the deployment of LiDAR, ultrasonic sensors, and vision-based systems in real-time navigation and mapping [9]. Arevalo Ancona et al. (2021) proposed a deep learning-based method for indoor navigation and localization with a monocular vision system. The CNN-based method applied enhanced object detection and environmental awareness for mobile robots [8].

Sensor fusion is a central technology for the improvement of autonomous navigation accuracy and reliability. Integrating data from various sensors allows robots to more accurately perceive the world and make well-informed decisions. Alatise and Hancke (2020) investigated the integration of multiple sensors, such as LiDAR, ultrasonic sensors, and cameras, for navigation and localization. They highlight the requirement for the unification of competitive, complementary, and cooperative sensor fusion techniques capable of enhancing robotic system robustness [9]. Liu et al. (2024) investigated single-sensor methods' strength and weakness and provided multi-sensor fusion techniques for application in indoor autonomous robots [10].

The Internet of Things (IoT) has revolutionized healthcare by facilitating seamless communication among devices and systems. IoT-based robotic systems can provide real-time monitoring of data, remote operation, and improved decision-making. Senthilkumar et al. (2024) designed an IoT-embedded robotic system that was communicating with a centralized cloud-based controller. This enabled healthcare staff to observe patients and enable remote control of robots, enhancing the efficiency and safety of medicine delivery [5]. Liu et al. (2024) highlighted the importance of sensor networks with IoT capabilities in enhancing real-time data processing and decision-making for autonomous robots [11].

As robots more and more interact with people in social settings, it is of interest to keep their behavior aligned with social norms and expectations. Socially aware robotics is an emphasis on developing robots that can navigate human-occupied spaces safely. Singh et al. (2022) tackled the challenges of socially aware robot navigation (SARN) by incorporating social conventions and human motion prediction into their SLAM algorithm. Their strategy guaranteed the robot would move in densely populated areas without disturbing or making people uncomfortable [6]. Ngoc et al. (2023) investigated applying YOLO-based human detection models in SLAM frameworks, improving robots' performance to detect and react to humans' presence indoors [10].

In spite of tremendous advancements in robotic medicine delivery systems, some challenges such as dynamic environments, where hospitals are extremely chaotic, with ever-changing obstacles like moving patients, staff, and equipment still exist. Alatise and Hancke (2020) accorded priority to the emphasis placed on the necessity of strong navigation algorithms capable of adapting to these changes in real-time [9]. Product cost and scalability is another challenge since the high cost of sophisticated sensors and IoT infrastructure will be a limiting factor for the mass adoption of robotic systems in healthcare. Senthilkumar et al. (2024) felt that future studies need to place greater emphasis on formulating cost-effective solutions that are easily deployable across various healthcare environments [5]. Compliance with regulations is also a significant issue, as robotic systems must meet healthcare regulations and safety standards. Singh et al. (2022) assigned priority for doing thorough testing and validation to achieve the safety and reliability of robotic systems in healthcare [6].

III. METHODOLOGY

Autonomous Mobile Robots, or AMRs, are changing the game in today's industries by being able to move in an unknown environment, map it, and even avoid obstacles on their path. They are equipped with high tech sensors to sense around them, figure out where they are and make decisions on their own. So they can work without people having to jump in and help. This means AMRs can work in any scenario, moving goods, caring for people's health, jumping into action in disaster scenarios. They make everything run smoother, reduce human error and increase productivity.

AMRs have had a big impact on the health industry. They are used for tasks like dispensing meds, moving medical equipment and keeping hospital space clean. By reducing human to human contact they reduce the chance of infection especially during pandemics [9] [8]. Hospital logistics also gets a big boost from AMRs. These robots manage and sort stock and put them in order, move through tight spaces with precision. They adapt and work with people avoiding obstacles and finding the best route. That shows their flexibility in dynamic environments [7] [11].

Although they have many benefits, they are not easy to use in human centric environments. They need to follow social norms, e.g. keep a safe distance from humans, move through crowded spaces and dynamically adjust their behavior to avoid interference. Solving these problems involves combining the latest technologies like Artificial Intelligence (AI), Internet of Things (IoT), sensor fusion and deep learning to allow AMRs to navigate through difficult environments safely and efficiently. IoT is at the heart of real time data exchange between robots and hospital systems to improve coordination and responsiveness. AI driven decision making provides the potential to learn from the environment and adjust to conditions to maximize operations. Sensor fusion integrates information from multiple sensors to enhance spatial awareness and threat detection to enable AMRs to move around in unstructured environments. All these technologies combined have the capability of enabling hospital Robots to carry out activities more precisely, efficiently and safely and eventually improve patient care and operational efficiency [9] [2] [1].

The next sections elucidate the essential modules employed to create the AMRs, based on their features and integration within the healthcare facility.

A. *Sensing Technologies: The Foundation of Autonomous Mobility*

AMRs need their sensory equipment to move around in complex environments and make smart choices. The sensors created a foundation for the robot, which allowed them to understand the surroundings, sense anything in front of them, and operate with dynamicaly varying environments. Some of of the most important sensors used by AMRs are LiDAR, cameras, ultrasonic sensors, and IMUs which allow it to traverse the environment smoothly.

LiDAR is a fundamental technology in AMRs, prized for its precision in building rich 3D or 2D environmental maps, with the more costly 3D LiDAR able to measure depth information and provide full spatial awareness. 3D LiDAR emits laser pulses in several directions, generating high-resolution point clouds providing a full three-dimensional view of the world, and is therefore best applied in sophisticated navigation and obstacle detection. 2D LiDAR sweeps a single plane, scanning the world in two-dimensional fashion, which is sufficient for operations requiring flat surface sensing and nominal obstacle sensing. By emitting laser pulses and sensing their reflection, LiDAR sensors build precise environmental maps, which are charged with precise localization and real-time navigation. This is particularly critical in dense environments such as hospitals, where precision is the issue of not colliding with medical equipment or being able to navigate through dense corridors. When combined with SLAM algorithms, LiDAR greatly enhances the robot's capacity to map the world and understand its position within it, allowing for safe and effective autonomous navigation [1] [6].

Stereo cameras supplement LiDAR with object classification and depth sensing. The v-disparity algorithm is one that allows stereo cameras to distinguish between obstacles and ground planes and are therefore very effective in dynamic obstacle environments like moving people or machines [9] [2]. This enables robots to see and navigate around patients, hospital beds, and even hospital carts. Monocular cameras, supported by convolutional neural networks (CNNs), enable semantic segmentation of the scene in a way that lets the robot label areas as accessible or restricted [5]

Ultrasonic sensors play a pivotal role in object detection at close range, especially where reflective surfaces such as glass walls create LiDAR challenge. It can readily detect such surfaces, giving the robot the ability to navigate areas with diverse material texture. IMUs are central to the delivery of odometry data like angular acceleration and velocity, which are very important in the maintenance of orientation and trajectory. IMUs do experience drift when used for long periods and are susceptible to needing fusion with LiDAR or cameras to ensure long-term localization accuracy [7] [1].

IoT application also offers the means for these functionalities to be realized. With IoT connectivity, robots can dynamically interact in real-time with central systems, making for better monitoring and dynamic decision-making. In a hospital, for example, IoT systems can provide real-time information regarding room availability or temporary occlusion, and robots can dynamically plan routes accordingly. IoT facilitates predictive analytics and sensor performance monitoring and detection of maintenance requirements prior to system failure are made possible [8].

B. *Sensor Fusion: Enhancing Accuracy and Robustness*

Sensor fusion is one of the pillars of autonomous mobile robotics technology in which data from multiple sensors can be fused in a manner to have a more and stronger perception of the world. Sensor fusion enhances the robot's perception for obstacle detection and classification, localization, and navigation in dense environments, particularly in dynamic environments like warehouses or hospitals. Every sensor is strong in one use and weak in another; LiDAR offers accurate 2D or 3D maps but is weak on reflective surfaces, while cameras are strong at offering detailed visual information but are light sensitive. By integrating information from several sensors and more, AMRs become stronger and more versatile [9] [7].

At the center of sensor fusion techniques are advanced filtering techniques such as the Kalman Filter and Particle Filters. The Kalman Filter is widely used for state estimation in linear systems with Gaussian noise [1] [9]. It works by predicting the robot's state, such as position and velocity, and then correcting these predictions using sensor measurements. The Kalman Filter excels in scenarios where the system dynamics are well understood and the noise can be modelled effectively. However, it is less effective in highly nonlinear systems or environments with significant uncertainties, which are common in real-world AMR operations [1] [9].

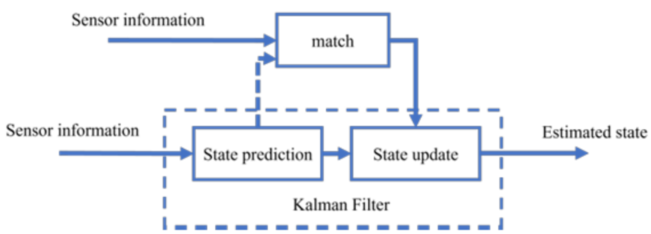

Fig. 1. Kalman Filter[1]

Particle Filters, on the other hand, are non-parametric methods that excel in handling nonlinear and non-Gaussian systems. By representing the state space with a set of weighted particles, it provides a flexible approach to estimating the robot's location and mapping its environment. These filters are particularly effective in scenarios where the robot must deal with complex dynamics or ambiguous sensory inputs, such as navigating through crowded hospital corridors or industrial settings with variable layouts [11] [1].

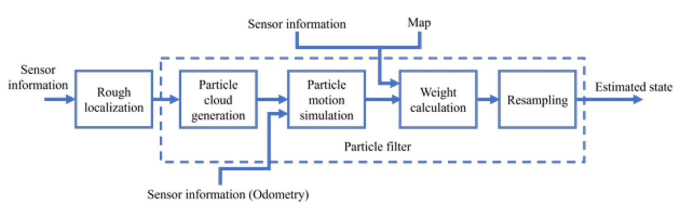

Fig. 2. Particle Filter[1]

In recent years, sensor fusion has been further enhanced by the incorporation of neural networks. Deep learning models are being employed to process and combine sensory data, enabling AMRs to handle complex scenarios with greater efficiency. Neural networks can learn to identify patterns and correlations across different sensor modalities, such as LiDAR, cameras, and IMUs, providing a more holistic view of the environment. For example, CNNs are able to process vision information from cameras while at the same time fusing depth information from LiDAR to obtain a rich 3D description of the world. In the same way, Recurrent Neural Networks (RNNs) are utilized to learn temporal relationships in sensor data so that the robot can better predict motion trajectories and identify dynamic obstacles [2] [10] [3].

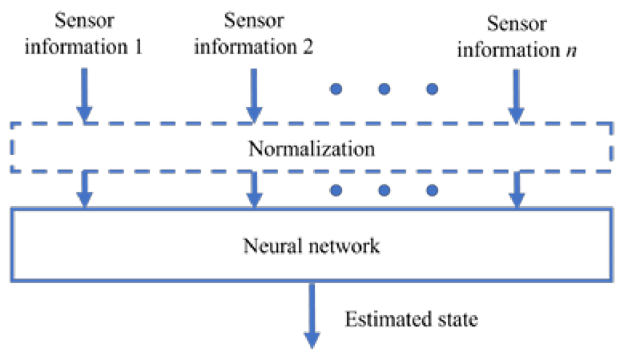

Fig. 3. Neural Network[1]

One notable application of sensor fusion with neural networks is in human-centric environments, where the robot must not only navigate physical obstacles but also interpret and respond to human behavior. By combining visual data with proximity information from ultrasonic sensors and trajectory predictions from IMUs, neural networks enable robots to classify humans, predict their movements, and adjust navigation paths accordingly. This is particularly valuable in hospitals, where maintaining safety and comfort is paramount [8] [1].

C. SLAM Techniques: Mapping the Path to Autonomy

SLAM is a cornerstone technology in AMRs, enabling them to create detailed maps of their environment while simultaneously determining their location. SLAM combines sensory data from LiDAR, cameras, and other sensors to generate accurate representations of the robot's surroundings. This dual capability of mapping and localization is critical for robots operating in dynamic and complex environments.

Filter-based SLAM techniques, such as GMapping, have been widely used for grid-based mapping. These methods rely on Rao-Blackwellized Particle Filters to estimate the robot's trajectory and generate maps in real-time. While effective for small-scale applications, filter-based SLAM faces scalability issues when deployed in larger environments or dynamic scenarios [9] [7]. The computational demands of these algorithms increase significantly with the size of the environment, limiting their applicability in high-demand settings such as hospitals.

Graph-based SLAM techniques, such as Cartographer, address these challenges by separating local and global SLAM tasks. These methods employ loop closure algorithms to correct mapping errors and reduce cumulative inaccuracies. Cartographer's ability to integrate data from multiple sensors allows it to generate highly accurate maps, even in environments with frequent changes [9] [8]. However, graph-based SLAM requires significant computational resources, making real-time operation challenging without optimized hardware.

The SLAM_toolbox offers a comprehensive solution to these limitations. With features like multi-session mapping, real-time localization, and dynamic map merging, SLAM_toolbox is designed to handle large-scale and dynamic environments efficiently.In medical contexts, SLAM_toolbox allows robots to move through hospital corridors without re-mapping too often, improving efficiency. Serialization of the mapping sessions by the toolbox also means that the robots can pick up where they left off after an interruption, a highly useful feature in environments as hectic as hospitals [9] [2].

Active SLAM is an advancement of the traditional SLAM to enable robots to make optimal routes in real-time. It is a technology that fuses the information from IoT systems and advanced sensors to provide real-time dynamic adaptation based on dynamic environmental changes. It is particularly beneficial in human-centric environments, where robots should not hit moving humans but should be safe and efficient [9] [8].

D. Advanced Social Navigation: Robots in Human-Centric Environments

Socially aware navigation is a very required skill for robots to use in human spaces. Socially aware navigation is a branch of robotics whose aim is to allow robots to anticipate human behavior, acquire social conventions, and move around without bothering or agitating humans.

Social navigation is based on deep learning. Neural networks are trained in human patterns of movement so that robots can predict paths and take shortcuts as a response. A robot navigating a hospital corridor can decelerate or come to a halt as it detects a patient or a group of people in the way. The anticipation minimizes the possibility of collision and enables the robot to move in a way that is understandable to humans [9] [8].

Proxemics, or the analysis of human personal space, is also being integrated into robot navigation algorithms increasingly. Maintaining to proxemics-based distances, robots maintain distance from humans and do not inconvenience or bump into them. Robots adjust speed and route in crowded places to stay away from personal space, thereby becoming integrable into social spaces [9] [2].

E. IoT-Driven Efficiency and Collaboration

The application of IoT technology to AMRs has enhanced their efficiency and the functions they provide. Thanks to IoT, these robots can communicate with large computer systems, share data during operation, and coordinate with each other. In hospitals, the IoT setups let robots check which rooms are free, how patients are doing, and the environmental conditions like room temperature. In this way, they can find their way around clearly and optimally divide the tasks [8].

IoT makes it way easier to predict when components might break by keeping a non-stop watch on how robot parts are doing. It takes a look at all the data coming from sensors and actuators that move the robot, and figures out if there's going to be trouble before anything goes wrong. In this manner, it keeps running operations super smooth especially for important jobs like getting medicines to patients. [8] [4].

IV. FUTURE SCOPE

The road ahead for AMRs in healthcare transport looks promising thanks to improving AI, IoT, and sensor technologies. Hospitals and medical centers are gearing up for further developments into smart hospitals with deployments of teams of robots that work together. These robots will use IoT connections to share information during operations and team up to get medical staff medical gear, and lab tools where it needs to go in a quick manner. They can be a great help when emergencies needing a lot of staff occur [8] [9].

Medical delivery robots will get better with reinforcement learning making their way through busy hospitals better. They will get better at avoiding dynamic obstacles like patients and staff who suddenly appear. These smart robots will be able to figure out which deliveries are urgent and pick the best route to get around the hospital, so that they don't slow down any emergency care [9] [7].

Also, moving forward, it will be possible to see medical drop-offs that are tailored to each person. These high-tech AMRs are going to team up and collaborate with Electronic Health Record (EHR) systems to make sure that the right medications and treatments get to the right person. This means messing up because of human slip-ups is way less likely. Additionally, with IoT-enabled monitoring, staff will have the power to track and confirm matters on the spot, which means the robot can move important medical materials like blood samples, vaccines, and medications without making mistakes [8].

Another focus point is how to make resources last longer without harming our planet. Scientists are making smart building designs that don't use up much power and researching ways to get energy from inexhaustable resources, in order to power AMRs and reduce their environmental impact in healthcare sector ensure sustainable development. These big advancements are going to help the robots get better at saving money and energy, allowing them to work for a long time in resource-constrained settings [8] [1].

Finally, blockchain integration will enhance the security and traceability of medical deliveries. By ensuring data integrity, authentication, and secure logging of transactions, blockchain will address privacy concerns in healthcare, ensuring that sensitive medical shipments remain tamper-proof and transparent throughout the supply chain [8].

V. CONCLUSION

Autonomous mobile robots play a pivotal role in hospital management by redesigning medical product logistics service and creating advanced solutions for patient needs in healthcare facilities. Contemporary medical innovation leads with these robots because they enable supply transport and environment navigation and assist with patient observation and can perform both diagnostic tasks and disinfection tasks. Healthcare robots function with high precision in dynamic medical spaces because of important sensing technology advancements including LiDAR and stereo cameras together with ultrasonic sensors and IMUs.

Real-time mapping capabilities in clinics and hospitals became accessible through SLAM alongside Active SLAM algorithms that medical robots now employ to operate effectively in both clinics and assisted living facilities. The technology enables smooth movement through all hospital corridors along with patient rooms and sterilized areas without getting in the way of medical staff or equipment.

The healthcare robots have received substantial improvements in their object detection and semantic segmentation and decision-making capabilities through artificial intelligence approaches especially YOLO and U-Net deep learning models. The technologies enable robots to detect patients together with medical tools and hospital critical areas thereby enabling precise task completion. Through their integration with IoT-based healthcare systems AMRs enable smooth communication as well as predictive maintenance together with real-time data sharing to medical personnel to optimize workflow efficiency and bolster patient care quality. AI-powered socially aware navigation systems with proxemics capabilities make robots operate efficiently in areas that humans occupy while maintaining safety measures for patients and strict hospital guidelines.

Medical AMRs will evolve through two significant advancements that consist of collaborative multi-robot systems and personalized patient care and AI-driven diagnosis and blockchain-secured medical data privacy. Next-generation AMR feature upgrades will make them applicable in geriatric care and tele-diagnostics and emergency services to address the issue of accessibility in healthcare in the world. By the integration of adaptive AI models and reinforcement learning algorithms such robots will be more efficient and autonomous in nature which allows them to perform sophisticated medical procedures with minimal human intervention.

Healthcare AMRs will persist in their medical revolution of delivery systems and enhance patient outcomes once researchers break through security challenges, optimization hurdles, and sustainability strategies. The integration of these robots into hospital operations represents a double accomplishment of robotic innovation and a core transformation of automated healthcare networks for enhanced efficiency. The vast potential of AMRs in medicine will expand as their technology improves to deliver greater benefits to healthcare delivery and medical resource optimization as well as patient safety.

REFERENCES

[1] Mary B Alatise and Gerhard P Hancke. A review on challenges of autonomous mobile robot and sensor fusion methods. *IEEE Access*, 8:39830–39846, 2020.

[2] Rodrigo Eduardo Arevalo Ancona, Leonel Germán Corona Ramírez, and Oscar Octavio Gutiérrez Frías. Indoor localization and navigation based on deep learning using a monocular visual system. *International Journal of Advanced Computer Science and Applications*, 12(6), 2021.

[3] Farzin Foroughi, Zonghai Chen, and Jikai Wang. A cnn-based system for mobile robot navigation in indoor environments via visual localization with a small dataset. *World Electric Vehicle Journal*, 12(3):134, 2021.

[4] Gengyu Ge, Zhong Qin, and Xin Chen. Integrating wsn and laser slam for mobile robot indoor localization. *Computers, Materials & Continua*, 74(3), 2023.

[5] Mario Kusuma, Carmadi Machbub, et al. Humanoid robot path planning and rerouting using a-star search algorithm. In *2019 IEEE international conference on signals and systems (ICSigSys)*, pages 110–115. IEEE, 2019.

[6] Yu Liu, Shuting Wang, Yuanlong Xie, Tifan Xiong, and Mingyuan Wu. A review of sensing technologies for indoor autonomous mobile robots. *Sensors*, 24(4):1222, 2024.

[7] Hoang Tran Ngoc, Nghi Nguyen Vinh, Nguyen Trung Nguyen, and Luyl-Da Quach. Efficient evaluation of slam methods and integration of human detection with yolo based on multiple optimization in ros2. *International Journal of Advanced Computer Science & Applications*, 14(11), 2023.

[8] Senthilkumar Selvaraj, B Dhanalakshmi, P Shanmuga Prabha, Amit Verma, Elangovan Muniyandy, and S Sridhar. An iot intelligent approach for safety and efficiency of robotic medicine delivery in hospitals. *Journal of Electrical Systems*, 20(2s):820–827, 2024.

[9] Kiran Jot Singh, Divneet S Kapoor, Khushal Thakur, Anshul Sharma, Anand Nayyar, Shubham Mahajan, and Mohd Asif Shah. Map making in social indoor environment through robot navigation using active slam. *IEEE Access*, 10:134455–134465, 2022.

[10] Anne Steenbeek. Cnn based dense monocular visual slam for indoor mapping and autonomous exploration. Master's thesis, University of Twente, 2020.

[11] Qin Zou, Qin Sun, Long Chen, Bu Nie, and Qingquan Li. A comparative analysis of lidar slam-based indoor navigation for autonomous vehicles. *IEEE Transactions on Intelligent Transportation Systems*, 23(7):6907–6921, 2021.