ISSN: 2249-7196
IJMRR/March-May 2024/ Volume 14/Issue 3/194-202
R. Swetha Sree / International Journal of Management Research & Review

# Autonomous Environment Monitoring Using IoT for Indoor Data Collection via AMR

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***Abstract***

*This paper describes a system for gathering indoor environmental data autonomously using an Autonomous Mobile Robot (AMR). The robot carries IoT-enabled sensors that measure temperature, humidity and air quality, and navigates indoor spaces to collect readings and transmit them to a central server for analysis and visualization. Unlike a fixed sensor network, which measures only the points where sensors happen to be installed, a mobile platform samples the whole space, so a problem confined to one corner of a room is not missed. The robot is built on a Raspberry Pi with a LiDAR sensor for navigation, a camera for perception, BO motors driven through an L298N motor driver, and a Li-ion battery. Environmental sensing uses a DHT-11 for temperature and humidity, an MQ-135 for general air quality including CO2, and an MQ-7 for carbon monoxide. Readings are uploaded to an Adafruit IO dashboard, where they are viewed as live feeds and line charts. The software stack is built on the Robot Operating System (ROS), which supplies hardware abstraction, message passing between nodes and visualization tools. The system provides real-time insight into indoor conditions, supporting decisions about ventilation, energy use and occupant safety.*

***Index Terms—*** *Adafruit IO, air quality monitoring, autonomous mobile robot, DHT-11, indoor environment monitoring, Internet of Things, MQ-135, Raspberry Pi, ROS.*

## I. **Introduction**

The convergence of autonomous mobile robots and the Internet of Things has opened new possibilities for indoor environment monitoring. Deploying an AMR equipped with sensors and IoT communication allows an organization to collect and act on real-time data about its indoor spaces.

Traditional indoor monitoring relies on manual inspection or on stationary sensor networks, both of which limit the scope of data collection. A manual survey gives a snapshot at one moment; a fixed network gives continuous readings but only at the points where sensors were installed, and adding coverage means adding hardware. An autonomous system based on IoT and an AMR traverses the space while continuously capturing environmental parameters, giving coverage that a fixed installation would need many more sensors to match.

Parameters such as temperature, humidity, air quality and occupancy give the granular insight needed for decisions about ventilation and energy use. IoT connectivity further allows the AMR to communicate with building infrastructure, so that environmental changes can trigger automated responses. As organizations give more attention to sustainability and occupant comfort, autonomous monitoring of this kind becomes a practical option.

*A. Robot Operating System*

ROS is an open-source framework providing tools, libraries and conventions for building and controlling robots. Despite the name it is not an operating system in the sense that Windows or Linux is; it is middleware that sits on top of an operating system and gives the components of a robot system a standard way to communicate.

ROS offers hardware abstraction, message passing between nodes, package management and visualization tools, so that a developer can work on one part of the robot — perception, motion planning or control — while the parts still integrate. Its distributed architecture breaks a complex system into smaller modular components called nodes, which may run on different computers or processors and communicate through a publish-subscribe messaging system. This is what makes it practical to run navigation on one process and environmental sensing on another while both share the same clock and coordinate frame.

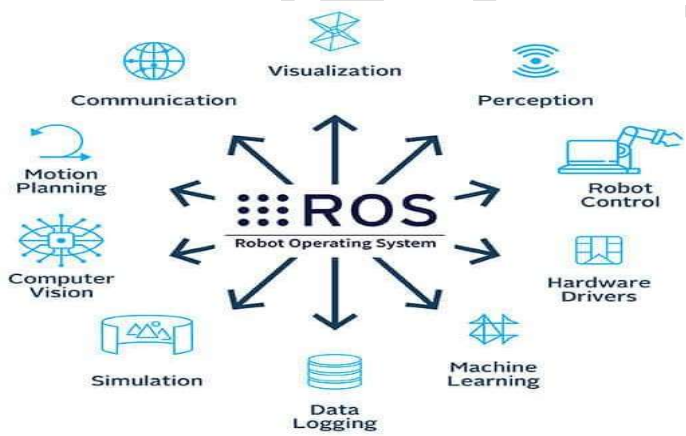


**Fig. 1. Robot Operating System.**

## II. Literature Survey

Ma et al., published in IEEE Access in 2020, present the design and implementation of an autonomous indoor environmental monitoring system using IoT. The system integrates sensors for temperature, humidity and air quality, with data collection and transmission through IoT protocols and automated meter reading techniques for efficient retrieval. The study demonstrates the feasibility of autonomous monitoring in indoor settings.

Sharma and Gupta, in the International Journal of Engineering and Advanced Technology in 2019, explore the integration of IoT with AMR systems for monitoring in smart buildings, emphasizing real-time data collection for optimizing energy use and occupant comfort. Their system enables autonomous monitoring and control of indoor conditions, contributing to energy efficiency.

Gupta and Kumar, at the International Conference on Intelligent Sustainable Systems in 2021, present an autonomous indoor air quality monitoring system using IoT and AMR technologies. A network of sensors monitors

CO2 levels, particulate matter and volatile organic compounds, highlighting the importance of autonomous monitoring for healthy indoor environments.

Verma et al., in the International Journal of Engineering Research and Technology in 2020, present a smart environmental monitoring system for indoor air quality management, integrating sensors for temperature, humidity, CO2 and air pollutants with IoT connectivity for autonomous data collection, transmission and analysis.

Singh et al., at the International Conference on Communication, Computing and Internet of Things in 2020, present an IoT-based system tailored to indoor applications, using a sensor network with IoT connectivity for transmission and AMR technology for efficient data retrieval. Patel et al., in the International Journal of Advanced Computer Science and Applications in 2018, report a similar design combining IoT connectivity and AMR infrastructure for real-time collection and analysis.

Taken together these studies show that sensor networks, IoT connectivity and AMR infrastructure can deliver real-time monitoring and control of indoor conditions. What most have in common is that the mobile element is used for data retrieval rather than for sensing; the system described here puts the sensors on the robot itself.

## III. Hardware

*A. Chassis, Motors and Wheels*

The chassis plate is the foundational structure, providing support, stability and mounting points for the other components. It is made of a durable material such as steel or aluminium and carries the weight of the electronics, motors and battery.

Brushed DC motors, commonly called BO motors, convert electrical energy into rotational motion through the interaction of magnetic fields, using a rotating armature, commutator, brushes and stationary magnets. They are widely used in robotics for their simplicity, low cost and ease of control. Wheels provide traction and support, and come in configurations suited to different surfaces and motion requirements.

*B. Raspberry Pi and Camera*

The Raspberry Pi serves as the onboard computer, providing computational capability, connectivity options and access to a large software ecosystem. It runs the ROS nodes, reads the sensors and handles the network connection to the server.

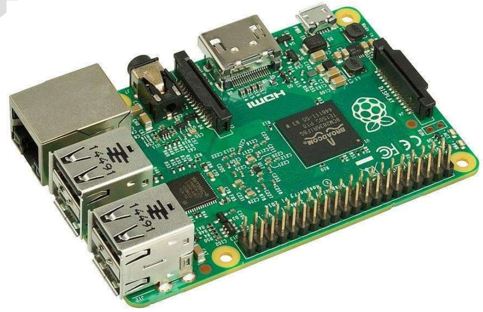

**Fig. 2. Raspberry Pi microprocessor.**

The Raspberry Pi Camera module gives the robot vision sensing, capturing images and video of its surroundings. The visual data supports object detection, recognition, tracking, navigation and localization. An SD card provides storage for the operating system, program code and logged data.

*C. Motor Driver and Battery*

The L298N motor driver controls the DC motors. Its dual H-bridge configuration gives bidirectional control, so the robot can move forward, backward and turn. The driver operates at voltages up to 46 V and supplies continuous current up to 2 A per channel, with a peak of 3 A. It supports pulse width modulation for speed control, varying the width of the pulse sent to the motor and so the average voltage applied, which is what allows the robot to slow down for a turn rather than moving at one fixed speed.

A lithium-ion battery powers the robot. Li-ion cells have a high energy density compared with lead-acid or nickel-metal hydride, storing a large amount of energy in a compact and lightweight package. This matters on a mobile platform, where weight and space are constrained and where a longer run between charges means more of the building can be surveyed in one pass.

*D. LiDAR Sensor*

The LiDAR sensor emits laser pulses and measures the time taken for the light to return, giving precise distance and depth measurements. It allows the robot to determine its position relative to its surroundings, and combined with odometry it supports accurate localization even where GPS is unavailable, which is always the case indoors. LiDAR-based SLAM algorithms let the robot map its surroundings and locate itself within that map at the same time, which is the capability that makes autonomous exploration of an unfamiliar indoor space possible.

**Fig. 3. LiDAR sensor.**

*E. DHT-11 Temperature and Humidity Sensor*

The DHT-11 measures temperature and humidity. It reads temperatures from 0 °C to 50 °C with an accuracy of ±2 °C, and relative humidity from 20% to 80% with an accuracy of ±5%. It provides a digital output, so it interfaces with the microcontroller directly without analogue-to-digital conversion. Its accuracy is modest, but adequate for detecting the changes in comfort conditions that this application is concerned with.

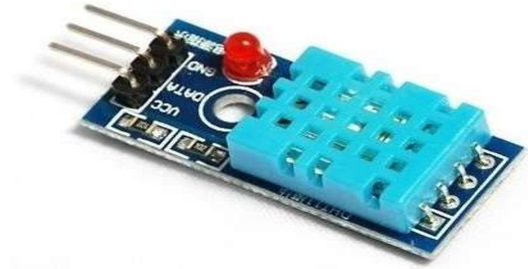


**Fig. 4. DHT-11 sensor.**

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IJMRR/March-May 2024/ Volume 14/Issue 3/194-202
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*F. MQ-135 Air Quality Sensor*

The MQ-135 is a gas sensor that detects ammonia, benzene, alcohol, smoke and CO2. It provides an analogue output voltage proportional to the concentration of the detected gas, which simplifies interfacing for data processing. It is inexpensive, which is a considerable part of why a robot carrying several such sensors remains affordable. In healthcare settings the same sensor is used to monitor indoor air quality in medical facilities and patient homes.

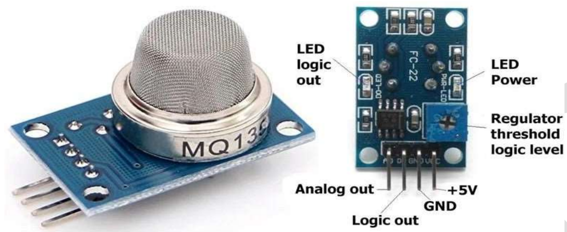


**Fig. 5. MQ-135 sensor.**

*G. MQ-7 Carbon Monoxide Sensor*

The MQ-7 detects carbon monoxide, a colourless, odourless and highly toxic gas. It is specifically designed for CO, making it sensitive and selective for that gas, which matters for indoor safety in buildings with gas appliances, boilers or attached garages. This is the sensor whose readings have direct safety consequences rather than comfort ones.

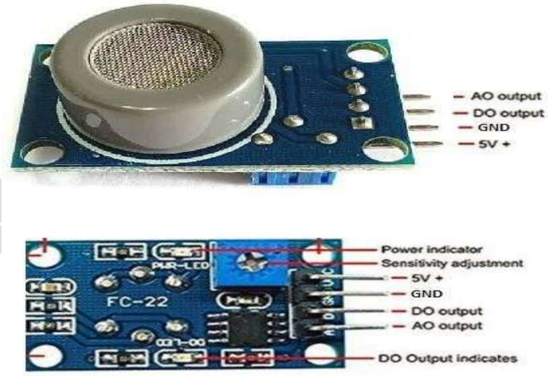


**Fig. 6. MQ-7 sensor.**

## IV. Software And Data Platform

*A. Development Environment*

VirtualBox is used to run Ubuntu alongside the host operating system, so ROS can be developed without disturbing the existing system configuration. Tilix provides the terminal environment. Fusion 360 is used for the mechanical design of the chassis and mounting components.

*B. Adafruit IO*

Sensor readings are uploaded to Adafruit IO, which provides feeds and a dashboard. A feed is created for each measured quantity — temperature, humidity and gas concentration — and the robot publishes readings to those feeds over its network connection. Dashboard blocks, including line charts, display the incoming data, so trends over time are visible rather than just the current value. Because the dashboard is web-based, the readings can be viewed from anywhere, which removes the need for anyone to be present in the monitored space.

```
// pin connected to DH22 data line
#define DATA_PIN 2
```

**Fig. 7. Adafruit IO feed setup.**

*C. Python Interface*

The Python side uses the Adafruit IO Python library with its REST client. Sensor values are read on the Raspberry Pi, formatted and sent to the corresponding feed. The library handles authentication and the HTTP exchange, so the application code stays confined to reading sensors and deciding when to publish.

## V. System Operation

In operation the robot navigates the indoor space using LiDAR-based SLAM, building a map and localizing itself within it. As it moves, the DHT-11, MQ-135 and MQ-7 are sampled and their readings published to Adafruit IO along with the robot's position. Because each reading is associated with a location, the result is not a single figure for the building but a distribution across it.

This is the practical advantage over a fixed installation. A stationary sensor at the entrance to a room reports conditions at the entrance; if the far corner is poorly ventilated, that sensor will not show it. A mobile platform sampling the whole floor detects the gradient. The trade-off is that any one point is sampled only when the robot passes it, so a mobile system gives spatial coverage in place of temporal continuity, and is best suited to detecting persistent problems rather than sudden events.

## VI. Results

The system was tested under two conditions: normal indoor temperature and humidity, and an elevated case. Figs. 8 and 9 show the readings received on the dashboard in each case, and Fig. 10 shows the same data plotted over time.

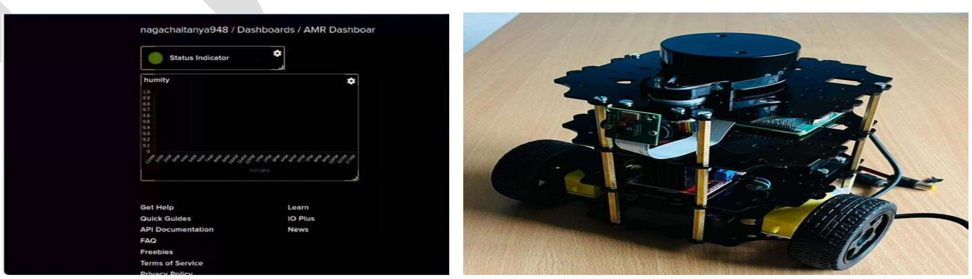


**Fig. 8. Output for normal temperature and humidity.**

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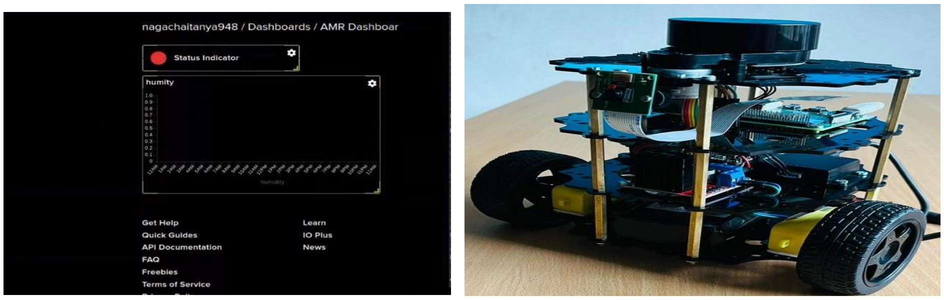


**Fig. 9. Output for high temperature and humidity.**

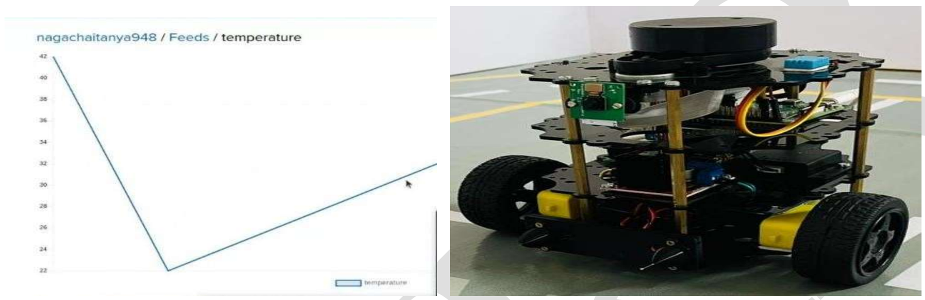


**Fig. 10. Graphical representation of temperature and humidity.**

The readings updated on the dashboard as the robot moved, and the elevated condition was reflected in both the numeric feed and the chart. The line chart is what makes the data useful in practice: a single high reading could be a sensor artefact, whereas a sustained rise across successive samples indicates a real change in conditions.

## VII. Conclusion

Integrating an autonomous mobile robot with IoT technology for indoor environment monitoring offers a workable approach to improving efficiency, sustainability and comfort in indoor spaces. Deploying an AMR with sensors allows real-time monitoring of temperature, humidity, air quality and occupancy, giving a level of spatial detail that a fixed sensor network would need substantially more hardware to provide.

The data supports better resource use, earlier identification of maintenance issues, and environments tuned to the needs of the people in them. Combined with smart building infrastructure, the same data can drive automated adjustment of environmental conditions and reduce energy waste.

The limitations should be acknowledged. Sensor accuracy is modest at this price point; the DHT-11 in particular is a comfort-grade rather than instrument-grade device. Any location is sampled only when the robot reaches it. Data security, privacy and interoperability all need attention before a system of this kind is deployed at scale in a building occupied by people.

## VIII. Future Scope

*Enhanced efficiency.* As sensor technology improves, an AMR can collect data more accurately and cover more of a building in a single pass.

*Customization and adaptability.* Machine learning applied to the collected data could optimize environmental conditions according to occupancy patterns and energy efficiency targets.

*Integration with smart buildings.* HVAC systems could adjust their settings from the data collected by the robot, optimizing energy consumption while maintaining comfort.

*Predictive maintenance.* The robot could inspect equipment and infrastructure autonomously, identifying leaks or malfunctions before they cause failures.

*Data analytics.* Larger data volumes justify better analytics and visualization tools, with predictive modelling used to extract trends from the accumulated record.

*Scalability and security.* A modular design would allow additional sensors to be added as requirements change, and encryption and authentication are needed to protect the collected data.

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