BIG SMOKE - CIGARETTE SMOKE DETECTION AND ODOR NEUTRALIZATION ROBOT

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ABSTRACT

The increasing prevalence of electronic cigarette usage among Vietnamese students poses a significant public health concern. Recent data indicate that the rate of electronic cigarette use among students aged 15-17 rose from 2.6% in 2019 to 3.5% among students aged 13-15 by 2022, highlighting a troubling trend [1]. Research shows that cigarette smoke contains harmful substances like Butadiene, Arsenic, Benzene, and Cadmium, which adversely impact respiratory health [3]. Carbon monoxide emissions and other flammable gases also exacerbate environmental hazards [5]. A study by U.S. researchers underscores the importance of advanced air filtration and monitoring technologies in combating tobacco-related hazards in public spaces (Smith et al., 2020).

Despite existing measures, such as awareness campaigns and stationary air purifiers, these interventions remain limited in scope and efficiency [6]. This study introduces the "Big Smoke" project, a robotic solution utilizing IoT and AI technologies to autonomously detect, filter, and deodorize tobacco 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.

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

INTRODUCTION

Electronic cigarette use among students is a rising global concern. In Vietnam, the rate of usage increased from 2.6% in 2019 to 3.5% by 2022, according to Associate Professor Dr. Luong Ngoc Khue. This mirrors international trends, with similar findings reported in a 2018 study by the Centers for Disease Control and Prevention (CDC) indicating a 78% increase in e-cigarette usage among U.S. high school students between 2017 and 2018 (CDC, 2019). Tobacco smoke contains numerous toxic chemicals, such as Benzene and Arsenic, which significantly harm human health. Furthermore, environmental pollutants, including carbon monoxide and flammable gases, amplify risks for respiratory and safety hazards.

Existing solutions in schools, including awareness campaigns and manual monitoring, face challenges due to limited resources and the static nature of air purification systems. A study from Japan highlights the effectiveness of mobile robotic technologies in environmental health monitoring, emphasizing their adaptability in dynamic spaces (Tanaka et al., 2021). The "Big Smoke" project introduces a mobile robotic solution equipped with IoT and AI capabilities in light of these advancements. This robot will autonomously patrol school premises, detect and neutralize tobacco smoke, and provide early warnings for fire and gas-related incidents. Integrating cutting-edge technology, "Big Smoke" offers a novel approach to addressing air quality and safety challenges, contributing to a healthier school environment.

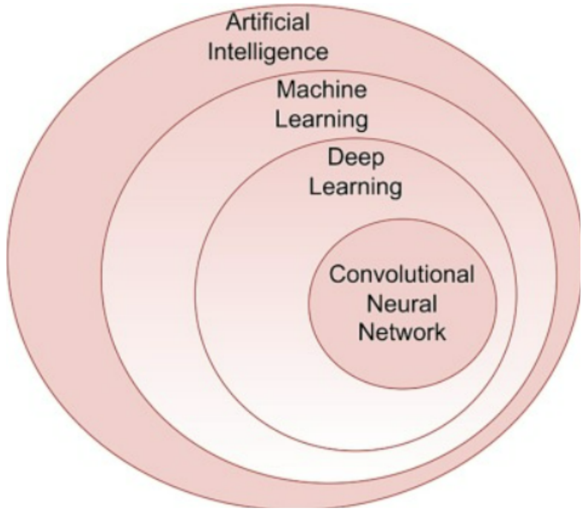
THEORETICAL BASIS

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 cigarette 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 cigarette 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 cigarette 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 cigarette 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 cigarette smoke and fine dust particles.

+ Smoke Extraction, Filtration, Disinfection, and Deodorization

- Exhaust Fan: Draws cigarette 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 cigarette 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 cigarette 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

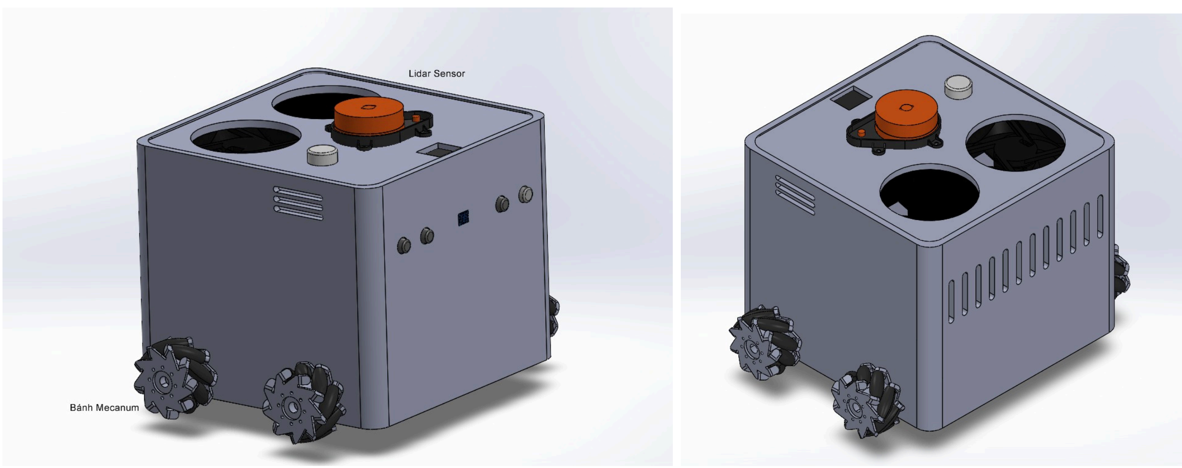


Figure 1: General model

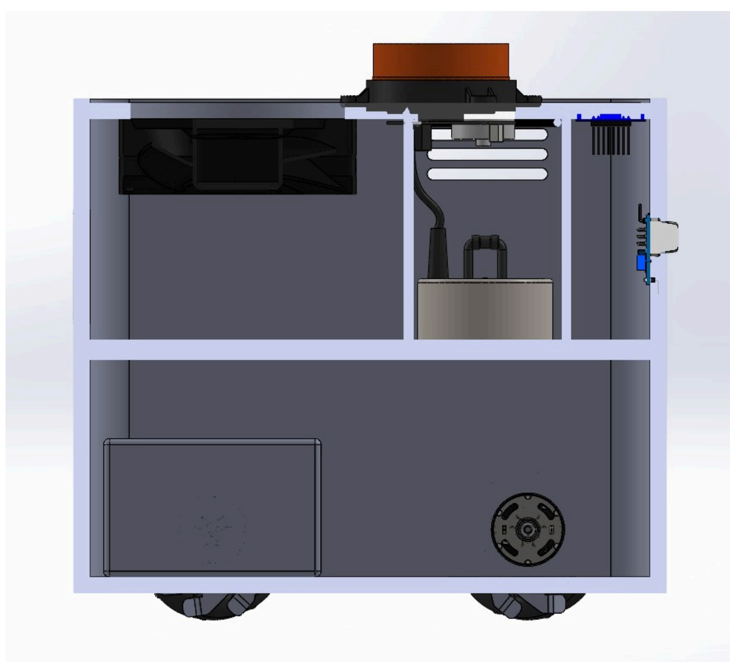


Figure 2: Longitudinal section of the robot

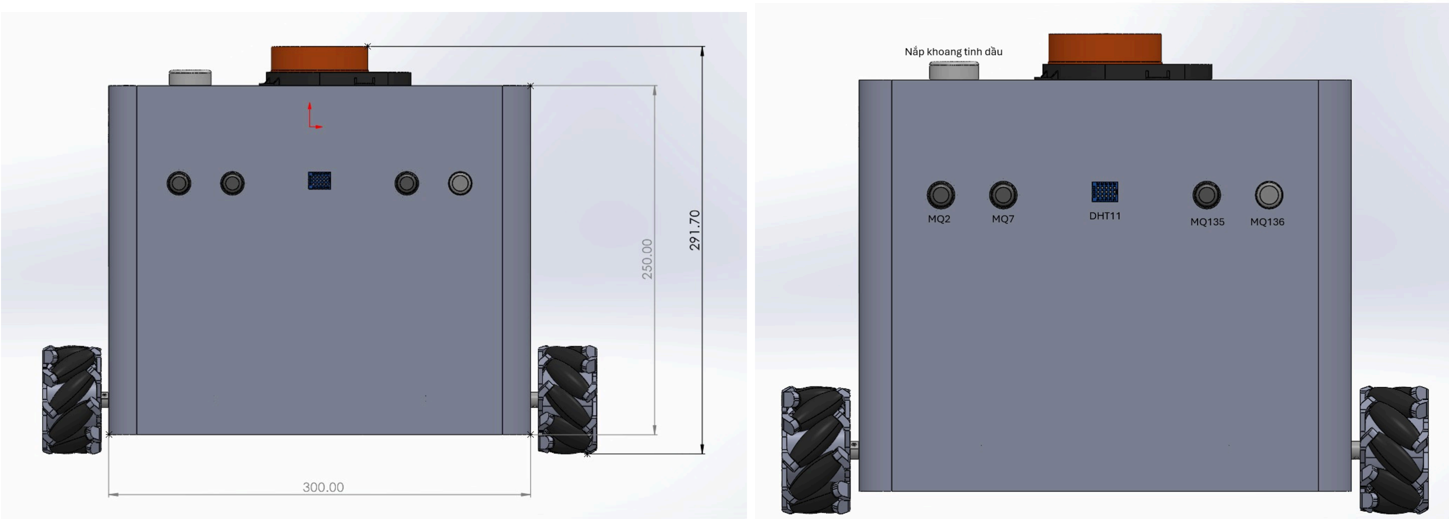


Figure 3: Front view of the robot

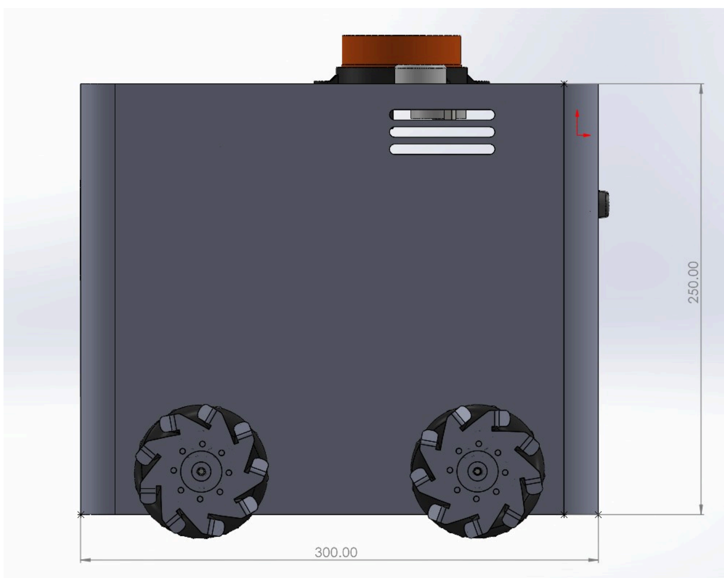


Figure 4: Robot side view

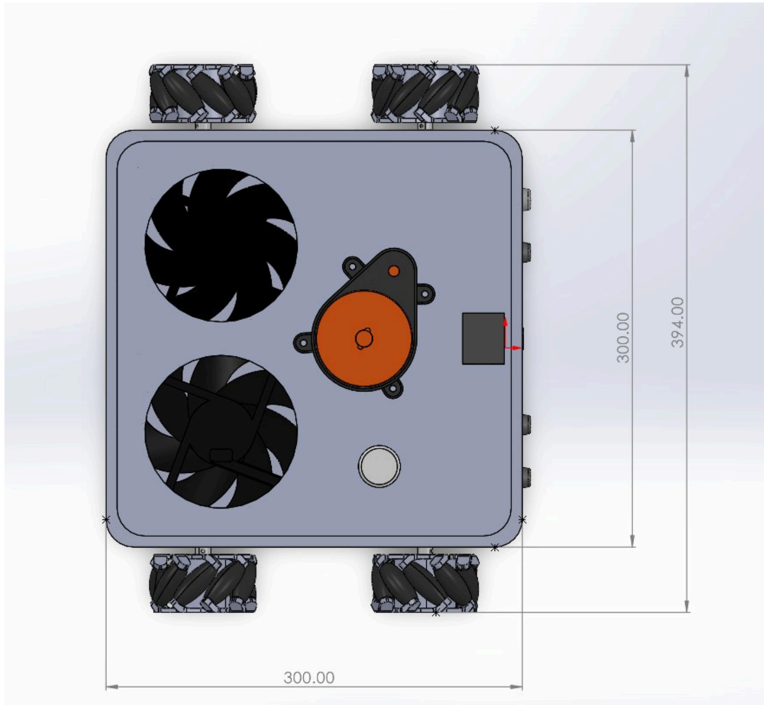


Figure 5: Robot lid

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

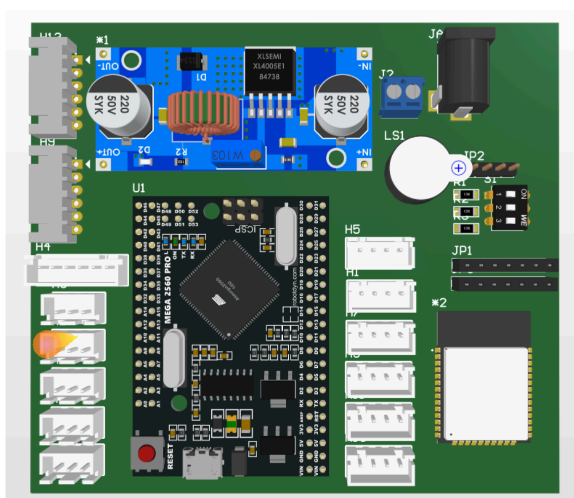


Figure 6: 3D circuit simulation of the device

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

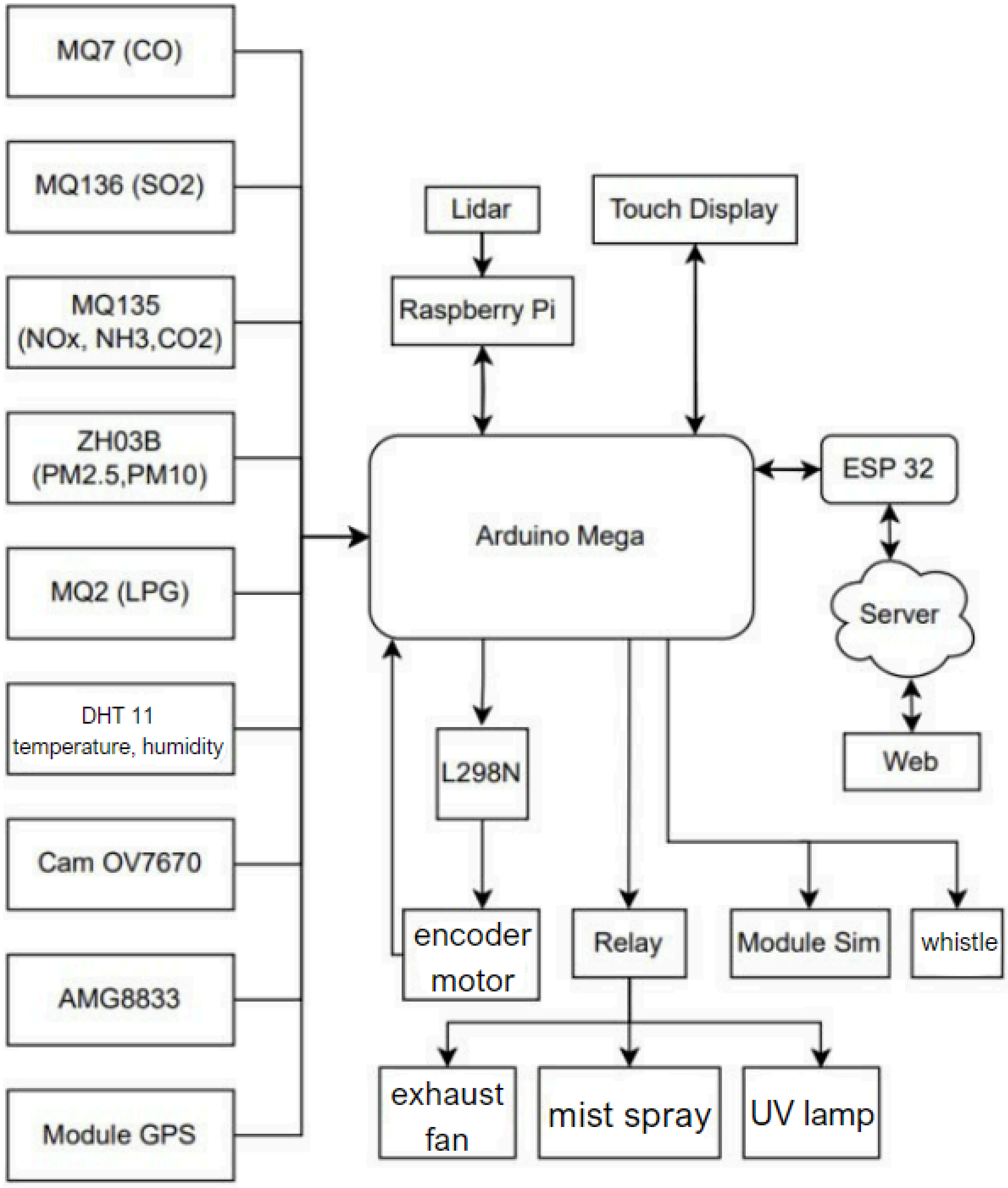


Figure 7: System block diagram of the device

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

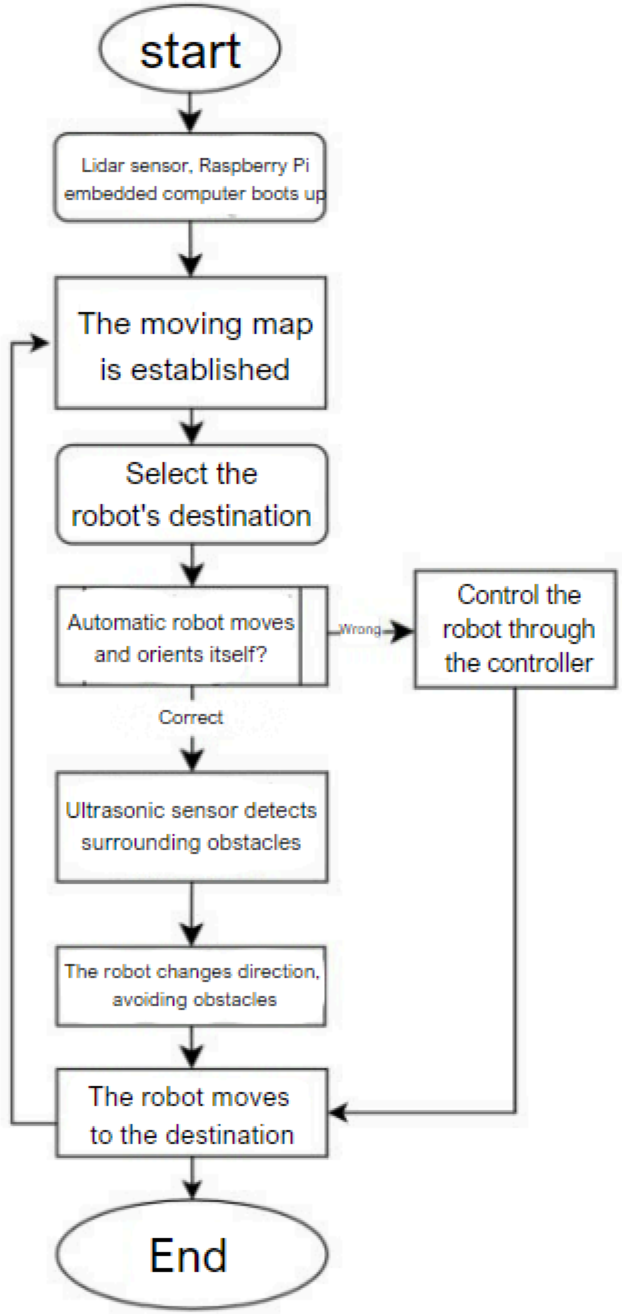


Figure 8: Flow chart of the moving part algorithm of the device

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

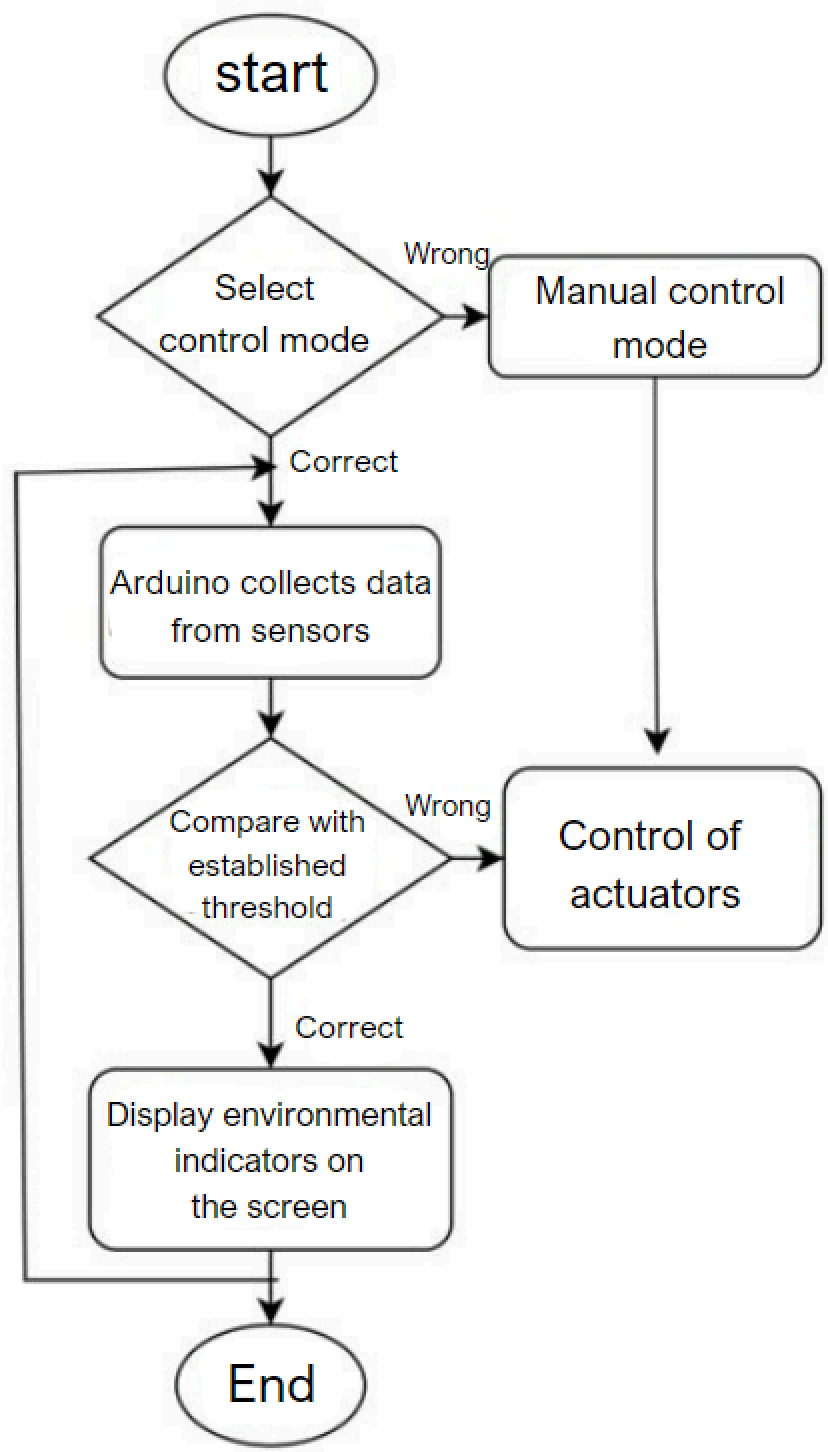


Figure 9: Flow chart of the device's control algorithm

- **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 cigarette 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

The growing prevalence of electronic cigarette use among students, both in Vietnam and globally, poses significant health and environmental risks. Toxic chemicals like benzene, arsenic, and carbon monoxide exacerbate respiratory and safety hazards, highlighting the urgent need for innovative solutions. Current efforts, such as awareness campaigns and manual monitoring, face limitations due to resource constraints and static technologies.

The "Big Smoke" project addresses these challenges through a cutting-edge mobile robotic system equipped with IoT and AI capabilities. By autonomously patrolling school premises, detecting and neutralizing cigarette smoke, and issuing early warnings for fire and gas-related threats, this solution bridges critical gaps in traditional air quality management systems. Inspired by advancements in robotic environmental health monitoring, the project provides a dynamic, adaptable approach to ensuring healthier and safer school environments.

With its ability to integrate real-time detection, response, and odor neutralization, "Big Smoke" demonstrates the potential of technology to create sustainable and proactive strategies for addressing air quality concerns. This research serves as a foundation for future innovations in environmental health monitoring and contributes to the collective effort to mitigate the health risks posed by tobacco products in educational settings.

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