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IoT-Based Wi-Fi Enabled Floor Monitor Robot with Camera, Obstacle Detection and Voice Interaction

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***Abstract*—In educational institutions, classroom assistance and material delivery are common tasks, where teachers or staff usually carry notebooks and study materials manually from one classroom to another, which takes time and requires physical effort, especially in large campuses. To solve this problem, this project presents the development of an IoT-based Wi- Fi enabled floor monitor robot with camera, obstacle detection, and voice interaction that can safely deliver notebooks and materials. The robot can be controlled remotely using a mobile phone or computer through a wireless connection, allowing the user to give simple commands like forward, backward, left, right, and stop for easy movement. It is built using an ESP8266 microcontroller, which acts as the main control unit by connecting the robot to a Wi-Fi network and enabling communication between the user and the robot. For safety, an ultrasonic sensor is used to detect obstacles by continuously measuring the distance between the robot and nearby objects, allowing it to stop or change direction to avoid collisions. The robot also includes a camera module that provides live video streaming,helping the user monitor its movement and surroundings in real time, which is useful for observing classrooms and corridors. Additionally, the robot features voice interaction by playing pre- recorded messages such as "Excuse me, please take your notebook.Thank you," making it more interactive and user-friendly. The main aim of this project is to design a simple, reliable, and efficient system that reduces manual work, saves time, and assists teachers and staff in managing classroom activities effectively, demonstrating how IoT and robotics can be applied to create smart solutions for real-life problems in educational environments.**

keywords: IoT, Wi-Fi Enabled Robot, Floor Monitoring Robot, ESP8266, Obstacle Detection, Ultrasonic Sensor, ESP32-CAM, Real-Time Monitoring, Voice Interaction, Robotics, Embedded Systems, Automation

I. Introduction

The tremendous development of robotics and automation has greatly impacted our current industries and households. The multi-functional robotic system has been considered highly beneficial due to its ability to carry out multiple functions using a single device [1]. Such systems minimize human efforts, increase productivity, and boost accuracy in applications like manufacturing industries, healthcare services, and other sectors [2].

Due to the evolution of the Internet of Things (IoT), the robotics system has gained intelligence. IoT provides seamless communication among devices through wireless connections, thus making possible remote and online monitoring and control of processes [3]. The merging of IoT and robotics has enabled the automation process in environments that lack human presence [4].

Additionally, the evolution of embedded and wireless technologies has resulted in efficient robotics systems with capabilities to carry out complex tasks [5].

However, for activities like monitoring the corridor and movement of objects within indoor settings such as schools and office spaces, humans continue to play a critical role, demanding much labor and potentially causing inefficiencies [6]. In most cases, monitoring using humans is unreliable, and it is impossible to ensure round-the-clock surveillance in large buildings [7].

Current research efforts have concentrated on designing robotic systems that can detect obstacles and navigate effectively. Different sensor technologies including IR, ultrasonic, and visual sensors are employed to ensure that robots can detect obstacles and move freely [8]. Among them, ultrasonic sensors are highly preferred due to their effectiveness under various environmental settings [9].

Apart from that, multifunctional robots have also been invented to handle complex activities such as surveillance, manipulation of objects, and interaction [10].

Apart from navigation, the inclusion of real-time monitoring has been identified as another important element of robotics. By incorporating camera modules in robots, they can stream real-time video images for people to observe their surroundings [11]. In situations requiring visual information for decision making, this will be of much benefit.

Efficient energy use in robotics has seen the use of alternative energy sources such as solar energy in powering robots, making robotic systems environment friendly [12]. With regards to mechanisms, mobility of robotic systems has been improved through mobile robots with advanced mechanisms [13].

Communication has remained one of the aspects of importance in robotic systems. Through wireless communication, effective data transfer and remote manipulation of robotic systems can be achieved [14]. These developments have ensured that the robotics field remains innovative in the development of intelligent robotic systems [15].

The emergence of IoT technology has further improved the capabilities of robotic systems due to integration possibilities that they offer. IoT systems allow collecting, analyzing and sharing information among various systems, thus improving efficiency of these systems' operation [16]. In addition, IoT-based technologies create the basis for building smart systems in which devices would be able to communicate and operate independently [17].

Finally, recent advances in computer vision and machine learning algorithms have enabled enhancing the perception ability and decision-making skills of robots. Object recognition and tracking algorithms help robots perceive their surroundings more precisely and operate within them more efficiently [18]. Optimization techniques can be applied to improve the performance of robot navigation and grasping abilities [19].

Despite the above advances, many existing robotic systems remain resource and complex to implement [20].

In order to tackle some of these problems, there has been a lot of work done recently towards enhancing the efficiency of communication and making IoT-based robotic systems more secure and reliable [21]. Some efforts have also been made towards optimizing the performance of the IoT network by introducing efficient clustering and data transfer techniques [22]. Wireless sensor networks have been successfully used in conjunction with cloud computing in order to achieve efficient data exchange [23].

With the increasing necessity for secure and scalable systems, many researchers have explored new technologies, including blockchain technology for achieving secure data exchange [24]. Such approaches improve data integrity and enable efficient and reliable communication [25].

These developments demonstrate the importance of combining different technologies for achieving efficient robotic solutions.

Moreover, IoT-based robotic systems have been implemented in different sectors including healthcare, smart cities, and rural development for enhancing efficiency and providing better services [26]. It can be seen that IoT-based robotic systems are versatile enough to meet different needs and demands [27]. In this regard, IoT-based health care systems offer enhanced monitoring and service provision via interconnected systems [28].

In the same way, smart infrastructure construction projects and rural village development projects make use of IoT technology in order to increase the quality of life and efficient resource utilization [29]. Moreover, wireless communication networks have been employed in disaster management during emergencies [30].

On the other hand, sophisticated control mechanisms, like swarm intelligence, have been utilized to provide efficient obstacle avoidance and navigation features to robots [31].

II. Literature Survey

Robotic systems have come a long way with the development in automation and intelligent control systems. Initially, the research on human-robot interaction involved systems that could operate in an environment with humans, and they would coordinate tasks together with humans for safer execution of processes [1].

In the recent past, multifunctional robotics have received some attention because they can perform more than one process from one platform. For instance, autonomous cleaning robotic systems have shown how integration of mobility and cleaning features works effectively [3]. Moreover, solar power-based robotics has been applied in creating more sustainable autonomous machines [4].

The integration of IoT systems has provided robots with the ability to control and monitor actions remotely. Distributed computation systems have been employed for faster response in IoT-enabled robots [5].

Other recent works have investigated the role of artificial intelligence and deep learning algorithms in robotics. Such algorithms facilitate pattern recognition, interpretation of information, and intelligent decision making using environmental inputs [6]. In industrial applications, the use of IoT-enabled predictive maintenance has been considered to increase safety and efficiency [7].

Moreover, cloud computing and data analytics have been incorporated into IoT technologies to support extensive data analysis and intelligent decision making [8]. Additionally, studies related to IoT communication infrastructures have discussed issues like scalability, interoperability, and network dependability [9].

In addition, multifunctional companion robots have been proposed that are capable of executing sophisticated functions such as manipulating objects and interacting with humans [10].

The safety and interaction of humans with the robotic system have been an important consideration in designing robotic systems. Human perception and safety have been analyzed in relation to robots, especially when they operate in collaborative settings [11]. Additionally, robots that clean the floor through reconfiguration have been introduced to make the task more efficient [12].

There have been advancements in energy-efficient robotic systems through the utilization of renewable energy sources like solar energy [13]. Agricultural robots have also been designed to perform their tasks, such as monitoring and spraying, by harnessing the power of the sun [14].

Specialized robotic systems have also been designed for certain applications, including robotic systems that clean solar panels [15].

IoT use within the field of robotics has already received much attention in scientific literature, with topics like connection and communication between devices being discussed [16]. Thanks to the Internet of Things, it was possible to create connected systems that were able to exchange data and act in a coordinated manner [17].

Modern advances in computer vision helped to significantly increase the robot capability for perception of the surrounding world. Multi-camera object detection and 3D perception helped to enhance navigation and interaction with the environment by robots [18]. Also, some optimization methods using machine learning algorithms have been proposed to make robotic grasping and recognition more effective [19].

Unfortunately, there are still some difficulties associated with computational complexity and expensive hardware that cannot be easily avoided [20].

Security and reliability have become important considerations for IoT-based robotics systems. Security issues associated with such systems have centered around the need for secure communication methods that ensure safe data transmission between connected devices [21]. Clustering and optimization of the network have also been suggested as means of improving the performance and efficiency of IoT systems [22].

Wireless sensor networking with cloud computing has also been integrated into IoT systems to make data collection and analysis real-time processes [23]. Blockchain technology has also been considered in order to enhance security within IoT systems [24].

Secure IoT architectures have been proposed as a means of addressing privacy and data integrity concerns [25].

Applications based on IoT have been used in several areas like healthcare, smart city, and rural development to optimize efficiency and deliver services effectively [26]. Such applications show the potential of IoT-based systems for dealing with practical problems [27]. Applications in healthcare have utilized IoT-based systems for better monitoring and treatment of patients [28].

In the same way, smart villages have applied IoT systems to manage resources and improve the quality of life [29]. Also, in disaster management, wireless communication technology has been used to create a connection between the victims and the rescue team [30].

Moreover, swarm intelligence algorithms have been adopted to enhance obstacle detection and navigation features of robots [31]. Such applications have shown the significance of combining different technologies for creating intelligent robots.

III. Proposed System

This section discusses a proposed system involving the design and implementation of a floor monitor robot with IoT capabilities that will be Wi-Fi enabled. As shown in Fig 1, the system architecture illustrates the interaction between the user interface, microcontroller, sensors, and actuators. It utilizes robotics technology, embedded systems, wireless communications, and sensors to achieve effective and intelligent solutions [1]. The core aim is to increase efficiency and effectiveness in operations while reducing manual effort through remote monitoring [2].

The floor monitor robot is designed using an IoT-enabled microcontroller like ESP8266 or ESP32 to act as the processing unit in the system. The main functions of this controller include managing communications between the robot and the user as well as processing sensor data. The system also connects to the Internet to facilitate remote operation of the robot via its web interface using any compatible device [3].

This system adopts a client-server architecture, where the robot performs all its tasks after receiving commands from the user [4].

Movement of the robot is made possible by DC motors that use a motor driver IC like L298N for operation [6]. The motor driver works as a bridge between the controller and the motors to provide efficient control of speed and rotation [7]. Through appropriate signals provided by the controller, movement of the robot in all directions is possible. Through appropriate signals provided by the controller, movement of the robot in all directions is possible.

To ensure safe movement, the system features an ultrasonic sensor which detects any obstacles that may be in the way of the robot by measuring the distance between the robot and the obstacles using ultrasonic waves [8]. If there are obstacles within a particular distance, the robot avoids collision by stopping or changing course [9].

Moreover, the robot system allows the robot to undertake monitoring while at the same time moving around.

Other noteworthy aspects of the system under consideration include real-time monitoring through the implementation of a camera module. It allows for streaming live videos, providing an opportunity for remote observation of the environment that the robot operates in [11]. This aspect is vital for surveillance and inspection purposes when visual input is required for further analysis.

Moreover, energy efficiency is taken into account while designing the proposed robotic system, thanks to the use of optimized components and low power consumption [12]. Additionally, the robotic system itself can easily adapt to various indoor conditions, making its operation effortless [13].

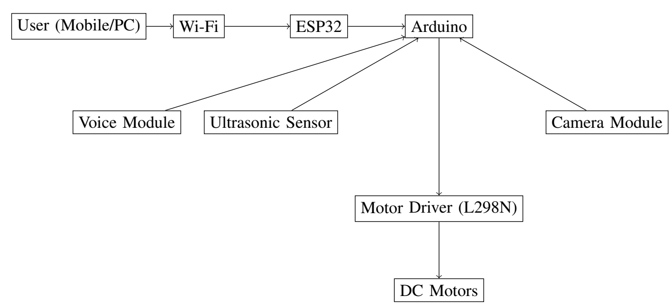

Fig. 1. Block Diagram of Proposed IoT-Based Floor Monitor Robot

The system under consideration also involves wireless communication, facilitating remote control and data exchange. Wi-Fi technology is used to provide seamless connection between the robot and the user interface [14], improving efficiency and convenience [15].

Introducing IoT technology in the proposed system increases its ability to collect, process and communicate data [16]. It enables the system to perform within the framework of the network, making the work process more effective and efficient [17]. Besides, the proposed system can be extended with more sophisticated features such as data analysis and intelligent decision-making.

With the recent improvements in computer vision and machine learning, robotic systems can be equipped with advanced perception capabilities [18]. Although the proposed system does not contain such a sophisticated technology due to cost considerations, it is possible to develop and integrate into the system other optimization techniques [19].

Nevertheless, the problem that still remains unsolved is that most current technologies require complicated equipment and significant computing power; hence, it makes robotic systems expensive and inefficient [20]. The proposed technology solves these issues.

Security and reliability are critical factors when designing an IoT-based system. The suggested system utilizes secure communication to provide security during the transfer of information from the robot to the user [21]. Effective information management and communication strategies are applied to increase efficiency and reliability [22].

The combination of wireless sensor networks with the cloud platform is crucial in facilitating the efficient collection and sharing of data in real-time. New technologies such as blockchain may be integrated into the system to improve security and transparency [23]. This strategy will provide a framework for implementing a secure and scalable IoT-based robotic system [24].

The design of the system guarantees ease of implementation, low costs, and scalability, making it applicable in indoor settings such as schools and workplaces.

The suggested method can be used in different areas including the medical industry, smart building construction, and learning organizations in order to increase their efficiency and automation [26]. This proves the flexibility of IoT-based robots in solving practical problems [27]. For example, robots may be useful in healthcare settings where they can monitor patients' behavior and help in performing everyday activities [28].

In addition, smart facilities construction and other development projects may implement IoT technologies in order to manage resources better and achieve higher efficiency levels [29]. In case of emergencies, wireless communication network technology is essential for ensuring uninterrupted communication and faster reactions [30].

Moreover, modern control strategies such as the use of swarms may be implemented to improve navigation and obstacle avoidance functions in robots [31].

IV. Implementation

The implementation process of the proposed system comprises integrating different hardware and software components to design a Wi-Fi enabled floor monitoring robot. The proposed system will be capable of performing remote monitoring, detecting obstacles, and communication with the help of IoT and embedded systems. The overall architecture of the proposed system will consist of different communication modules, control units, sensors, and actuators to facilitate effective performance.

ESP8266 Wi-Fi Module: In the proposed system, the ESP8266 microcontroller will work as a communication module. This module will establish a wireless connection between the robot and the user by creating a web-based interface. The ESP8266 module will connect to the Wi-Fi network and enable users to provide command signals from mobile devices or computers. These command signals will be sent to the controller for executing actions.

Arduino Uno Controller: The Arduino Uno microcontroller will serve as the control unit for the robot. It will receive and execute commands from the communication module.

Motor Driver (L298N): The motor driver module L298N is used to control the speed and direction of the two DC motors. The L298N motor driver module serves as an interface between the microcontroller and motors and supplies the necessary current for the motor's operation. Thus, the robot can maneuver in four different directions, such as front, back, left, and right.

DC Motors and Wheels: The DC motors help in moving the robot. These DC motors transform the electrical energy supplied to mechanical energy, which powers the wheel movement of the robot.

Ultrasonic Sensor: The ultrasonic sensor is utilized for detecting the presence of obstacles ahead. Ultrasonic sensors generate ultrasonic waves, which reflect from the obstacles and return to the sensor. On the basis of this information, the distance from the nearest object is calculated. If an obstacle is within the range of the robot, it stops or changes its trajectory.

ESP32-CAM Module: The ESP32-CAM module is used for real-time surveillance. It takes pictures and videos of the environment around the robot and allows users to monitor the environment from a distance.

Voice Module and Amplifier: The APR9600 voice module allows voice communication by providing the ability to record and play messages. An amplifier amplifies the audio signal, while the speaker transmits the sound clearly for communication purposes.

Power Source and Software Implementation: The power source for the project is a 12V battery that powers all other hardware parts. The software is implemented using Embedded C programming language in the Arduino development environment. The software controls all functions including sending instructions, processing sensory input, motor control, and communication.The hardware components that are required for making the robot are listed in fig 2.

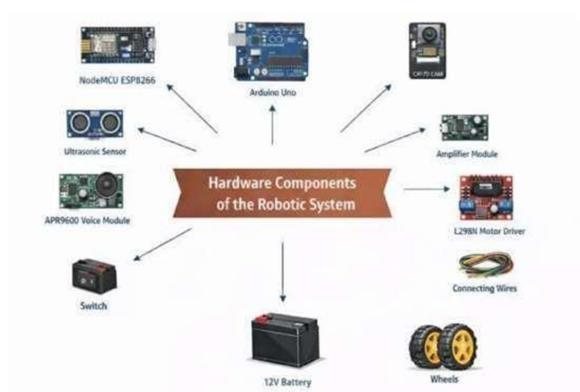

Fig. 2. Hardware components required for the robot

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V. Results

The Wi-Fi enabled floor monitoring robot was efficiently developed using the IoT concept in an indoor environment. The robot showed efficient working in the areas of remote control, obstacle sensing, real-time monitoring, and voice interaction. These results prove that the combination of robotics with IoT technology is extremely effective in reducing efforts and increasing efficiency.

Operation of Remote Control: For controlling the floor monitoring robot, a web interface was used via wireless internet. The commands for moving the robot forward, backward, left, right, and stop could be issued from a mobile device or computer. All the received commands were executed by the robot almost instantly.

Connection of System: An ESP8266 module was used for connecting the floor monitoring robot with the Wi-Fi network. The connection between the robot and the user interface was consistent and uninterrupted during tests.

The system reduces manual effort and improves efficiency in indoor environments such as classrooms and offices.

Fig. 3. Implementation of IoT based floor monitoring robot

Safety and Navigation: With the incorporation of an ultrasonic sensor, the safety of the project was ensured since collisions were prevented. The robot was able to sense any obstacle and take the appropriate action, which is required when the environment has moving obstacles like humans or objects.

Monitoring Ability: With the installation of the ESP32-CAM module, the monitoring ability of the robot was increased, and hence it could perform surveillance tasks alongside the transportation of materials.

Human Interaction: With the incorporation of the voice module, interaction with humans was made easier and more convenient.

Limitations: Despite the effectiveness of the system, there are some limitations. First of all, the robot needs a steady connection to the Internet since it needs Wi-Fi connectivity to operate correctly. Moreover, this system was developed with the idea of indoor usage in mind and might need changes for outdoor usage.

Future Scope: There is still much room for improvement in the system, and this can be done through introducing such advanced technologies as artificial intelligence and machine learning. Improved sensors and batteries can also play an important role here.

To conclude, this paper has shown how IoT and robotics can be used successfully in creating intelligent monitoring robots. The discussion and the results have proven that the presented system is both practical and efficient.

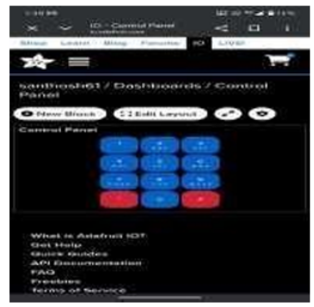

Fig. 4. Adafruit web interface for robot controlling

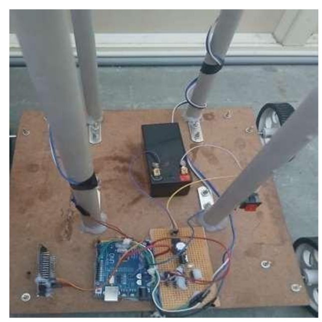

Fig. 5. Hardware implementation of the proposed Robot

VI. Conclusion

This study presents the success in designing and developing IoT based floor monitoring robot with wi-fi capabilities for accomplishing tasks like remote monitoring, obstacle detection, and automated movement in indoor environments. The system has employed various technological aspects of robotics, embedded system, wireless communication, and sensors to achieve a solution that minimizes manual involvement in operations.

As seen from the tests performed on the robot, the system could perform movement in desired directions like forwards, backwards, left, right, and stop using the web-based interface. The ultrasonic sensor helped detect any obstacles to prevent collision of the robot with objects in its surroundings. The ESP32-CAM module was used to monitor the robot's environment in real time and provided audio interaction capabilities via voice module.

Wi-Fi technology was applied to make the system remotely controllable and the control module developed using Arduino technology helped to coordinate various parts of the system. The use of battery in the system made it portable and useful for indoor purposes.

Therefore, this is a very efficient and affordable solution for automated monitoring and material transport.

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