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AI-Based IoT Gas Leakage and Fire Detection

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Abstract

Gas leakage, fire incidents, and abnormal envi-ronmental conditions create safety risks in homes, laborato-ries, workshops, and industrial settings. This paper presents RiskSense, an ESP32-based Internet of Things (IoT) prototype designed to monitor gas-sensitive readings, flame status, tempera-ture, and humidity. The prototype combines an MQ-2 gas sensor, a digital flame sensor, and a DHT11 sensor with local indicators, a buzzer, a motor driver, and the Blynk IoT platform. Sensor readings are processed using configurable thresholdbased logic for local alarms, while status values and alerts can be viewed remotely through a Wi-Fi-connected dashboard. An artificial intelligence (AI) layer based on a Random Forest classifier is implemented to classify the monitored conditions into NORMAL, WARNING, and CRITICAL risk categories. Isolation Forest for unusual sensor-pattern detection is proposed as future work. The paper describes the system architecture, hardware and software design, control logic, the Random Forest algorithm used, implementation methodology, validation plan, limitations, and future work. Since measured experimental results and numerical model-evaluation metrics have not been provided, no numerical performance claims are made.

Keywords : *s*Internet of Things, ESP32, MQ-2, flame detec-tion, DHT11, gas leakage, fire detection, environmental monitor-ing, Blynk, Random Forest, machine learning.

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I. Introduction

Injury, damage to property and environmental harm can result from gas leakage, fire, and high temperature. Therefore, early detection of abnormal conditions is crucial in residential, lab, workshop or industrial settings. Typical low-cost mon-itoring solutions are based on single sensors or thresholds. These systems are helpful for simple warning but can provide only a limited degree of remote monitoring and very little assistance in viewing trends and combinations of changing sensor measurements.

The RiskSense prototype integrates several sensing mod-ules, an ESP32 microcontroller, and a dashboard in the cloud. The ESP32 reads analog output from MQ-2, digital output of flamesensor and temperature & humidity data from DHT11. Looks at available readings and compares with set conditions and controls LEDs, buzzer and motor-driver output. Blynk is a way to view sensor values, and operating status, remotely.

The project also offers risk assessment based on data. The AI algorithm employed for classification of sensor observa-tions is a Random Forest classifier, which is divided into 3 risk classes: NORMAL, WARNING and CRITICAL. The rules for independent local alarms are still kept and Isolation Forestbased anomaly detection is proposed as an enhancement. This paper makes the following contributions: (1) A low cost multi-sensor IoT prototype is described; (2) Sensors, processing, alerting and dashboard layers of the prototype are documented; (3) Control rules are specified and a functional validation plan is documented; (4) A Random Forest classifier is implemented for AI-based risk classification, while keeping the local alarms independent.

II. Problem Statement

A monitoring system which tracks only one environmental condition can give incomplete information on a developing hazard. It can also be difficult to check the sensor readings and the status of the system at a single point when there are separate devices. The needs the project meets are the following:

RiskSense meets these needs by integrating sensors, pro-cessing using ESP32, communicating via the RiskSense dash-board (Blynk application), output control, and a Random Forest risk-classifier.

III. Literature Review

Various IoT systems designed for gas leak detection have been published. Jumaa *et al.* describe a gas leak alarming system that uses the Blynk platform [7]. Similarly, Aman *et al.* constructed an MQ-6 sensor and NodeMCU (ESP8266) that combines it with a relay based exhaust fan which decreases the concentration of gas. An application sends the message in

TABLE I

Summary of Related Research

Author / Year	Methodology Used	Key Findings	Limitations
Salhi *et al.* [10], 2019	Machine learning for early detection of gas leakage and fire in a smart home.	Proposes an early detection system for gas leakage and fire.	Targets smart-home environments.

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Ralevski and Risteska Stojkoska [9], 2019	Low-cost IoT system measuring tem-perature and gas concentration; moving-average time-series forecasting to reduce transmitted packets.	Enables early detection of house fire and gas leaks in smart kitchens.	Evaluated in a simulated kitchen sce-nario.
Gusdevi *etal.* [8], 2020	LPG leakage detector prototype using a flame sensor and an MQ-2 sensor.	Combines gas sensing and flame sensing in one prototype.	Focuses on LPG leakage.
Jumaa *et al.* [7], 2022	Gas leakage detection and alarming us-ing the Blynk platform.	Provides gas leakage detection with alarms through Blynk.	Focuses on gas leakage only.
Aman *et al.* [6], 2022	MQ-6 sensor, NodeMCU (ESP8266), relay-controlled exhaust fan and app no-tification.	Reduces gas concentration through the exhaust fan while sending alerts.	Focuses on LPG leakage and ventilation.
Tsoukas *etal.* [5], 2023	TinyML on a microcontroller with BLE smartphone alerts and an integrated screen.	F1-score of 0.77 (smoke) and 0.70 (am-monia).	Evaluated on two test cases only.
Kumar *et al.* [4], 2024	IoT-HGDS: six MOS gas-sensor arrays, DHT22, AWS-IoT platform and ma-chine learning.	Handles false fire alarms and detects VOCs, gases and odors.	Designed for smart-kitchen settings.
El Barkani *et al.* [3], 2024	MLX90640 thermal camera with Mo-bileNetV1 and EfficientNet-B0 on an Arduino Nano 33 BLE Sense.	Accuracy of 88.92% and 91.73%; infer-ence time of 1414 ms.	Relies on thermal-camera imaging in-stead of gas-sensor readings.
Ladeira and Silva [2], 2025	Machine-learning decision-support sys-tem on the RuraLTHINGS IoT ecosys-tem.	Predicted future trends of indoor hazardous-gas data.	Aimed at monitoring in rural and remote areas.
Pawar *et al.* [1], 2026	NodeMCU, MQ- sensor and GSM module. 2	Automated gas leakage detection, safety monitoring and remote alerts.	Focuses on gas leakage in kitchens.

one instance [6]. Another smart kitchen system was presented by Pawar *et al.* using NodeMCU, MQ-2 sensor and GSM for gas leakage detection [1]. There are instances when gas sensing technology was used with fire detection technology. For example, Gusdevi *et al.* created a prototype of LPG leakage detector that makes use of fire sensor along with MQ-2 [8]. Ralevski and Risteska Stojkoska proposed a cost-effective IoT system that ensures quick fire outbreak and detection of gas leaks in kitchens based on indicator of temperature and level of gas concentration. There are numerous online systems that have been studied so far, which are basically only gas leakage detectors only having a specific place of action

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such as kitchen or a different sensor than used in this research. One of the systems RiskSense using MQ-2 gas sensors along with digital flame sensor and DHT11 is operated on ESP32 board and equipped with the local alarms in consideration with threshold values, Blynk dashboard and a random forest classifier making it capable of categorizing the risk into normal, warning and critical.

In general, the systems that were investigated only monitor gas leakage, are suited for a specific location such as the kitchen, or make use of different sensors and systems com-pared to the one discussed here. However, RiskSense employs the MQ-2 gas sensor, a flame sensor, the DHT11 sensor, and an ESP32 with threshold-based local alarms, the Blynk system, and the Random Forest algorithm for classifying the events as NORMAL, WARNING, or CRITICAL while the warnings remain local.

IV. Objectives

The key aim is to create a budget-friendly IoT system based on ESP32 that will identify gas leaks, recognize fire and high temperature and rank the monitored states by levels of risk with the help of breakthrough machine learning technology. The goals include:

1) To design IoT prototype with a multitude of sensors to monitor gas-sensitive readings, flame, temperature and humidity using the MQ-2 gas sensor, digital flame sensor and DHT11 sensor attached to the ESP32.
2) To ensure that a configurable threshold-based control logic that would activate the local LED and buzzer as well as the motor driver output in case of danger in conditions is used.
3) To guarantee that remote monitoring of sensor readings, system conditions and alarm notifications would be made possible through Blynk IoT dashboard with the help of Wi-Fi.
4) To use Random Forest classifier for the purpose of classi-fying the monitored conditions as NORMAL, WARNING and CRITICAL with the local alarms still functioning independently from the classifier in question.
5) To develop a plan for functional validation and a means of collecting historical data and pattern analysis in the future with the use of Isolation Forest anomaly detection.

V. Background and Related Technology

A. Air Quality Monitoring

The Internet of Things (IoT) system is a mix of physical sensors, embedded controllers, communication networks and user applications. The ESP32 is used as the processing and communication device in this prototype. Blynk offers the dashboard layer to show readings and selected status values. As a result of cloud connectivity, there is enhanced visibility of all events when working remotely, but if the network is not available, local warning logic should be kept in place.

B. Sensor-Based Detection

The MQ-2 module generates an analog output signal which varies according to its sensitivity to some combustible gases and smokerelated parameters. The value that the ESP32 reads is an analogto-digital converter (ADC) number, and not a measured concentration in parts per million. A Digital Flame module shows whether the output of detection is active or not and the actual polarity is to be checked with the

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specific module. The DHT11 is designed to measure temperature and relative-humidity; it has a lower accuracy and response speed than more sophisticated sensors.

C. AI for Risk Assessment

Machine learning can use sensor measurements and trends to detect patterns which are not easy to model using a single threshold. In this work, observations are classified as either NORMAL, WARNING or CRITICAL using a Random Forest classifier [13]. In the future, Isolation Forest can be used as an additional technique for identifying unusual combinations of readings and be evaluated. These algorithms need represen-tative and labelled data, testing, and validation prior to use in a safety application.

VI. Research Methodology

A. Study Design

Here the authors' design of an educational hardware pro-totype equipped with a risk classifier implemented using the Random Forest algorithm and a structured validation plan are described. The components, connections, thresholds, Blynk datastreams and intended control behavior is defined by the source project specification. Physical Perhaps you can help clarify what these terms mean. Maybe you can explain what these terms mean to me. Blynk IoT Remote dashboard and configured event notifications test results and numerical model-evaluation metrics are not provided, and the paper makes a distinction between specified behavior and results that have to be measured.

B. System Layers

The architecture has five layers. The sensor layer collects gas, flame, temperature and humidity data. The processing layer is used to read the states of the sensors and cross-check the state with the configured thresholds. The response layer is used to control the LEDs, buzzer and motor driver. The reading and status information are published by the IoT layer

TABLE II

Principal Hardware and Platform Components

Component	Role in the prototype
ESP32 DevKit V1	Sensor processing, control logic, Wi-Fi communication
MQ-2 gas sensor	Analog gas-sensitive reading
Digital flame sensor	Flame-status input
DHT11	Temperature and humidity measurement
Red/green LEDs and buzzer	Local visual and audible indication
L298N and 12 V DC motor	Motor output controlled by programmed logic
Blynk IoT	Remote dashboard and configured event notifications

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TABLE III

SPECIFIED THRESHOLD-BASED OUTPUT BEHAVIOR

G	F	T	Status	Red	Green	Buzzer	Motor
No	No	No	NORMAL	OFF	ON	OFF	OFF
Yes	No	No	CRITICAL	ON	OFF	ON	ON
No	Yes	No	CRITICAL	ON	OFF	ON	ON
No	No	Yes	WARNING	ON	OFF	OFF	ON
Any danger	—	Any	CRITICAL	ON	OFF	ON	ON

to Blynk. The AI layer applies a Random Forest classifier to the data collected by the sensors and provides a risk category (NORMAL, WARNING, or CRITICAL). Proposed extension of this layer is the anomaly indication using the method of Isolation Forest.

C. Software and Tools

The architecture has five layers. The sensor layer collects gas, flame, temperature and humidity data. The processing layer is used to read the states of the sensors and cross-check the state with the configured thresholds. The response layer is used to control the LEDs, buzzer and motor driver. The reading and status information are published by the IoT layer to Blynk. The AI layer applies a Random Forest classifier to the data collected by the sensors and provides a risk category (NORMAL, WARNING, or CRITICAL). Proposed extension of this layer is the anomaly indication using the method of Isolation Forest.

VII. SYSTEM ARCHITECTURE

The sensing and processing process starts when ESP32 initializes its GPIO pins, DHT11 interface, Wi-Fi and Blynk connection. It then reads the sensors, checks the gas threshold, checks for flame and checks for valid temperature readings. The resulting state controls local indicators and the motor re-quest. Values and status variables from the sensor are uploaded to the dashboard, and when sensors' monitored conditions change from inactive to active, configured Blynk events are triggered. The threshold-based status is combined with an AI-derived risk category provided by the Random Forest classifier from the sensors measurements.

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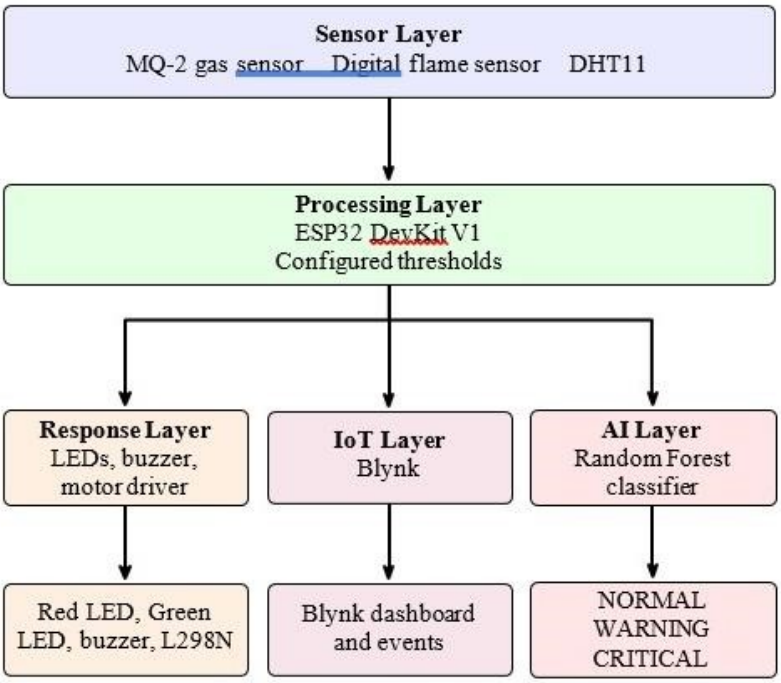


Fig. 1. RiskSense five-layer system architecture.

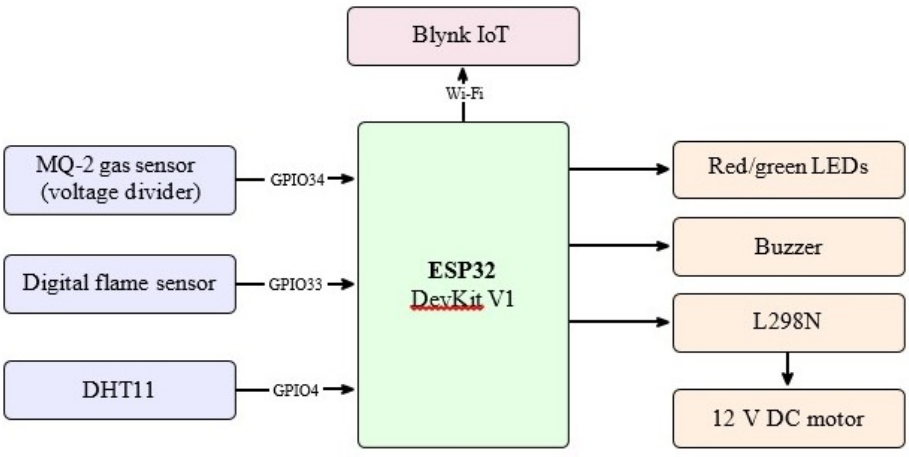


Fig. 2. RiskSense hardware connections.

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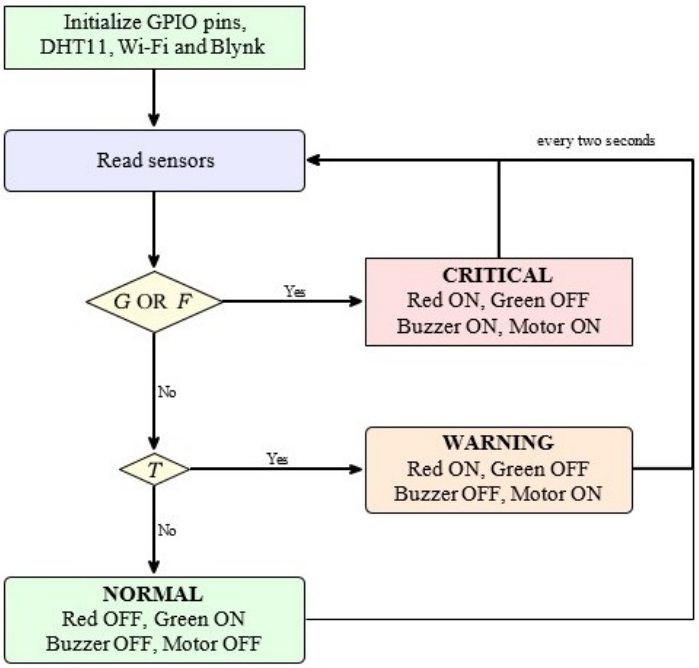


Fig. 3. RiskSense local control-logic flowchart.

A. Sensor Layer

Using a voltage divider, the analog output of the MQ-2 is connected to GPIO34. DHT11 data pin is attached to GPIO4, digital output from the flame sensor is attached to GPIO33. Before powering the circuit it is important to check the supply voltage and logic compatibility with the actual module specification.

B. Processing Layer

There is a configurable gas threshold (initially set to 750 ADC counts) and a high-temperature threshold of 40 °C in the firmware. The logic contained in the flame-sensor is written for an active-LOW module. The following assumptions should be validated during calibration due to possible variation in sensors and installation conditions.

C. Response and IoT Layers

Red LED and buzzer will trigger for gas danger and/or flame detection. If a high-temperature condition occurs (no gas or flame), the red LED will be on and the buzzer will sound off. Green = normal state. The gas danger signal, flame detection signal or high temperature signal are active, then the motor request is active. Blynk datastreams include the temperature, humidity, raw gas reading, flame condition, safety condition,

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VIII. Control Logic

The control sequence is checked around every two seconds. Assume G to be a gas reading above the programmed reading, F to be a reading of flame detected, and T to be a valid temperature reading of at least 40 °C. The following is a summary of the decision rules used for the local alarms and outputs.

G = (gasValue > gasThreshold), F = (digitalRead(FLAME_PIN) == LOW), T = (valid temperature ≥ 40 °C). Motor request is G OR F OR T . If the DHT11 read fails, the invalid temperature value will not be compared to a high temperature.

The current motor expression does not contain this motor input, but the Blynk V7 datastream is defined as a motor request, manual. It is not considered "in operation" until the firmware is updated to include this manual request and the change is tested.

IX. Blynk Dashboard and Notifications

The Blynk template is set up for the ESP32 hardware and WiFi connectivity. The virtual datastreams it provides are: V0 temperature in °C, V1 humidity in %, V2 gas reading (ADC counts), V3 flame detected (0/1), V4 safety status (NOR-MAL/WARNING/CRITICAL), V5 motor status, V6 alarm status, V7 manual motor request, and V8 gas threshold. Gauges or value displays for temperature and humidity, gas (labelled display/gauge and chart), flame/motor/alarm (LED indicators), switch for V7 and slider for V8 are suggested dashboard widgets.

Gas_alert is given when the gas threshold is crossed, flame_alert is given when the flame detection is reached and high_temp_alert is given when temperature is above 40 °C.

The event identifiers in the firmware have to be identical to the Blynk Console configuration. The event settings should be set so that push notifications are enabled.

X.AI Algorithm Used: Random Forest Classifier

A. Algorithm Overview

The Random Forest classifier is used as an AI algorithm in this project. Random Forest is an ensemble learning ap-proach which constructs numerous decision trees on randomly sampled training data and attributes and aggregates the results through majority voting to decide the classes [13]. By averag-ing over many trees, this helps to avoid over fitting a single decision tree and to enable non-linear combinations of sensor readings to be learned. The classifier is developed with the scikit-learn (sklearn) library [11].

B. Risk Classification

The monitored environmental condition is classified into any of three risk classes by the Random Forest Classifier:

- NORMAL: Sensor readings are safe;
- WARNING: readings mean there is an increased or emerging risk; and
- CRITICAL: readings are an indication of dangerous gas or fire condition.

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As input features, the classifier receives the ADC reading value of the MQ-2, temperature and humidity values, and flame state value. Training records are annotated with a time stamp under controlled and safe test conditions, training data and testing data are separated and the performance on the data that has not been seen is estimated.

XI. Implementation and Validation Plan

There are eight stages for implementation. Prepare the ESP32, sensors, LEDs and buzzer. Second, join the L298N and motor together with care taken to check the power ratings and common ground. Third, upload the firmware for the sensor acquisition, the threshold evaluation, the output control and the Blynk communication. Fourth, set-up datastreams, widgets and event notifications. 5th, Take baseline readings, warm MQ2 up as needed, select test threshold, test flame sensor polarity and DHT11 readings. The sixth is to test each input and each output separately, and then combined-condition tests. 7th, save and label the sensor data from the controlled experiments. Eight, train and test the Random Forest classifier on the labelled data set to get the NORMAL, WARNING and CRITICAL predictions.

XII. Results and Discussion

The design specification is to ensure the expected behavior of a multi-sensor embedded prototype to read the gas sensitive, flame, temperature and humidity input and publish the values that are available to Blynk. With the given control rules, the red LED and buzzer should be triggered upon exceeding the gas limit or when the flames are detected and the motor should be turned on. A high temperature condition with no gas or flame should trigger WARNING and turn on the red LED, and may ask to operate the motor, but should not activate the buzzer. The Random Forest classifier is expected to output one of the three categories, NORMAL, WARNING or CRITICAL, with the corresponding sensor conditions.

These are not results of experiments, but are expected results from the defined logic and model design. Physical hardware tests should be performed and the actual results need to be recorded, including baseline MQ2 readings, threshold set, sensor response, dashboard update, notification delivery, motor response, and the classifier's performance when shown a data set it had not been trained on. The output of the MQ-2 is not a calibrated reading of the gas concentration; it depends on the warm up of the sensor, the kind of gas being read, the environment, and variations in the sensor modules. It should then be determined by experiment and cannot be considered a standard safety limit.

A prototype shows the integration of embedded sensing, visualization of the IoT, programmed output control and machine learning classifier. The usefulness of the Random Forest model will be based on data quality, representative test conditions, false negative analysis and independent evaluation.

XIII. Limitations and Safety Considerations

The threshold of the MQ-2 ADC is not a calibrated gas concentration.

The DHT11 has a relatively low accuracy and response speed.

The performance of flamesensors is dependent on their type, location and field of view and environmental conditions.

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Wi-Fi or cloud connectivity may be lost—local warning logic should not rely on the availability of cloud connectivity.

Set thresholds may lead to false alarms or not detect all hazardous conditions.

The Random Forest classifier relies on the quality, size of training data, may misclassify conditions that have not been seen during training.

In this paper no numerical performance of the classifier is reported.

Isolation Forest anomaly detection is NOT available.

The L298N and the normal DC motor are not suitable for hazardous gas areas.

This educational prototype is not a life-safety device and should not be used in place of approved detectors, fire alarms or life-safety system.

The motor response given is a prototype response only. Powering regular electrical motors in a potentially explosive environment will add ignition possibilities and a qualified safety engineer and suitable equipment will need to be used in a real installation.

XIV. Future Scope

Report accuracy, precision, recall, F1-score and confusion matrix for the Random Forest classifier using the held out data.

Discuss Isolating Forest on sensor anomaly detection. Keep sensor history for trend analysis and model retraining,

with time stamping.

TABLE IV

Functional Validation Plan; Results Require Physical Testing

ID	Test case	Expected behavior	Result
T01	ESP32 startup	Firmware initializes and sets output states	To be recorded
T02	Blynk connection	Dashboard receives updates	To be recorded
T03	Normal gas reading	No gas alarm	To be recorded
T04	Gas above threshold	Red LED, buzzer, motor request activate	To be recorded
T05	Flame detected	CRITICAL status, red LED, buzzer and motor request	To be recorded
T06	Temperature ≥ 40 °C only	WARNING, red LED and motor request; buzzer off	To be recorded
T07	Normal state restored	NORMAL status and motor off if no trigger remains	To be recorded

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T08	DHT11 read failure	Invalid reading is not treated as high temperature	To be recorded
T09	Event transition	New Blynk event is triggered on activation	To be recorded
T10	Random Forest prediction	Model returns NORMAL, WARNING, or CRITICAL consistent with the sensor condition	To be recorded

Show an AI-generated risk score in addition to the sensor and alarm indications.

If there is enough room for the ESP32 and you have the time, explore offline inference.

- Introduce sensor-fault detection and communication-health monitoring.
- Improve calibration and consider more suitable gas and temperature sensors.
- Use secure device communication and appropriate access controls.
- Install the correct size ventilation equipment for actual gashan-dling use.
- Repeat testings and report performance and uncertainty as measured.

XV. Conclusion

RiskSense is a merging of an ESP32 microcontroller, MQ-2 gassensitive sensor, flame detection, DHT11 temp & humidity, local indicators, motor control and Blynk IoT. It has fixed thresholds and digital sensor states and configured abnormal conditions which it identifies and reports sensor readings and condition to remote monitoring. The system offers a hands-on learning environment for embedded sensing, IoT Dashboard integration and automated response logic.

The AI part of the system is implemented using a Random Forest classifier that classifies a risk as NORMAL, WARNING and CRITICAL. The following work should include reports on the measured performance of classifiers with controlled experiments, and explore the potential of using Isolation Forest for anomaly detection. Performance need to be measured, not assumed and independent local alarms need to be maintained. In a real application of fire and gas detection and protection, the equipment used must be certified to detect the fire and gas, while the hardware must be rated to meet the requirements of the application.

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