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Design and Development of AI-Integrated Smart Surveying Robot with Multi-Application for Civil Engineering

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Abstract: In this paper, the idea for developing an AI integrated surveying robot was suggested for improving efficiency, safety, and precision in civil engineering applications. Traditional approaches in surveying may be inefficient, costly, laborious, and error-prone. Thus, to overcome the above-stated problems, an innovative solution based on several functionalities will be discussed. A set of measuring sensors will help the robot in conducting precise surveys of space. Besides, a metal detector would assist in finding hidden metallic objects underneath the earth. Moreover, the proposed device will have a levelling function for making sure that the surface is levelled. The robot will include a robotic arm that could perform small tasks. In addition, a fire safety module will be useful for identifying possible hazards in a work area. Also, a soil moisture sensor could provide estimates on the availability of underground water basins using soil conditions, which could be cheaper than conventional methods. The robot will be developed using ESP32 microcontrollers, which could enable it to communicate wirelessly and remotely with smartphones. An AI integrated memory device would help the machine to reduce repeated mistakes by remembering its previous actions.

Keywords: Smart Surveying Robot, ESP32, Metal Detection, Soil Moisture Sensor, Fire Detection, Robotic Arm, Camera Surveillance, Civil Engineering Automation.

I. INTRODUCTION

Surveying played a significant role in civil engineering activities, ranging from project planning and analysis to infrastructure building. Traditional surveying required intensive human effort, making the process not only slow but inaccurate and possibly dangerous, particularly when dealing with hazardous sites.

As robots and embedded systems became more advanced, there arose a need for innovative surveying tools to address the shortcomings of traditional surveying techniques. It is in this backdrop that this research work introduced a smart surveying robot that incorporated different features within one single device.

The robot designed in the experiment was meant to conduct several necessary survey and safety operations. These include measuring distances with suitable sensors, detecting metallic substances buried beneath the ground with a metal detector module, and estimating the presence of underground water based on soil moisture. It also conducted leveling analysis in order to determine whether the area is level, which is important in constructions. A fire detector was included to detect any fire threats, thus improving the safety levels. Also, a camera was installed to monitor the site remotely. Lastly, a robotic arm was added to move around and manipulate objects that might be dangerous and inaccessible by humans.

Conclusively, the system created had the capacity to make surveying more efficient, minimize efforts, and improve safety.

II. LITERATURE REVIEW

Previous works in the topic of robotic surveying systems had centered mostly around the creation of individualized units, such as distance meters and metal detectors. The devices functioned well in carrying out their own tasks, but did not have the capability of functioning together as an integrated unit. This meant that several pieces of equipment would be needed in order to accomplish the entire surveying process

Some robots had already been created specifically for inspection and monitoring in construction sites and industrial facilities. The advantages of automation and remote control were evident in the use of these machines; yet, they were not equipped with the integration of different sensor modules and functionalities essential for a comprehensive surveying process.

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Works dealing with soil moisture sensors had proven successful in the agricultural sector, more specifically in the fields of irrigation and soil testing. They could give indirect readings from the underground layers. Nevertheless, there had been very few studies conducted regarding the use of soil moisture sensors in civil engineering for measuring the presence of underground water during surveying processes.

Moreover, there had been extensive use of robotic arms and video surveillance technology in the field of industrial automation for functions like handling objects, inspection, and surveillance purposes. Although these technologies had been effective, they were rarely used in surveying robots, thus limiting the adaptability of the current surveying systems.

Consequently, there was a need for an integrated system design that would incorporate various sensing methods, robotic manipulation, and other intelligent capabilities within the same framework. This was the primary objective of the present study, which sought to develop a smart surveying robot through the integration of several capabilities to improve efficiency.

III. METHODOLOGY

A. *System Architecture*

The ESP32 microcontroller was used for designing the proposed system because it could provide computing power as well as the facility of wireless communication including Bluetooth and WiFi. The ESP32 worked as the main CPU of the system and took care of acquiring data from the sensors as well as controlling actuators.

All the sensors and other modules were interfaced with ESP32 to develop a central and efficient system architecture. Wireless control of the robot was possible through the interface of smartphones. Besides, a soil detector was incorporated into the design that could be used to determine the properties of soil.

B. *Hardware Components*

components:	Use for
ESP32 Microcontroller	Main controller for processing and communication
Ultrasonic Sensor (HC-SR04)	Measures distance
Soil Moisture Sensor	Determines level of underground water
Soil Detection Sensor (Soil Condition Analysis)	Detects soil condition (whether dry, wet, loose or compact)
Metal Detector Module	Detects metal in the ground
MPU6050 Sensor	Detects level and tilt
Fire Sensor Module	Detects fire
Camera Module	For real-time monitoring
Robotic Arm (Servo Motors)	Object manipulation
Motor Driver (L298N)	Motor controlling

C. Working Principle

A mobile phone was used to control the robot wirelessly, thereby facilitating live tracking and observation. The Ultrasonic sensor measured the distance to any object in the vicinity and was responsible for detecting any obstruction. The Metal sensor detected the existence of any metallic objects hidden under the ground. Moisture content in the soil was detected with help from the soil moisture sensor.

Apart from moisture detection, a soil detection function was added to measure and categorize different types of soil based on their nature. Soil can be of many kinds, like dry, moist, loose, or compact, depending on the moisture content. The information gathered through this method can be very useful while planning construction works.

MPU6050 sensor gave an indication whether the surface level was tilted in some way, thus facilitating level measurements. Fire sensor helped detect fire hazards as well as other unusual conditions.

Camera module helped in providing live visuals, while the robotic arm could handle objects in dangerous zones.

D. Distance Calculation

$$Distance = \frac{Speed \times Time}{2}$$

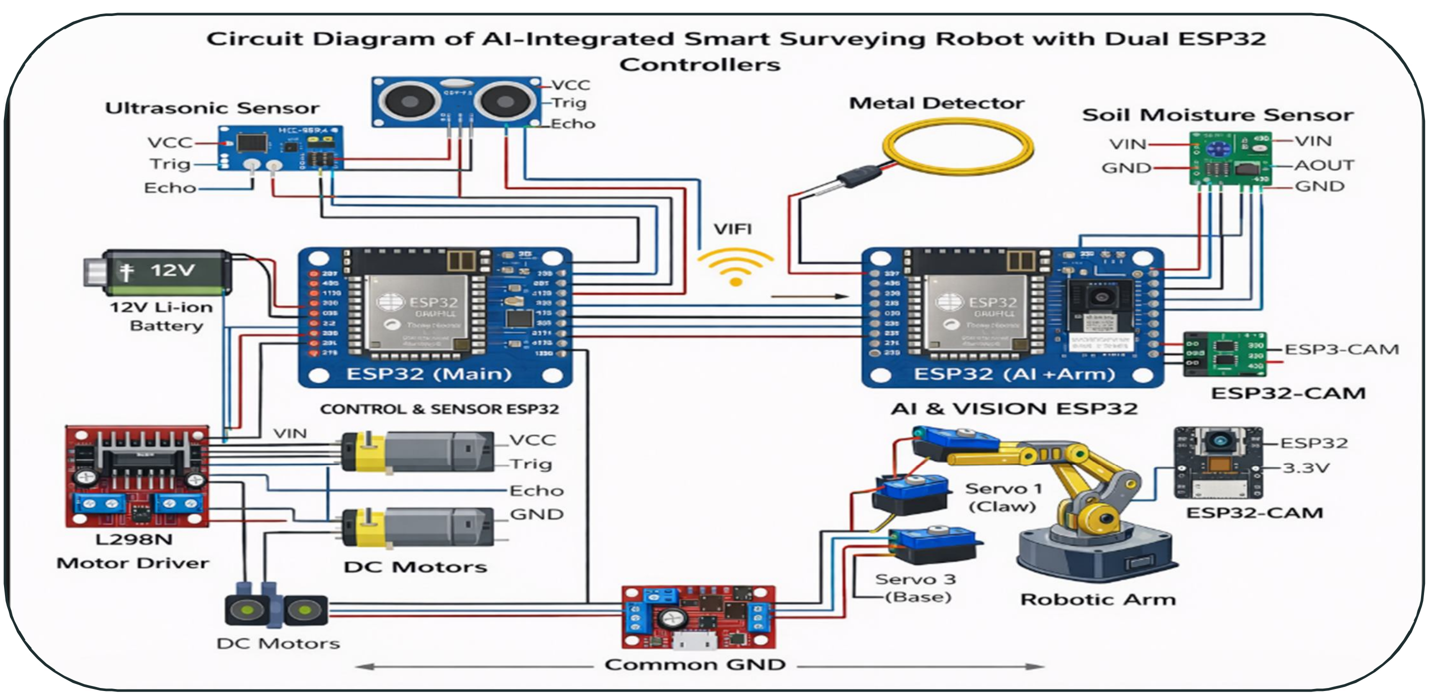
Where:

- Speed = Speed of sound (≈ 343 m/s)
- Time = Time taken by ultrasonic wave

E. Soil Detecting

Soil detection was made through analyzing sensor readings. The reading from the soil moisture sensors were interpreted as follows:
Low reading – dry soil
Moderate reading – normal soil
High reading – wet soil
Inconsistency in readings – loose soil
This analysis assisted in identifying the right areas for construction and avoiding risks like poor foundations and water accumulation.

F. Circuit Diagram



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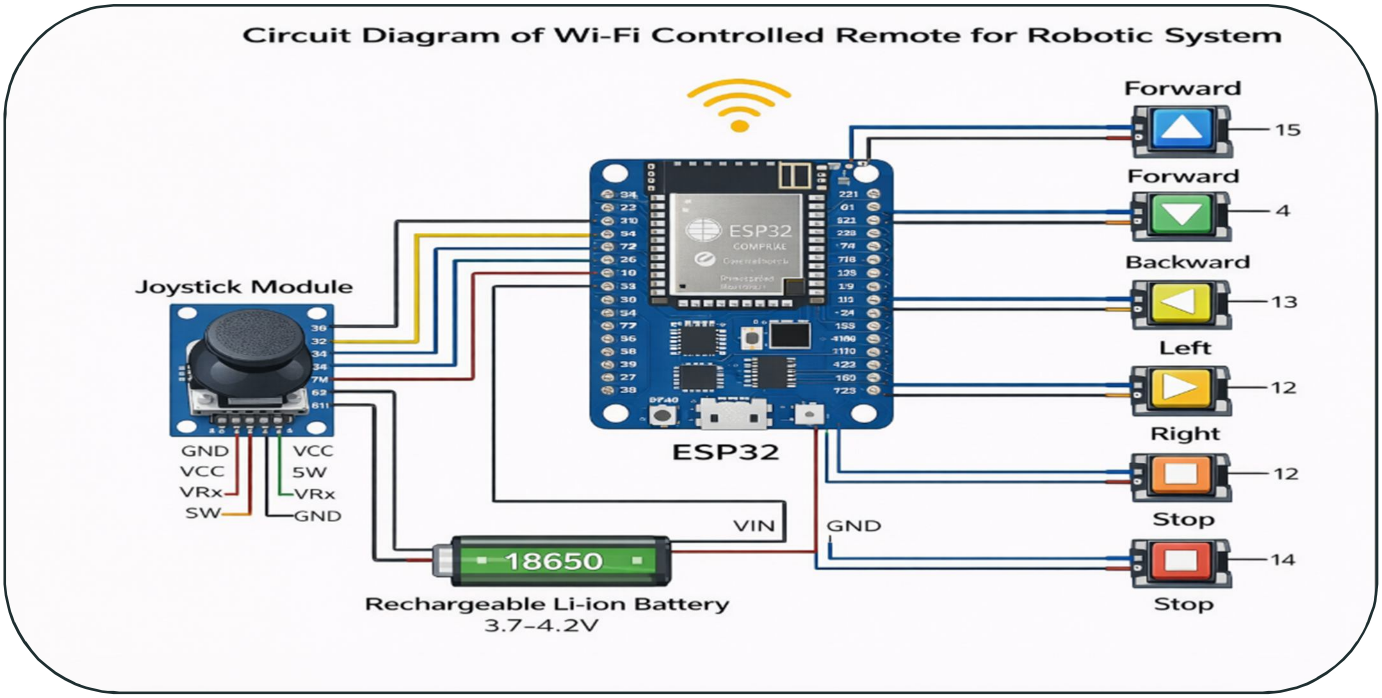
G. Code

ssx



IV. RESULTS AND DISCUSSION

To investigate the performance and accuracy of the designed surveying robot, several tests were conducted considering different types of environments and operating conditions. System functionality was evaluated through analyzing the operation of individual modules and the efficiency of the entire system. In particular, the distance measuring module that included an ultrasonic sensor showed accuracy within ±2 cm under standard operational conditions. The obtained accuracy was considered enough for short-distance measurements during surveying and detecting obstacles.The metal detection module managed to detect buried metals. The sensor showed stability and high reliability during its operation within the optimal detection range. Thus, the proposed design could be used to inspect construction sites and identify possible hazards. Finally, the soil moisture sensor allowed detecting changes in soil conditions. It was also possible to estimate indirectly the presence of subsurface water basing on moisture indicators. Moreover, the soil detection module classified soil condition into three groups: dry, normal, and wet.Leveling was done successfully, and the system was able to detect when the surface is level or tilted by utilizing the MPU6050 sensor. The tilt angle was effectively measured for better analysis of data.Fire detection module provided instant reaction to fire detection and gave users alerts about it, increasing their safety in dangerous places. Camera module made remote observations and analysis possible.

Robotic arm was capable of grabbing and manipulating objects to some extent, which made unnecessary any further actions from humans.As can be seen from the above points, the integration of several different functions made it possible to reduce manual work and increase operational efficiency as well as safety. Thus, the system possesses high application value in modern civil engineering practice.

Module	Performance
Distance Sensor	±2 cm accuracy
Metal Detector	Reliable detection
Soil Sensor	Effective classification
Leveling System	Accurate tilt detection
Fire Sensor	Instant response
Camera	Real-time monitoring
Robotic Arm	Successful object handling

V. ADVANTAGES

There were many notable strengths that made the suggested smart surveying robot superior to both conventional surveying practices and other robots built for single purposes.

First and foremost, the robot was equipped with numerous functions within one body. Distance measuring, metal detecting, soil testing, levelling, fire detecting, and continuous monitoring were some of its capabilities. It meant that there would be no need to use different equipment for these purposes anymore.Another strength of the system was that it considerably increased safety in dangerous conditions. Being able to control it remotely using a smartphone application prevented people from being in perilous locations such as on fire or rough terrain.

Moreover, the robot substantially saved human power. Automation of the information collection process and analysis made surveying and building processes much faster and easier.

The ability to monitor the environment in real time was another great benefit due to the camera module and the wireless communication capabilities. With the help of the system, one can observe the environment conditions remotely, get sensor readings immediately, and make informed decisions even if they were not at the place. Moreover, the project was quite cost-effective because the use of commonly available parts like ESP32 and sensors made its implementation possible.

Lastly, thanks to the modular approach, which is typical of robots, the system could be further improved by adding extra sensors or other technologies based on artificial intelligence.

VI. LIMITATIONS

Nevertheless, despite its numerous benefits, there are certain limitations that have been identified in relation to this surveying smart robot system.

Firstly, due to the use of a soil moisture sensor as a means for underground water detection, the system lacked the capacity for obtaining accurate estimations since it could only provide indirect readings. Although the soil moisture sensor could detect the presence of underground moisture, it was unable to precisely estimate the exact depth or amount of underground water available.

Furthermore, one of the key problems with the functionality of the system is associated with a limited range of depths to which it can perform any of the described sensing operations. The metal detector and soil moisture sensor worked perfectly at a shallow depth only, making it inadequate for deep underground detection tasks in major civil construction works.

Finally, the system required regular calibration of sensors used due to their sensitivity to changes in various environmental factors.

VII. FUTURE SCOPE

The developed smart surveying robot appeared to be very promising, but there is still room for improvement of its functionality, accuracy, and use in practice.

Firstly, the inclusion of GPS functionality can considerably extend the capabilities of this device. With GPS support, the robot will be able to record its location and create accurate maps, which is extremely helpful for b tshr b tshr₹construction site planning.

Secondly, implementing a system based on artificial intelligence will make this robot even smarter. The machine learning algorithms will be used to analyze sensor information, predict possible weather changes, and make decisions autonomously, thus limiting the necessity to control the robot.Moreover, introducing computer vision with the help of a more powerful camera will improve navigation and obstacle avoidance.

Finally, the inclusion of a cloud-based system for data processing will make the use of the robot more convenient. Data from all sensors will be accessible online for analysis, and different people will be able to use this robot at once. In addition, the application of cutting-edge underground scanning equipment, for instance, Ground Penetrating Radar (GPR), may help increase the precision of the detection process through advanced geophysical methods which cannot be achieved using existing sensors.

Generally, these improvements will make the proposed system smarter, more autonomous, and scalable, making it ideal for applications in civil engineering and surveying.

VIII. CONCLUSION

The developed surveying robot is a successful example of how different modules of measuring, monitoring, and functioning are combined in one system. Such a system helps to overcome many limitations of conventional surveying approaches since it increases the effectiveness of operations, improves accuracy, and requires less human intervention.

By incorporating such modules as measuring distance, detecting metal objects, analyzing soil, working with the leveling system, detecting fire, and monitoring the environment via cameras, and operating with a robotic arm, the robot becomes able to conduct various activities that are important in civil engineering applications. In addition, the ability of the system to assess underground water levels and the composition of the soil makes it much more practical for civil engineers.

In addition, the use of wireless communications provided by an ESP32 microcontroller helps increase the safety and reliability of the system by making it possible to monitor processes and manage its functioning in real time. As a result, it becomes possible to reduce risks associated with the use of such equipment in a hazardous environment.

Thus, the discussed system can be seen as one of the key examples of future developments in the area of automation and building intelligent infrastructure.

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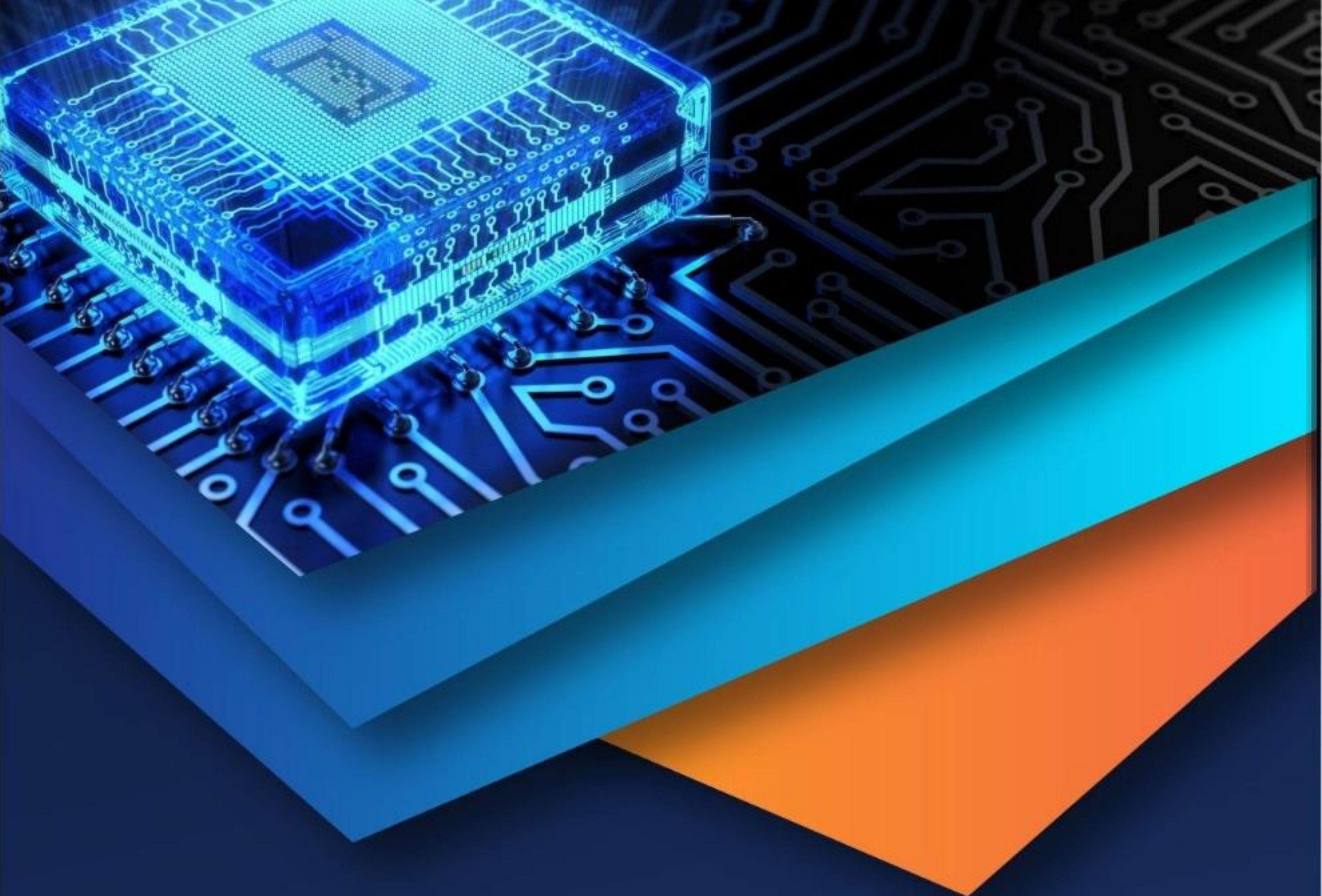

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