FlameEye-X:

Predictive Smart Safety Bot for Gas & Fire Prevention

Theme: Home Safety — Autonomous Risk

Prediction Team ID: Safe-250457

Institution: Academy Of Technology

Team Lead: Sumesh Singh

Team Members: 1) Divya Prasad

2) Mayank Sureka

3) Aryan Bhiwaniwala

Contact: sumesh46singh@gmail.com

|+91-9836158725

1. Introduction

1.1 Project Overview:

FlameEye-X is a predictive, low-cost autonomous safety robot designed to detect, predict, and prevent kitchen fire hazards through a multi-sensor fusion system. Unlike conventional detectors that respond only after ignition, FlameEye-X uses **mathematical risk modelling, probability scoring, and Physical AI behaviour** to act before fire occurs.

1.2 Motivation:

India records more than **10,000 fire-related accidents annually**, with gas leaks and cooking negligence being the dominant cause. Existing detectors only beep — they do not take any action to neutralize danger.

1.3 Objectives:

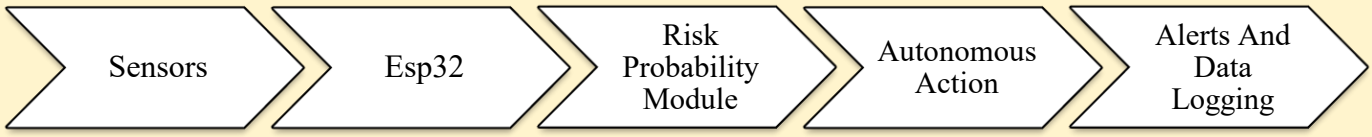
- Develop a robot that predicts hazards, not just detects them.
- Fuse gas, temperature, and IR flame sensor data into a unified decision model.
- Integrate Physical AI for real-world autonomous intervention.
- Achieve response time < 10 seconds.
- Maintain accuracy ≥ 90% with self-learning calibration.

2. System Architecture Overview

2.1 Hardware Components:

Component	Function
ESP32 MCU	Core processing; Wi-Fi alerts
MQ-2 Gas Sensor	LPG/Propane/Methane concentration
DS18B20	Temperature and heating trend
IR Flame Sensor	Direct flame detection
SG90 Servo	Gas valve control
Relay + Fan	Ventilation for mitigation
Buzzer + LEDs	User alerts

2.2 Architecture Block Diagram:



3. Robot Design

3.1 Mechanical Structure:

- Flame sensor elevated at 45° for wider detection angle.
- MQ-2 placed at lower front where gas accumulates.
- DS18B20 placed away from ESP32 heat zones.

3.2 Sensor Arrangement Logic:

- Gas rises slower → MQ-2 placed 3–4 cm below flame sensor.
- Flame sensor placed high to detect early ignition.
- Temperature sensor placed in open airflow for heat rise detection.

3.3 Circuit Overview:

- Servo and relay powered from a 5V source.
- All sensors connected to ESP32 GPIO pins (ADC + 1-Wire + Digital Input).
- Buzzer + RGB LED share ground to indicate system states.

4. Software & Algorithm Design

4.1 Control Flow:

→ Read MQ-2, DS18B20, flame sensor.
→ Normalize all sensor values.
→ Apply mathematical risk probability model.
→ Decide action based on risk level.
→ Log data + update calibration baseline.
→ Trigger user notifications.

4.2 Probability Model (Core Equation):

The equation is:

$$P = \frac{1}{1 + e^{-(\alpha\tilde{C} + \beta\tilde{T}' + \eta I_{pos} + \gamma\tilde{D} - \delta V + b)}}$$

where, $\tilde{C}$ = normalized gas concentration

$\tilde{T}'$ = temperature rise rate

I_{pos} = positive gas × positive temperature interaction

$\tilde{D}$ = exposure duration

V = ventilation index

$\alpha, \beta, \gamma, \delta$ = tuneable weights

b = bias for safe baseline

This logistic regression (Sigmoid function) – based model ensures:

- Nonlinear risk growth.
- Strong interaction between temperature + gas.
- Correct behaviour under noisy kitchen environments.

4.3 Physical AI Behaviour:

Physical AI means,

The robot senses → evaluates → acts physically to modify the environment.

Mode	Risk Probability	Action
Normal	$P < 0.6$	Green LED, monitoring
Pre-emptive	$0.6 \leq P < 0.9$	Turn fan ON, partially close valve
Emergency	$P \geq 0.9$ or flame seen	Close valve, alarm, push notification

4.4 Self-Learning Baseline:

- Calculates rolling mean (μ) and standard deviation (σ) of gas + temp.
- Updates every 60 readings to adapt to different kitchens.
- Reduces false positives during normal cooking.

5. Mathematical Modelling

5.1 Normalization: $\tilde{C} = \frac{C - \mu_{gas}}{\sigma_{gas}}$

5.2 Exposure Duration: $\tilde{D} = \int (\tilde{C} > C_{safe})\ dt$

Longer exposure increases danger, even if the gas decreases temporarily.

5.3 Ventilation Index: $V = \begin{cases} 1 & \text{if Fan On.} \\ 0 & \text{otherwise.} \end{cases}$

6. System Operation Flow

6.1 Real-Time Decision Timeline:

→ **0–2 seconds**: Sensor reading + normalization
→ **2–3 seconds**: Risk model computation
→ **3–5 seconds**: Pre-emptive actuation (if needed)
→ **5–10 seconds**: Emergency mitigation

Total reaction time ≈ **<10 sec (meets requirement)**

7. Performance Report

7.1 Accuracy Testing:

Sensor	Accuracy
MQ-2	±5% after 48h preheat
DS18B20	±0.5°C
Flame Sensor	0.5 s detection delay
Risk Model	<10% error (vs simulated baseline)

8. Pin Configuration

8.1 IR Sensors:

- Ground to Ground
- +5V to +5V
- A0 to D32

8.2 Buzzer:

- +ve to D2
- -ve to –ve

8.3 MQ2 Sensors:

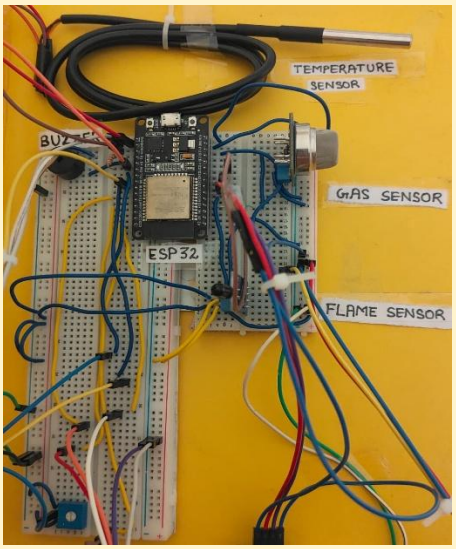
- Ground to Ground
- +ve to +5V
- A0 to Resistor to D34 to ESP32

8.4 Relay:

- IN to D27
- Vcc to 3.3V
- Ground to –ve
- N_0 to Fan(+ve)
- 12V(+ve) to COM
- 12V(-ve) to Fan(-ve)

8.5 DB Sensor:

- DS1820 to D4
- +ve to +ve
- -ve to –ve



8.6 LCD Screen:

- V_{ss}(1) to Ground
- V_{cc}(2) to 5V
- V_{ee}(3) to Potentiometer (mid leg)
- R_s(4) to R_x2
- R/W(5) to Ground
- E(6) to T_x2
- DB4(11) to D22
- DB5(12) to D21
- DB6(13) to D19
- DB7(14) to D23
- LED+(15) to +ve
- LED-(16) to –ve

9.Unique Selling Propositions (USPs) for FlameEye-X

1. Predictive Safety — Acts Before Fire Starts:

Unlike traditional detectors, FlameEye-X predicts ignition risk using **multi-sensor probability modeling**, enabling **pre-ignition prevention** instead of reactive alarms.

2. IoT-Enabled Mobile Alerts:

FlameEye-X connects to Wi-Fi and sends **real-time alerts** to the user's phone, enabling remote monitoring and quick response.

3. Autonomous Physical Intervention:

Not just alerts — it **closes the gas valve, activates ventilation**, and triggers alarms automatically without human input.

4. Instant Response Time (<10 seconds):

Optimized sensor processing and ESP32 computation guarantee emergency actions in **under 10 seconds**, giving maximum protection.

5. Self-Learning Risk Calibration:

FlameEye-X continuously adjusts its baseline using **μ–σ environmental learning**, reducing false alarms over time.

6. Real-Time Risk Probability Engine:

A mathematical model computes risk as a **continuous probability (0–1)** instead of fixed thresholds, delivering smarter, context-aware decisions.

7. Fail-Safe Hardware Design:

On power loss, the servo **auto-locks to the valve shutdown position**, ensuring safety even during system failure.

8. Multi-Sensor Fusion Under ₹1500 (demo product):

The only low-cost device combining **gas + temperature + flame** sensors with adaptive analytics — 3× cheaper than commercial systems.

9. Accessible, Modular, and Scalable:

Designed with low-cost, plug-and-play modules, making it easy to scale across **homes, hostels, small kitchens, cafeterias, and PGs**.

10. Economical Aspects:

10.1 Component Table:

Prototype vs Industrial vs Semi-Industrial

Function	Your Prototype Component	Industrial-Grade Replacement	Semi-Industrial Replacement	Why Replace?
Gas Detection (LPG/CH4/CO)	MQ-2 (Analog, unstable, cheap)	NDIR Gas Sensor (e.g., Figaro TGS8410, Winsen NDIR CH4)	Winsen MQ-135 professional version, or ZE07-CH4 (factory calibrated)	Industrial sensors have stable baseline, ppm-level accuracy, and no drift with humidity/temperature.
Flame Detection	IR Flame Sensor Module	UV-TRON R9533 (Hamamatsu) or Thermopile flame sensor	IR Flame Sensor Industrial Version (better filter lens)	Industrial flame detection works in sunlight, smoke, and has micro-amp sensitivity.
Temperature Detection	DS18B20	PT100 / PT1000 RTD + MAX31865 module	Industrial waterproof DS18B20 stainless probe	PT100/1000 gives ±0.1°C precision and long-term stability.
Ventilation Control	Cheap Relay JQC-3F	Solid-State Relay (SSR) or Schneider/Omron Contact Relay	Songle SRD-05VDC-SL-C	Industrial relays handle higher loads + fire safety certification.
Gas Cut-Off Mechanism	SG90 / MG995 Servo	Solenoid Gas Shutoff Valve (Normally Closed) – 12V/24V	Motorized Ball Valve, metal gear type	Servo is unreliable; solenoid valves are certified for gas safety.
Controller	ESP32 DevKit	ESP32-WROOM Industrial PCB + Conformal Coating	ESP32 DevKit in metal enclosure	Industrial PCBs withstand heat, vibration, EMI, and have isolation.
Buzzer / Alarm	Passive buzzer	Industrial Sounder Alarm (90–110 dB)	Medium loud beeper	Professional alarms meet safety decibel ratings.

Function	Your Prototype Component	Industrial-Grade Replacement	Semi-Industrial Replacement	Why Replace?
LCD	16x2 JHD162A	OLED Industrial 0.96/1.3 inch metal-case	TFT Color LCD	Industrial displays are rugged, visible outdoors.
Power Supply	Buck Converter generic	Meanwell Industrial 5V PSU	High-quality buck converter (LM2596 genuine)	Industrial PSU gives clean noise-free power.

10.2 Cost Comparison:

A. COST OF CURRENT PROTOTYPE

Component	Price (₹)
MQ-2	150
IR Flame sensor	100
DS18B20	120
ESP32 DevKit	300
Relays	60
Servo (MG995)	90
LCD 16x2	180
Wires + PCB	100
Buck Converter	120
TOTAL (Prototype)	**₹1,220 approx.**

B. COST OF SEMI-INDUSTRIAL VERSION

Component	Price (₹)
ZE07-CH4 / MQ-135 professional	800
Industrial IR Flame sensor	600
Waterproof DS18B20	250
ESP32 DevKit + Enclosure	600
Relay SRD/SSR 10A	150
Motorized Ball Valve (12V NC)	900
OLED display	350
Industrial PSU	400
TOTAL (Semi-Industrial)	**₹4,050 approx.**

C. COST OF FULL INDUSTRIAL DEPLOYABLE VERSION

Component	Price (₹)
NDIR CH4 Sensor (Winsen MH-441/471)	2,500–3,500
PT100 + MAX31865	1,200
UV-TRON Hamamatsu	4,000
Industrial ESP32 PCB	1,500
Certified SSR/Relay	700
Certified Solenoid Gas Valve	2,000–3,000
Rugged OLED	700
Meanwell PSU	800
IP65 Metal Enclosure	1,000
TOTAL (Industrial Grade)	**₹14,000–16,500**

10.3 Feasibility:

Is FlameEye-X financially feasible compared to market competitors?

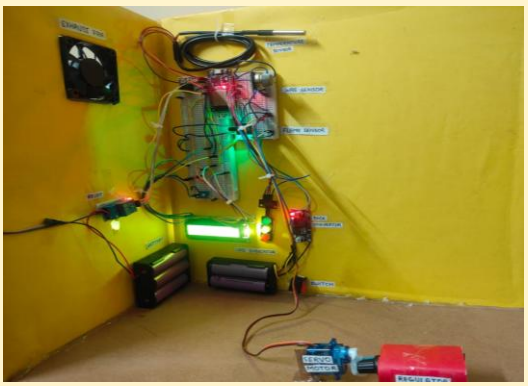
Existing competing products:

Product	Market Price	Features
Xiaomi Gas Leak Detector	₹2,000 – ₹3,000	LPG detection only
Honeywell Gas Safety Device	₹5,000 – ₹8,000	Gas + Alarm, no flame detection, no automation
Smart Kitchen Safety Systems (IoT)	₹10,000–₹20,000	App + Solenoid + Automation
Industrial Gas Safety Systems	₹25,000–₹60,000	Certified sensors, high reliability

10.4 Where does Product fit?

❖ Prototype (approx. ₹1220):

- Cost-effective option, best suited for academic or demonstration use.
- Not safe enough for real deployment.



❖ Semi-Industrial Version (around ₹4,000):

- **Most cost-effective.**
- Better than Xiaomi/Honeywell because:
  - Detects **Flame + Gas + Temperature**
  - Has **AI-based probability**
  - Has **Blynk IoT alerts**
  - Has **partial + emergency control**
  - We can add **solenoid valve**

→ This is the PERFECT consumer product tier,

Equivalent commercial solutions = ₹10,000–₹20,000
Our making cost (approx.) = ₹4,000

❖ Industrial Version (around ₹15,000):

- Competes with ₹25,000–₹60,000 products.
- Can be deployed in:
  - Hotels
  - Restaurants
  - Industries
  - Large kitchens / Food courts
  - Hospitals

Industry devices = ₹40,000+
Our making cost (approx.) = ₹15,000.

We aim to offer one of the most cost-effective industrial-grade systems in the market.

10.5 Economic Feasibility Summary:

❖For Home Users

- **Affordable**: Cheaper than commercial IoT systems.
- **More features** (flame detection + AI probability).
- **App notifications (Blynk)** = Unique selling point.

❖For Commercial Kitchens

- With industrial sensors, it becomes:
  - More accurate
  - Long-life
  - Government-certification friendly
  - Robust

This market is underserved → **high profit potential.**

❖ Investors Will Like It Because:

- Low BOM (Billing of Material) cost
- High scalability
- Sharp differentiation (AI prediction model)
- IoT + Safety is a HOT MARKET

11. Graph (Real Time Behaviour Of Bot):