SOLAR – POWERED AIR PURIFICATION

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ABSTRACT
Air pollution and fog significantly affect human health and visibility, creating the need for smart, portable solutions that can monitor and purify air in real time. This paper presents the design and development of a solar-assisted Smart Air Purifier Robot that combines mobility with environmental sensing. An Arduino-based controller integrates an MQ gas sensor to detect pollution levels, and the robot uses onboard sensing and control logic to trigger purification via a relay-driven module while providing user feedback. An ultrasonic sensor supports obstacle detection, and a DHT11 sensor provides temperature and humidity readings for environmental logging. The robot operates using a solar-charged battery supply to improve sustainability. When unsafe air quality is detected beyond a preset threshold, the robot halts and alerts the user, then activates the purification unit. The prototype demonstrates the integration of renewable energy, embedded systems and robotics for smart-city-ready, low-cost air quality monitoring and purification. The design is scalable for indoor and outdoor monitoring scenarios.

Keywords: Air pollution, Solar energy, Arduino, MQ gas sensor, DHT11, Ultrasonic sensor, Smart robot.

1.INTRODUCTION

Air pollution has emerged as a significant environmental and public health issue in urban and semi-urban areas. Because standard air monitoring stations are often permanent, costly, and sparsely distributed, they provide limited real-time knowledge at the street and community level. Although there are portable purification gadgets, their coverage is often restricted and they rely on grid electricity. By activating purification, when necessary, a mobile robot capable of detecting local air quality and communicating its status to users may enhance situational awareness and aid in the installation of smart cities. This study introduces a solar-powered air purifier robot that uses low-cost sensors to monitor pollution and functions independently with rudimentary obstacle avoidance.

2. LITERATURE SURVEY

Recent studies have looked at self-powered air purifier robots for indoor environments that combine particulate sensing with renewable energy harvesting [1]. Intelligent air purifier systems with adaptive sensing and control strategies have also been suggested to improve responsiveness [2]. More recent prototypes concentrate on automated robots capable of both monitoring pollution and performing purification in dynamic environments [3]. These initiatives inspire a low-cost, mobile solution that integrates user feedback, embedded sensing, and renewable energy for practical implementation

3. MATERIALS & METHODS

3.1. System Architecture:

The system under consideration has a relay-controlled purification module, a motor drive subsystem for movement, an Arduino controller, air quality and environmental sensors, and a solar-charged battery. The controller constantly reads sensor data, determines the best course of action for movement and purification, and updates the LCD and indicators.

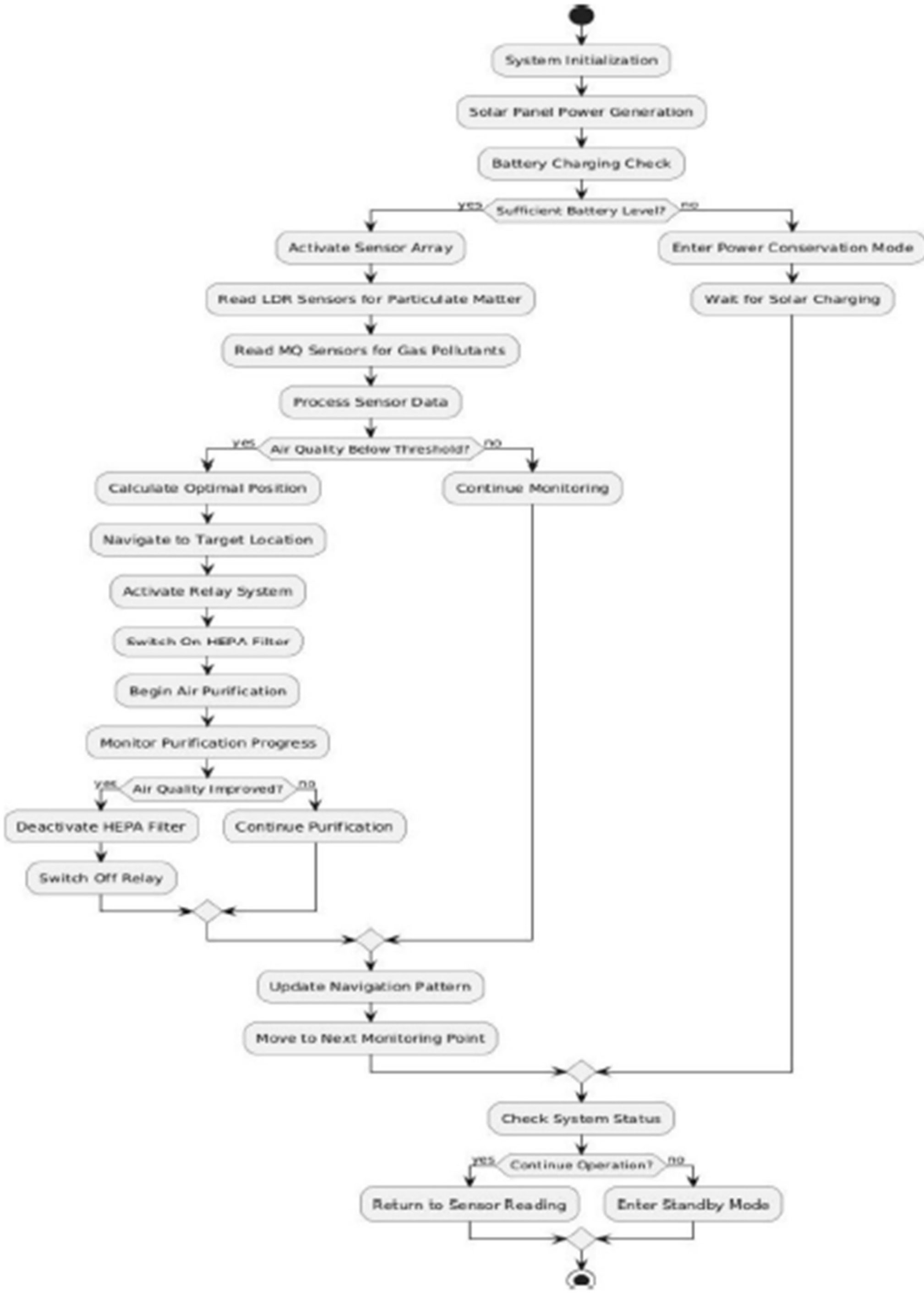

Fig. 1. Proposed system flow for sensing, decision making and purification.

3.2. Hardware Components

Table 1 summarizes the primary hardware components used in the prototype and their roles in sensing, actuation and user feedback.

Component	Model / Interface	Purpose in System
Microcontroller	Arduino Uno / ATmega328P	Central control, sensor readout and decision logic
Gas sensor	MQ-series (Analog A2)	Detects pollution level from gas/air quality
Ultrasonic sensor	HC-SR04 (Trig/Echo)	Obstacle detection and safe navigation
Temp/Humidity sensor	DHT11 (Digital pin 2)	Reads temperature and humidity for monitoring
Motor drive & motors	DC motors + driver	Robot mobility (forward/turn/stop)
Purification actuator	Relay module (pin 3)	Switches purification unit (fan/HEPA/ionizer)
Display	16×2 LCD (pins 8–13)	Shows status such as pollution/object detection
Power unit	Solar panel + battery	Sustainable energy supply and charging

Table 1. Main hardware components used in the Solar-Powered Air Purification Robot.

3.3. Control Logic and Key Equations

The gas level, temperature, humidity, and distance are continuously measured by the control firmware. The ultrasonic time-of-flight technique is used in obstacle avoidance, where the distance is calculated as:

(1) $d = (t\_echo \times v\_sound) / 2$, where $v\_sound \approx 0.034$ cm/μs

The implementation utilizes a safety threshold (for example, $d < 30$ cm) that initiates a stop action to prevent collisions. The MQ sensor analog reading (gasval) is used to measure air quality. The robot shows a pollution warning when the gasval value goes beyond a specified limit, and the purifier relay is turned on. The availability of solar energy is assessed using fundamental power relationships:

(2) $E = P\_solar \times t$, $P\_solar = V \times I$

Table 2 lists key I/O pin assignments used in the Arduino firmware.

Module	Pins	Function
LCD 16×2	RS=13, EN=12, D4=11, D5=10, D6=9, D7=8	Status display
Ultrasonic	Trig=14, Echo=15	Distance measurement
Motors	6, 7, 5, 4	Motor direction control
Relay	3	Purifier ON/OFF
DHT11	2	Temperature & humidity input
Gas Sensor	A2	Pollution sensing input

Table 2. Arduino pin mapping extracted from the implementation code.

4. RESULTS & DISCUSSION

The prototype was put together and tested for three main actions:

(1) obstruction identification and safe stop.

(ii) the identification of contaminants and the triggering of the purifier.

(iii) temperature and humidity sensing for environmental monitoring. The LCD display and hardware prototype.

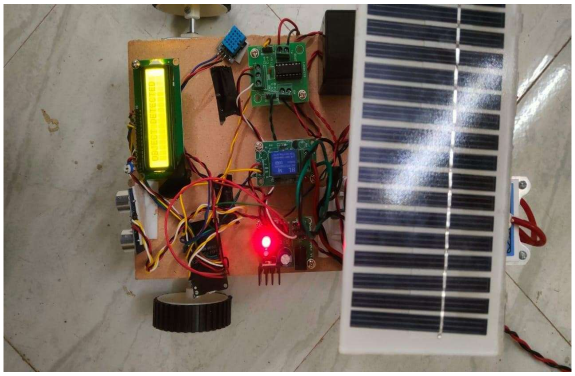

Fig.2 Hardwar Connection

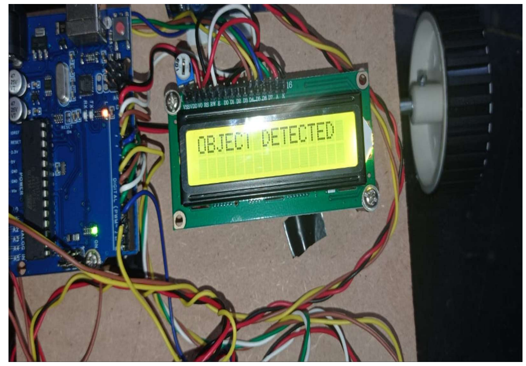

Fig.3 Object Detected

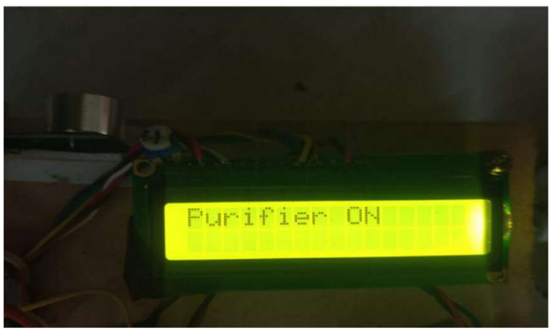

Fig.4 Purifier On

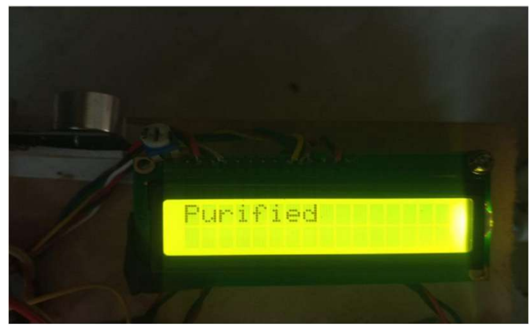

Fig.5 Air Purified

Table 3 Summarizes the decision logic implemented in the firmware for motion control and purification triggering.

Condition	Controller Action	User Feedback / Output
d < 30 cm	Stop robot (motors OFF)	LCD: "OBJECT DETECTED"
d ≥ 30 cm	Move forward	LCD: distance value
gasval > threshold	Activate relay; pause movement	LCD: "Pollution Detected"; purifier ON
gasval ≤ threshold	Keep relay OFF; continue monitoring	LCD: gas value
Periodic sampling	Read DHT11 temperature & humidity	LCD shows humidity and temperature

Table 3. Summary of firmware decision rules for detection and actuation.

According to the findings, the robot consistently halts when an obstacle is discovered within the predetermined distance limit, and the gas sensor reading can be utilized to activate purification and notify the user. A solar-charged battery allows for functioning without ongoing reliance on the grid, but performance is contingent upon sunlight availability and the battery's condition. Future improvements include integrating IoT connection for logging, incorporating sophisticated navigation for improved spatial coverage, and adding calibrated particulate matter sensors (PM2. 5/PM10).

5. CONCLUSION

The Solar-Powered Smart Air Purifier Robot is a functional prototype that combines robotics, embedded systems, and renewable energy to improve air quality knowledge and perform simple purification. The system offers a low-cost, extendable platform for environmental applications in smart cities by integrating gas detection, obstacle detection, user-friendly LCD feedback, and relay-controlled purification. The project demonstrates the promise of mobile monitoring and sustainable operation, as well as establishing a solid groundwork for future improvements in sensor accuracy, connectivity, and autonomous coverage.

6. ACKNOWLEDGEMENTS

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