BIG SMOKE - TOXIC SMOKE DETECTION AND ODOR NEUTRALIZATION ROBOT

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ABSTRACT

The issue of air pollution in Hanoi has reached alarming levels, posing serious threats to public health and diminishing the beauty of the natural environment. According to the Center for Environmental Monitoring, Hanoi's Air Quality Index (AQI) frequently registers in the "unhealthy" range, with PM2.5 concentrations averaging 50–60 µg/m³ in 2022—far exceeding the World Health Organization's (WHO) safe limit of 15 µg/m³. Dense smog and light pollution have enveloped the city, making it increasingly difficult to observe celestial phenomena such as constellations, eclipses, and meteor showers, depriving residents of their connection to the night sky.

Despite existing measures, such as awareness campaigns and stationary air purifiers, these interventions remain limited in scope and efficiency. This study introduces the "Big Smoke" project, a robotic solution utilizing IoT and AI technologies to autonomously detect, filter, and deodorize toxic smoke in school environments. Furthermore, the robot features sensors to detect fire and gas hazards, offering an integrated approach to improving air quality and safety.

This initiative seeks to improve air quality and public health while reviving the joy of stargazing and fostering a renewed appreciation for astronomy and environmental well-being.

Keywords: Toxic smoke, Arduino, Internet of Things, Artificial Intelligence (AI), Smoke detection, Air filtration and deodorization, Fire and gas hazard detection

INTRODUCTION

Air pollution in urban areas, particularly in cities like Hanoi, has become a significant environmental and public health issue, with construction sites being one of the major contributors. In Hanoi, the rapid pace of urbanization, coupled with the rise in construction activities, has led to a noticeable increase in air pollution. Construction sites, due to the extensive use of machinery, heavy equipment, and the disturbance of soil, release high amounts of dust, particulate matter (PM2.5), and other toxic gases into the atmosphere. In 2022, the average PM2.5 concentration in the city was recorded at 50-60 $\mu g/m^3$. This pollution not only compromises the health of workers and nearby residents but also contributes significantly to the overall environmental degradation of the city.

In addition to the health risks posed by airborne pollutants such as dust, nitrogen dioxide, and carbon monoxide, the pollution from these construction activities also contributes to severe light pollution and smog, further obstructing visibility. As a result, the residents of Hanoi have been deprived of the opportunity to observe celestial phenomena such as constellations, meteor showers, and planetary alignments. This has become an unfortunate side effect of the rapid urban growth and the increased number of construction projects taking place across the city.

To mitigate the effects of pollution, particularly around construction sites, the "Toxic Dust Detection and Odor Neutralization Robot" project offers a promising solution. This autonomous robot, equipped with advanced sensors and powered by the Internet of Things (IoT) and Artificial Intelligence (AI) technologies, is designed to detect harmful airborne particles and toxic gases generated by construction activities. The robot can purify the air and neutralize unpleasant odors in real time. Its mobility allows it to effectively target high-pollution areas like construction sites, improving air quality and restoring visibility of the night sky. This initiative not only aims to improve health conditions but also seeks to reduce the environmental impact of urban construction projects, creating a cleaner, safer, and more pleasant living environment for residents.

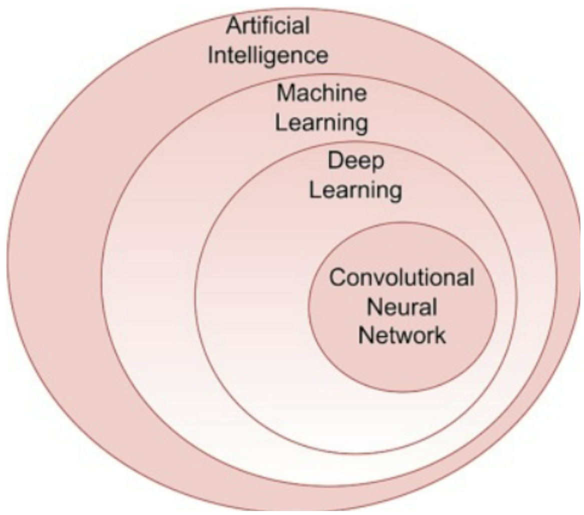
THEORETICAL BASIS

Internet of Things (IoT)

IoT enables real-time monitoring and control of environmental conditions through interconnected sensors and devices. In this project, IoT collects data from smoke, gas, and temperature sensors and transmits the data to a central processing unit for analysis and response. Smoke sensors (e.g., MQ-2, MQ-135) detect airborne contaminants and relay information for immediate action. Relevance: IoT ensures seamless communication and centralized management.

Artificial Intelligence (AI)

The most powerful technology in the world of detection and analysis is the Artificial Intelligence (AI) approach. Artificial intelligence (AI) is one of the driving forces of the so-called “fourth industrial revolution”. AI’s unique aspect is that control is transferred from people to technology, completely changing our previous understanding of people-technology relationships. AI includes a wide ecosystem of techniques within the computer science field where machines are programmed to simulate human intelligence, including the capacity to learn. AI covers many subfields, such as ML, and DL, among others. AI technology is found in countless devices, such as computers, mobile phones, smartwatches, cars, etc. Its applications are extensive, from the management of junk emails, robotics, and voice processing, to analyzing data from text images.



AI plays a critical role in processing sensor data and enabling intelligent decision-making. Computer Vision: Detects smoke or fire visually using AI-trained models. Machine Learning Algorithms: Analyze sensor patterns to predict abnormal environmental conditions such as increased smoke concentration or fire risks.

Air Filtration and Deodorization

Efficient air purification involves technologies like HEPA filters, activated carbon, and ionizers to remove particulate matter, toxic gases, and odors from the air. An essential oil diffuser also neutralizes toxic smoke odors, creating a more pleasant environment. HEPA filters capture fine particles, including smoke. Activated carbon absorbs volatile organic compounds (VOCs).

Autonomous Robotics

The robot's mobility is achieved through autonomous navigation, employing SLAM (Simultaneous Localization and Mapping) technology. SLAM Systems: Allow the robot to map its environment and navigate obstacles. Sensors: Lidar, ultrasonic, and cameras provide environmental data for path planning and collision avoidance.

Fire Detection and Warning

Integrated fire detection mechanisms monitor temperature and smoke density. AI processes these inputs to identify early warning signs of a potential fire, triggering alarms and notifications.

METHOD

Step 1: Literature review

During the implementation of this project, we studied various documents to gain knowledge and gather information, forming the scientific and practical basis for the topic, as follows:

- Understanding the harmful effects of tobacco on the human body.
- Studying the composition of toxic smoke.
- Researching the principles of operation and functionalities of the following hardware components:
    - Arduino Mega
    - ESP32 Board
    - GPS Module
    - Air quality sensors: MQ135, MQ2, MQ136, DHT11, ZH03B, MQ7
    - Infrared Camera AMG8833
    - OV7670T Camera
    - Exhaust fan
    - Touchscreen display
    - Memory card/USB or hard drive
    - DC encoder motor
    - UV light
    - Filtration devices (negative ion generator + filters)

- Essential oil diffuser
- Lidar sensor
- Motor driver circuit L298n
- Raspberry Pi

- Learning how to build and manage a Web Server.
- Exploring front-end and back-end design approaches for Web Servers.
- Understanding the structure, principles of operation, and connection of GPS modules to the control circuit.
- Researching documentation on li-ion battery systems and charging circuits to provide power to the device.
- Designing a web platform to assist teachers and students in monitoring air quality in specific areas and tracking the frequency of toxic smoke occurrences.
- Exploring the features and applications of the NodeMCU module and air quality sensors.
- Learning how to design 3D models for creating the product's frame.
- Studying existing products with similar functionalities available on the market and comparing them.

Product	Example	Mobility	Ability to filter air and deodorize	Ability to detect and warn of fire	Ability to save air quality information
Big Smoke		x	x	x	x
Air purifier Xiaomi Smart Air Purifier 4 compact EU (BHR5860EU) 27W			x		

Fire alarm Horing NQ-418				x	

Table 1: Compare Big Smoke products with devices on the market

Conclusion: It can be seen that the products on the market have one or several features, however, no product has integrated all the features into one device that can be suitable for the conditions of schools in Vietnam. Vietnam. From there, the AirGuard team built the "Big Smoke" product model to solve the remaining problems.

Step 2: Idea

Using IoT (Internet of Things) technology, the product can locate and monitor areas where toxic smoke frequently appears. The web server can record these areas and provide air quality alerts within the school, enabling the administration to identify zones where students smoke and warn about harmful air quality. This helps provide information about smoking-prone areas and alerts students about hazardous air conditions.

The device includes the following functionalities, implemented by specific hardware components:

+ Air composition Analysis and Smoke Detection

- Sensors (MQ136, MQ135, MQ2, DHT11, and ZH03B): Measure air quality and detect harmful components such as toxic smoke and fine dust particles.

+ Smoke Extraction, Filtration, Disinfection, and Deodorization

- Exhaust Fan: Draws toxic smoke into the system.

- Air Filter: Purifies the smoke using internal filtration.

- Essential Oil Diffuser: Releases essential oils to neutralize odors in the surrounding area.

+ Data Storage and Localization

- GPS Module: Logs locations where toxic smoke frequently appears.

- ESP32 Board: Tracks and patrols these areas by sending data to the web server.

- Lidar Sensor: Measures distances and detects obstacles around the device.

+ Real-Time Monitoring via Camera
  - OV7670 Camera: Captures images for monitoring.
  - Web Accessibility: Provides live camera feeds through the web server.
+ Fire Detection and Alerts
  - Infrared Camera (AMG8833): Detects abnormally high temperatures to identify potential fire hazards.
  - ESP32 Board: Sends immediate alerts to the web server for safety measures.
  - MQ2 and MQ7 Sensors: Detect flammable gases and toxic substances.
  - SMS Alerts: Sends text notifications to the administrator.
+ Nearby Area Sanitization
  - UV Light: Disinfects the surrounding area

Products are designed to serve key audiences

1. For schools:
   - The product assists teachers in identifying areas where students may smoke and places with poor air quality, enabling them to apply appropriate measures to improve the learning environment.
2. For students:
   - The product provides warning information about areas with poor air, helping students recognize and stay away from areas with air harmful to their health.
3. For families:
   - The product helps family members monitor indoor air quality, and detect toxic smoke and other pollutants to provide timely warnings. This helps protect the health of everyone, especially children and the elderly, who are vulnerable to poor air quality.

- ○ In addition, the product can detect signs of fire and explosion and send an immediate warning so the family can handle it promptly, ensuring safety for the whole house.

Step 3: Technology solutions

To realize ideas into actual product models, proposed technological solutions include 3D design models of circuits and products, general block diagrams of the system, flow charts, mathematics, and operating principles of the device.

- ***3D design model for product***
  - Material:
    - Frame: shaped aluminum
    - Formex
    - Plastic
  - Specifications:
    - Length: 300mm
    - Width: 300mm
    - Height: 250mm
    - Wheel diameter: 90mm

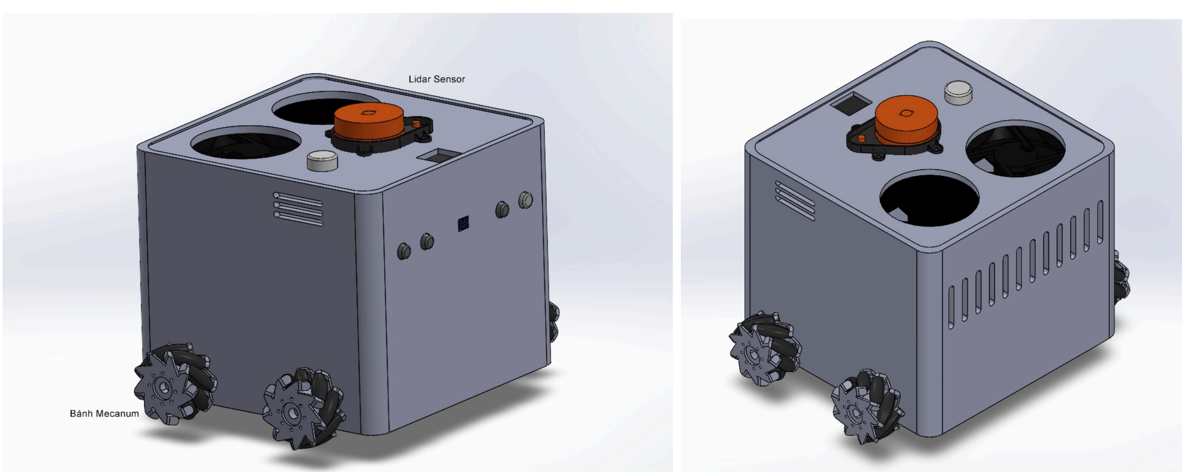


Figure 1: General model

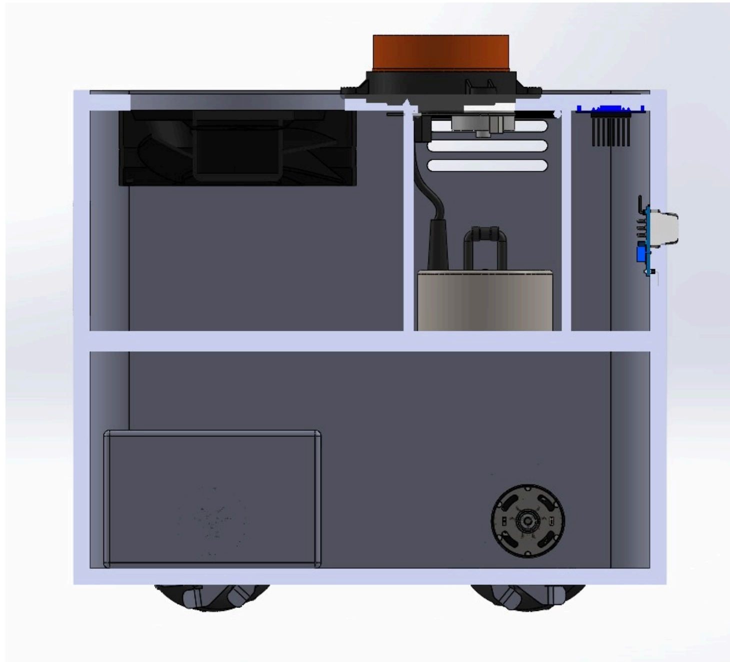


Figure 2: Longitudinal section of the robot

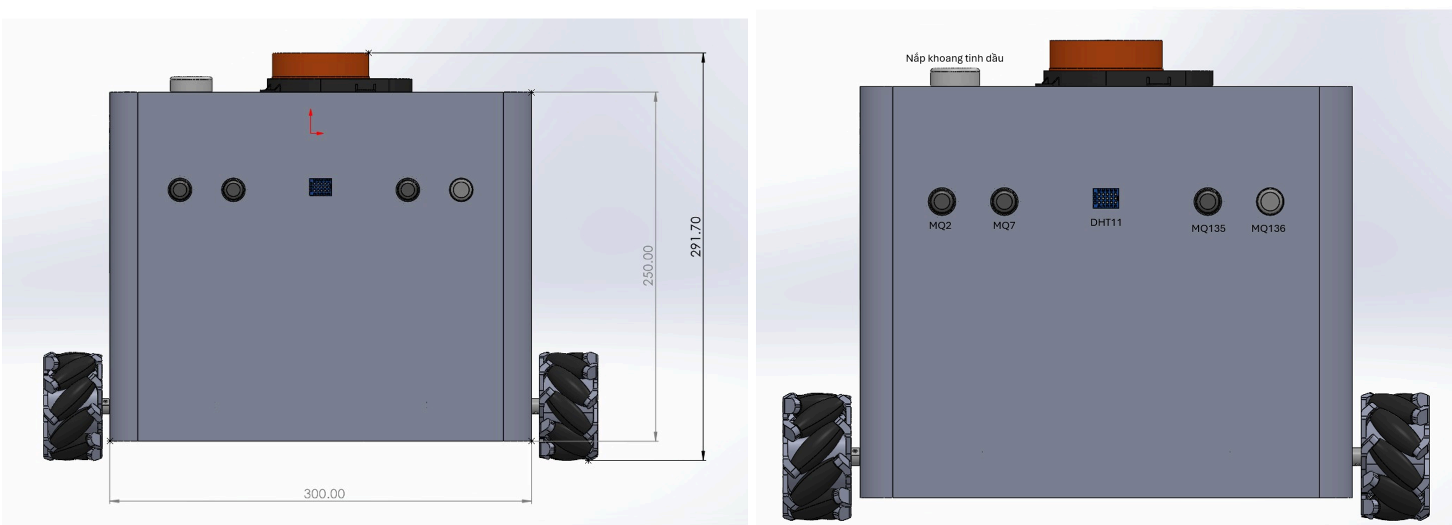


Figure 3: Front view of the robot

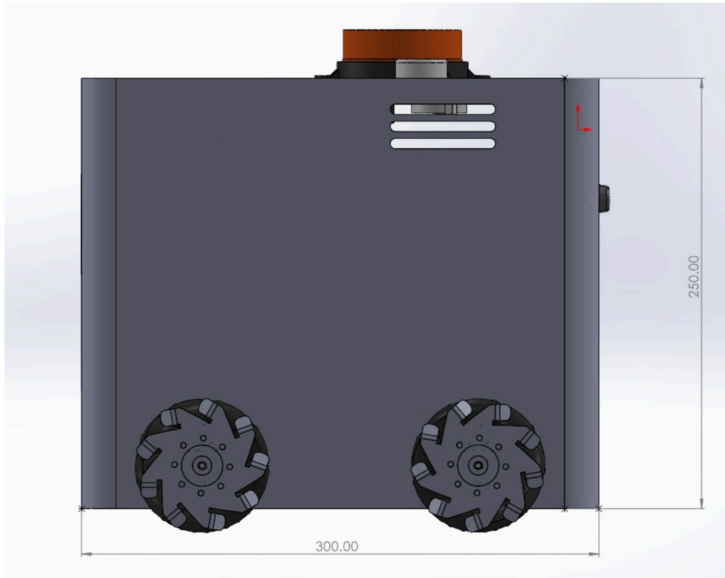


Figure 4: Robot side view

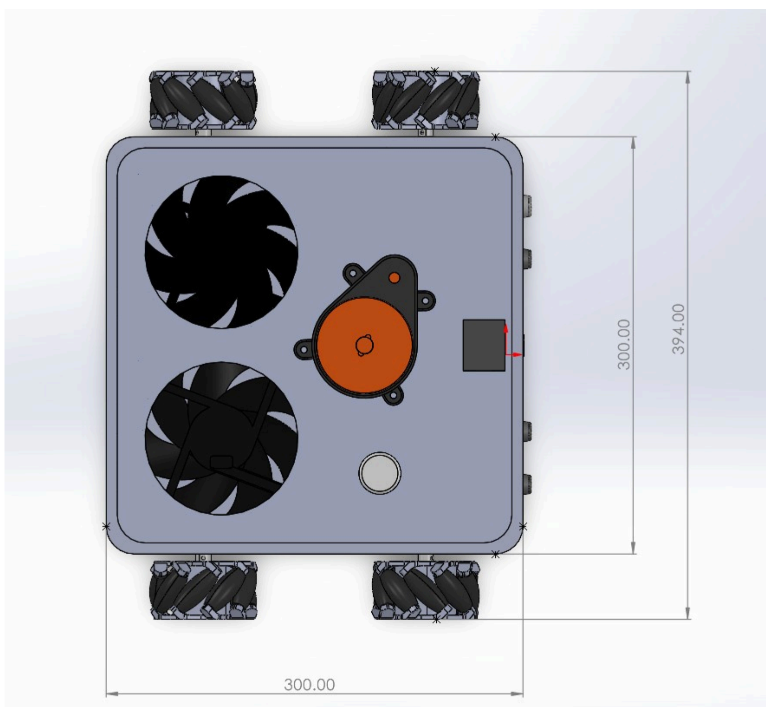


Figure 5: Robot lid

- ***3D circuit simulation of the device:***

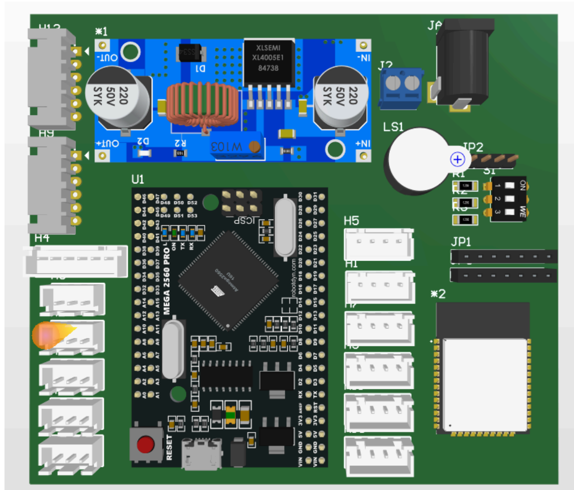


Figure 6: 3D circuit simulation of the device

- ***System block diagram of the device:***

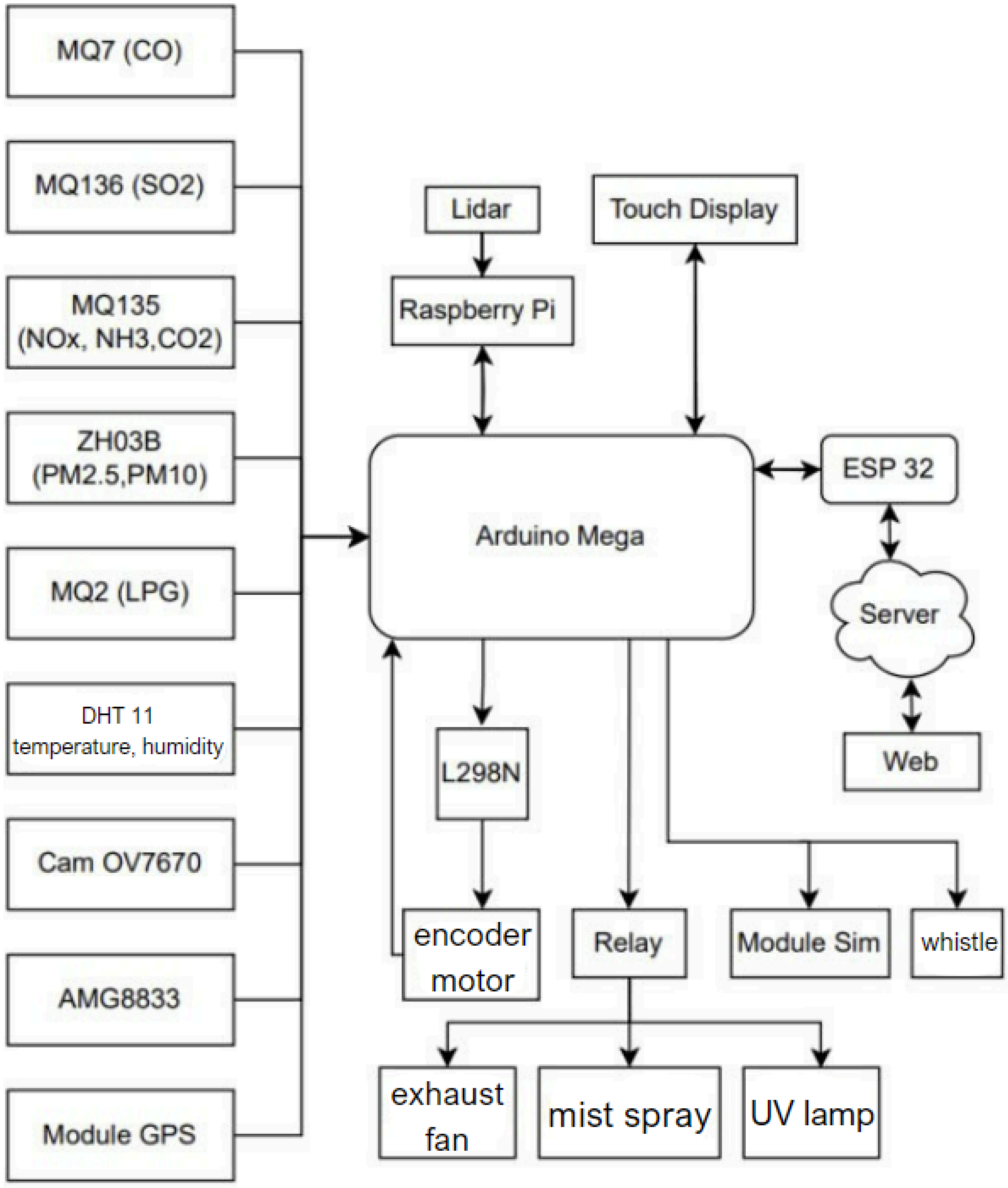


Figure 7: System block diagram of the device

- **Flow chart of the moving part algorithm of the device:**

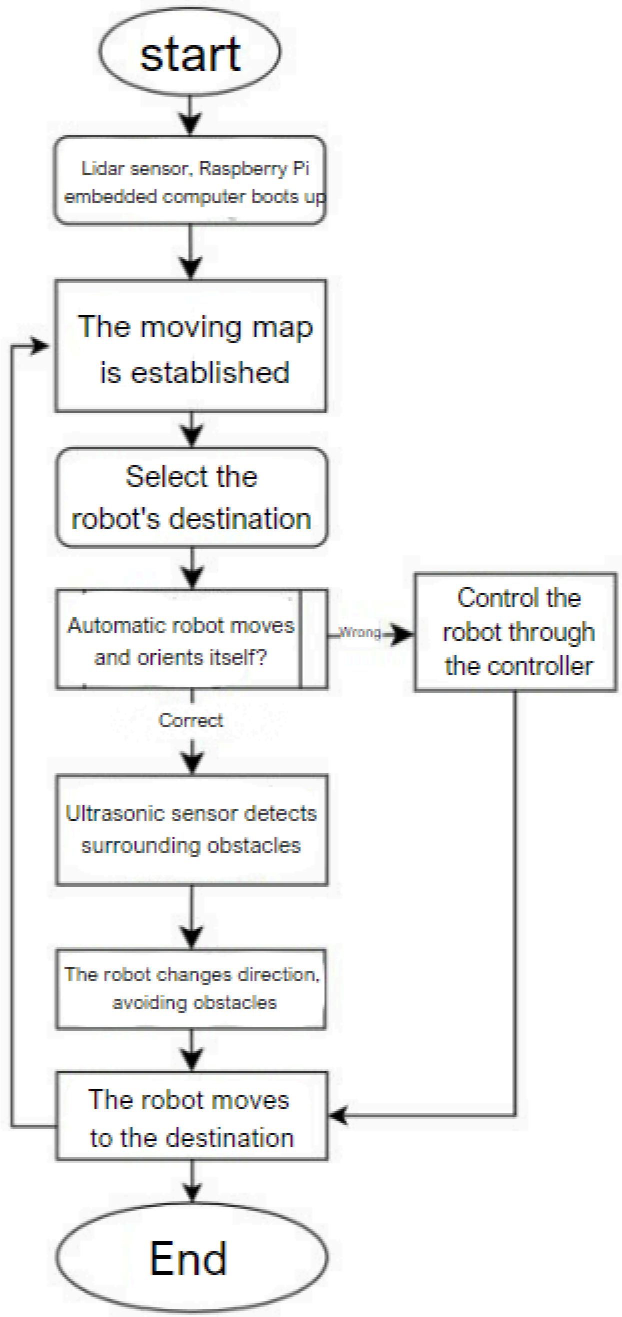


Figure 8: Flow chart of the moving part algorithm of the device

- **Flow chart of the device's control algorithm:**

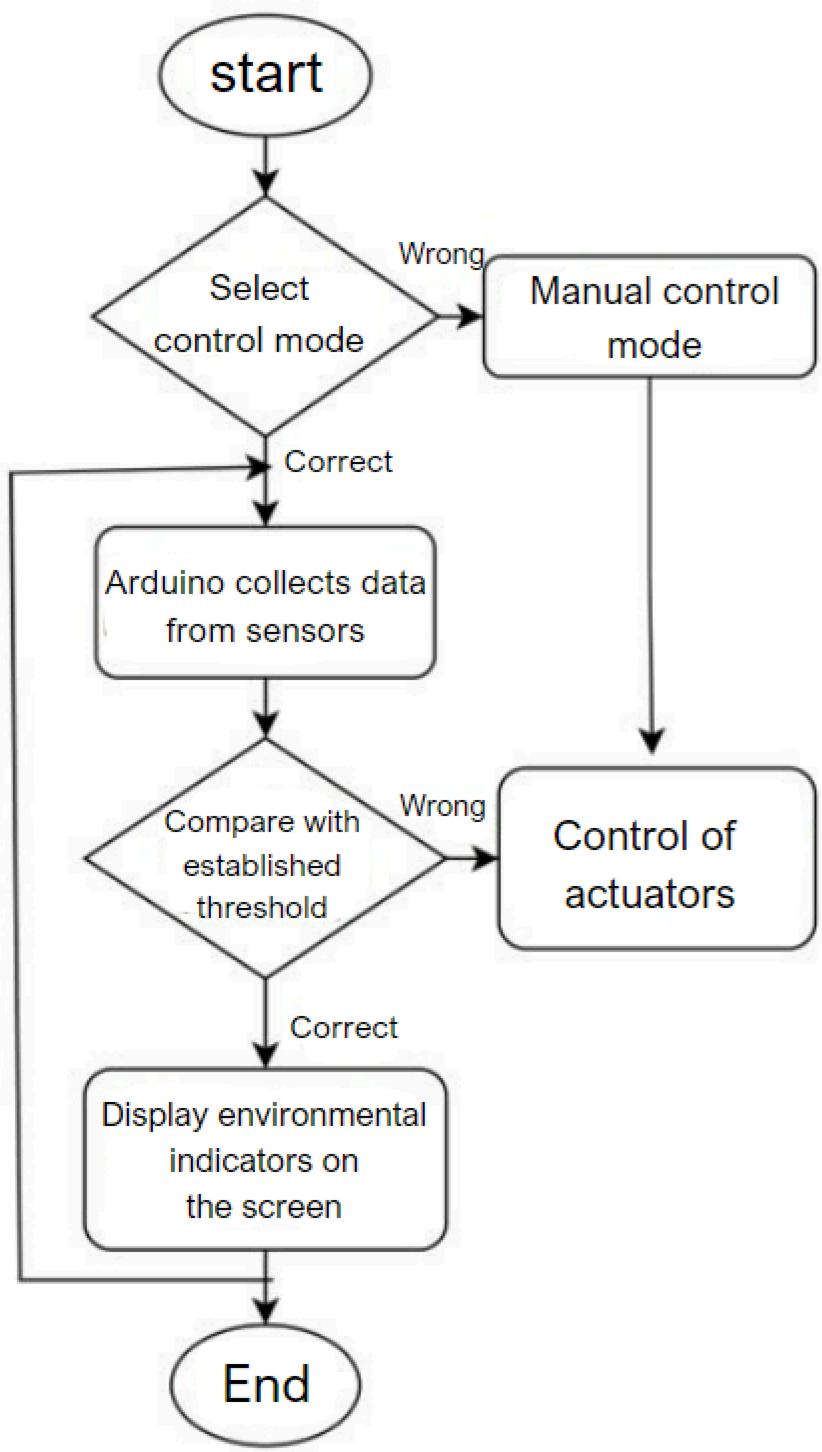


Figure 9: Flow chart of the device's control algorithm

- **Operating principle of the device**:

+ Measure, warn, handle:
  - When powering the system, the default running mode is Auto mode.
    + In Auto mode, after the system is powered and booted, the Arduino board will read the values of the sensors. The values after being read from the sensor will be sent by the Arduino Nano board to the NodeMCU module to be sent to the server and displayed on the web.
    + Conditions for controlling the exhaust fan and mist sprayer to operate automatically. Specifically :
      - When detecting toxic smoke or dust concentration exceeding the safe threshold (>45 µg/m3), the machine will start the exhaust fan to filter the air, turning off when the dust concentration is within the safe threshold (<30 µg/m3)
      - When the CO concentration exceeds the safety threshold (>30 ppm/m3), the machine will automatically warn, and turn on the air filtering function, the CO gas will be filtered through the activated carbon membrane, otherwise, the CO concentration in the air will be low. The machine will stop filtering air within the safety threshold (< 10 ppm/m3).
      - Gas concentration (> 15%) the machine will automatically warn.
  - Gas concentration (> 15%) the machine will automatically warn. In addition, during operation, the system can be switched to Manual mode via the push of a button: In this mode, the system reads the sensor, displays it on the screen, and sends it to NodeMCU for transmission to the website. The air filters and mist sprayers do not operate automatically but are turned on via a push-button system during a preset time.

+ Movement:
  - Use the server as a laptop to process the signal.
  - Raspberry Pi acts as an intermediary device connecting the robot's moving parts to the server, which is a laptop connected to the Raspberry Pi via Raspi's wifi using the SSH command to remotely control the Raspberry Pi.

- Raspberry Pi communicates 2-way with the Arduino mega board via uart to transmit velocity commands from the server to the Arduino and the Arduino will process the signal and output appropriate voltage levels to the h-bridge to control the motor. The motor responds to the signal from the encoder signal pin to the Arduino and sends it to the Raspberry for transmission to the server to calculate and determine the robot's position on the map.
- The lidar sensor communicates Uart with Raspberry to transmit RAW signals (angle and distance) to the server via the embedded Raspberry computer and releases signals to determine the direction and position of the robot. Most of the processing steps are on the server, which is a laptop because the Raspberry Pi is quite weak.

CONCLUSION

Air pollution in Hanoi, especially from construction activities, has become a serious issue, affecting public health and the environment. The harmful pollutants released by construction sites significantly degrade air quality, leading to respiratory issues and obstructing the visibility of celestial phenomena.

The "Toxic Dust Detection and Odor Neutralization Robot" provides an innovative solution to this problem. Equipped with IoT and AI technologies, this autonomous robot can detect and filter pollutants in real time, particularly in high-pollution areas like construction sites. Its mobility ensures efficient air purification and improved air quality across the city.

By reducing air pollution and improving visibility, this project has the potential to enhance public health and restore the enjoyment of astronomical events. The robot offers a promising model for addressing air pollution in Hanoi and could be expanded to other urban areas facing similar challenges.

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