



MULTITASKING AI ROBOT CAR FOR SMART HOME AND ASSISTANCE

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Abstract: With an emphasis on a scalable and reasonably priced home monitoring robot for smart homes, this survey provides a thorough review of recent developments in multi-sensor smart robots for indoor environmental monitoring. The system incorporates a Wireless Sensor Network (WSN) with sensors for gas (MQ-2), flame, water leakage, dust, and temperature-humidity (DHT11), all of which are controlled by a NodeMCU (ESP8266) microcontroller in order to meet the growing demand for intelligent home automation. Through the use of IR proximity sensors for obstacle avoidance and path-following algorithms, the robot facilitates autonomous indoor navigation while providing real-time monitoring and alerts through a mobile application and GSM-based notifications. To guarantee safety, it uses machine learning to anticipate dangerous situations, automates household appliances, and only works inside a predetermined indoor space. Sensor data is sent to a local dashboard or cloud server, giving consumers prompt warnings about dangers like gas leaks or unusual temperature increases. The robot was tested in a smart home environment and proved to be a dependable safety and environmental monitoring tool at a low implementation cost of less than INR 6000 (USD 100), making it a viable option for widespread smart home deployment.

Keywords: Home Monitoring Robot, IoT, Node MCU, Smart Home, Gas Detection, Fire Safety, Water Leakage, Wireless Sensor Network, Android App, Machine Learning.

I. Introduction:

The invention of smart homes has revolutionized human interactions with the living space, improving security, comfort, and energy efficiency. At the core of this technology are multi-sensor smart robots that monitor and regulate home conditions in an autonomous manner. These robots are equipped with an array of sensors like gas detectors, flame detectors, water leakage detectors, dust sensors, and environment monitors for the purpose of real-time detection of hazards and automation of the house. These systems include IoT technology integration along with wireless modules like Node MCU (ESP8266) and enable remote control and visualization of data using smartphones and web platforms. Though increasingly popular, there are no coherent, low-cost, and scalable solutions addressing all the most important aspects of home safety. This survey intends to investigate existing systems, their functionalities, employed technologies, and problems encountered in creating fully autonomous, cost-effective, and trustworthy smart monitoring robots for home use. Sensor Technologies for Environmental Monitoring

The idea of home automation has developed at a very fast pace with the growth of smart devices, Internet of Things (IoT), and embedded systems. With growing reliance on technology for urban life, there is a strong requirement for intelligent systems that not only automate domestic work but also provide safety and efficiency. One such promising solution is to use multi-sensor smart robots that are capable of independently monitoring different environmental factors and possible threats in a house.

These robots often embed a set of gas sensors, flame detectors, water leak sensors, dust monitors, and temperature-humidity sensors within a mobile robotic platform or fixed modular platforms. These sensor-collected data are processed in real time and transmitted over Wi-Fi-enabled microcontrollers such as Node MCU (ESP8266/ESP32). Reports and alarms are then transmitted to users through mobile apps, SMS notifications, or cloud portals.

The benefits of such robots include the early warning of hazards like gas leaks, fire, flood due to leakages, or unhealthy air conditions, as well as remote appliance control and ambient monitoring. The current solutions also have drawbacks in the form of high setup cost, poor integration of sensors, poor scalability, and absence of intelligent path-finding or avoidance of obstacles.

This survey offers a thorough review of existing research and advancements in home monitoring multi-sensor robotic systems. It analyzes different architectures, sensor modules, communication protocols, control interfaces, and machine learning usage. Additionally, the paper recognizes common challenges—like power consumption, sensor calibration, false alarms, and limited autonomy—and discusses future trends towards more adaptive, low-cost, and scalable home monitoring robots.

With the dawn of ubiquitous computing and intelligent automation, the vision of smart homes has shifted from being a luxury to a need. Growing urbanization, demand for enhanced household security, and the presence of low-cost microcontrollers and sensors have propelled the use of home monitoring systems. Whereas initial home automation attempts were primarily concerned with convenience—such as remote control of lights and appliances—current developments require systems that also provide safety,

environmental sensitivity, and autonomous decision-making. In this regard, multi-sensor smart robots present a key innovation, providing a mobile, real-time, and integrated solution for home monitoring.

These automated systems are normally fitted with a set of sensors—like MQ series gas sensors for detecting LPG or CO, flame sensors for identifying fires, DHT11 or DHT22 sensors for temperature and humidity detection, dust sensors for analyzing air quality, and specially designed water leakage sensors to detect moisture or flooding. Integrated with microcontrollers such as Node MCU (ESP8266/ESP32), Raspberry Pi, or Arduino, such robots can collect data independently, process it locally or in the cloud, and send alerts through mobile apps, SMS, or web interfaces. They usually also have actuators, allowing real-time actions such as triggering alarms, closing valves, or moving to critical positions.

Despite promising progress, a number of challenges persist in the creation of a dependable, scalable, and inexpensive household monitoring robot. Most solutions currently:

- Concentrate on stationary sensors as opposed to autonomous mobile devices.
- Are scattered, addressing one or two dangers such as gas or fire.
- Don't feature sophisticated path planning and obstacle detection.
- Need sophisticated setup and are unaffordable to ordinary consumers.
- Offer very limited utilization of data analytics or machine learning for proactive warnings.

This survey sets out to discover and solidify the different technological methods, hardware setups, communication protocols (i.e., MQTT, HTTP), and sensor fusion techniques applied to multi-sensor home monitoring robots. It weighs the performance versus cost, complexity, and scalability trade-offs. In addition, the paper presents an overview of existing literature, real-world deployments, and research contributions in academia and industry and determines the existing gaps and opportunities in this rapidly growing area of research.

In doing this, the research provides a foundation for developing future-generation smart robots that are enabled to offer autonomous, intelligent, and holistic home surveillance, helping make living spaces safer and smarter.

II. DATA FUSION TECHNIQUES

In smart robots for home monitoring that incorporate multiple sensors, data fusion is used to merge information from heterogeneous sensors to provide an overall and precise description of the environment. The robots typically have gas, flame, dust, temperature, humidity, and water leakage sensors, each of which gives a partial description of the home status. Through the fusion of data from these sources, the system is able to decrease uncertainty, enhance decision-making, and generate more trustworthy alarms. Fusion of data in such systems takes place at three main levels. At the low level (raw data fusion), raw sensor outputs are fused directly to create a consolidated observation. For example, values from two air-quality sensors such as MQ-2 and MQ-135 might be filtered or averaged to dampen noise and enhance gas concentration estimates. Mid-level fusion, or feature-level fusion, is the process of consolidating extracted features from sensor data—like increasing temperature patterns, humidity bursts, or abrupt gas level fluctuations. This level is particularly suitable for input to machine learning models, which can learn to predict or classify dangerous conditions. High-level or decision-level fusion fuses separate decisions or warnings generated by separate sensor modules. For instance, if both a flame sensor and a high-temperature sensor initiate an alarm, the system can safely conclude a fire event and activate emergency procedures. There are a variety of methods that aid these fusion processes. Rule-based systems, based on straightforward if-then reasoning, are still in favor because they are easy to understand and interpret. More sophisticated techniques, like Kalman filters, are used to minimize sensor noise and achieve precise state estimation over time. Probabilistic models like Bayesian networks provide a formal mechanism for dealing with uncertainty and interdependence between sensor measurements. Fuzzy logic controllers fit naturally into environments with imprecise information, permitting linguistic variables like "low," "medium," or "high" risk. Machine learning algorithms like decision trees, support vector machines, and neural networks can also be trained on tagged sensor data to identify patterns and classify environmental conditions like "safe," "warning," or "critical." Such methods allow predictive functionality and adaptive behavior in challenging real-world situations. Though advantageous, data fusion in home care robots is also confronted with obstacles in the form of sensor calibration, synchronization, and handling of lost or inconsistent data. Time synchronization between non-synchronized sensor outputs is crucial for successful fusion. Additionally, the relative weights or priorities of various sensors can be context-dependent—for example, a fire sensor could be more important than a dust sensor in the event of a suspected fire incident. Overcoming them is crucial to increasing the reliability and wisdom of smart home monitoring robots.

III. Challenges

Though multi-sensor intelligent robots can provide an impressive solution to multi-point home surveillance, their manufacture and installation meet some technical as well as real-world challenges. Perhaps the greatest concern is that of sensor reliability and calibration. Sensors like flame detectors, flame sensors, and dust monitors are prone to outputting noisy or incorrect data resulting from environmental aspects such as humidity, temperature variances, or aging of the sensor. Maintaining proper and stable output necessitates regular calibration and in some cases environmental compensation, adding to system complexity.

Another significant challenge is data fusion and interpretation. Data fusion from many heterogeneous sensors requires strong fusion algorithms capable of addressing uncertainty, disagreeing readings, and missing values. Creating fusion systems that are responsive yet minimize false alarms remains a challenging issue, particularly in dynamic home settings where humans and pets are continuously on the move. Communication dependability is also a challenge, especially when sending data via wireless modules such as Node MCU (ESP8266/ESP32) using Wi-Fi. Network outages, latency, and bandwidth constraints may cause crucial alerts

to be delayed or lost. Moreover, having secure communication and data confidentiality is important, especially when sending data to cloud services or mobile applications.

The power management challenge is particularly critical for mobile or semi-autonomous robots. Ongoing monitoring with a number of sensors and actuators drains energy quickly, and thus effective power-saving methods or sophisticated battery systems are necessary. In fixed installations, backup power during power outages is required to sustain system function. Mobility and obstacle avoidance in robotic systems demand intelligent navigation algorithms. Basic path-following mechanisms can fail in cluttered or dynamically changing home environments. The robot should be able to navigate through narrow passages, avoid furniture, and gain access to critical areas such as kitchens or bathrooms without human intervention.

In addition, budget limitations prevent widespread adoption. While attempts have been made to ensure the overall cost of the system is less than INR 6000 (USD 100), combining several high-quality sensors, microcontrollers, communication modules, and a mobile interface can drive costs up, particularly when scaling up for complete home coverage.

Finally, ease of use and maintenance are still pragmatic issues. Most users will not have the technical knowledge to diagnose hardware or software problems, upgrade firmware, or read sensor logs. Thus, making the system easy to use, plug-and-play, and low-maintenance is the key to broader acceptance.

IV. Future Directions

With increasing demand for intelligent and cost-effective home monitoring systems, multi-sensor smart robots are likely to advance with enhanced capabilities, increased autonomy, and better integration with users. Future advancements will likely overcome the present limitations through breakthroughs in sensing, processing, and system design.

A future direction of note is edge computing and AI on the device level, whereby robots can process locally sensor information utilizing light-weight machine learning models. This solution decouples the reliance on constant connectivity to the internet and provides speedier real-time decision-making capabilities for the crucial events like gas leaks or outbreak of fires. Specifically, the use of predictive analytics via AI models can be used to predict danger based on sensor data trends, enabling users to adopt preventive actions beforehand.

Improvements in robot mobility and navigation will also be a central interest. Technologies like simultaneous localization and mapping (SLAM), LIDAR, or sophisticated vision systems will enable household robots to autonomously navigate complicated indoor environments. These systems will have to dynamically adjust to furniture layouts, obstructions, and people moving around while keeping a predefined patrol path for complete home coverage.

Another significant objective is to enhance sensor miniaturization and resilience. Future sensors must be smaller, more energy-efficient, and less prone to environmental degradation, allowing longer operating life and better measurements. Additionally, multi-modal sensor fusion, which aggregates information from visual, thermal, acoustic, and environmental sensors, can greatly enhance the robot's awareness of its environment and improve decision-making.

In response to power limits, low-power electronics research, energy harvesting (such as solar indoor charging), and intelligent power management will play an ever-larger role. Combining that with modular hardware design will enable users to update or replace isolated parts (such as sensors or batteries) without having to redesign the whole system.

On the software front, coming systems will enjoy cloud connectivity with decentralized data management for better scalability and privacy. Robots can be part of collaborative sensing networks, where robots in various homes share anonymized information to enhance threat models world wide. Lastly, user experience and usability need to be enhanced. Upcoming systems ought to provide intuitive mobile interfaces, voice control (through integration with assistants such as Alexa or Google Assistant), and self-diagnosing features to help users troubleshoot. Open-source platforms and community-based platforms can also promote quick prototyping and innovation, allowing smart home robots to become more accessible to students, researchers, and hobbyists.

Finally, with the adoption of AI, robotics, and IoT technologies, future generations of multi-sensor smart home monitoring robots will become more intelligent, autonomous, and easy to use—enabling smarter, safer living environments.

V. Conclusion:

The incorporation of multi-sensor systems into home-monitoring smart robots is a major step towards the development of safer and smarter living spaces. These systems integrate the functionality of different environmental sensors like gas detectors, flame detectors, water leak sensors, dust sensors, and temperature/humidity modules to offer real-time awareness and automatic reactions to potentially dangerous situations. Utilizing microcontrollers such as Node MCU, wireless communication, and mobile interfaces, these robots are able to identify anomalies and notify users in real time by means of calls, alarms, or IoT-based dashboards.

This paper has discussed the basic building blocks, data fusion methods, issues, and the future of smart home monitoring robots. Although present systems show a lot of potential in low-cost, efficient home automation and security, there are some issues left to be solved, such as data reliability, power consumption, sensor calibration, and secure communication.

In the future, developments in machine learning, edge computing, sensor miniaturization, and smart navigation will make these robots more adaptive, autonomous, and precise. Increased synergy between artificial intelligence and embedded systems will not only increase real-time hazard sensing capabilities but also predictive features that prevent accidents before they happen.

In short, multi-sensor intelligent robots provide a revolutionary solution for contemporary home safety and automation. With ongoing technological advancements and affordability, such systems are likely to become an integral part of future smart homes that provide comfort, safety, and peace of mind.

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