

Problem Definition and Background

The Invisible Threat: Indoor air can be 2 to 5 times more polluted than outside air, causing headaches, poor sleep, and respiratory issues.

The "Dumb" Monitor Problem: Current consumer devices are reactive data collectors that lack context or actionable insights.

What Current Monitors Tell You	What else is required!
"Your P.M2.5 level is 150 ppm."	Is that high? Why? Is this just cooking which is temporary or dangerous smoke?
"The air quality is 'Moderate.'"	Is it going to stay moderate? Will it stay moderate or get better? Should I open a window (actionable insight)

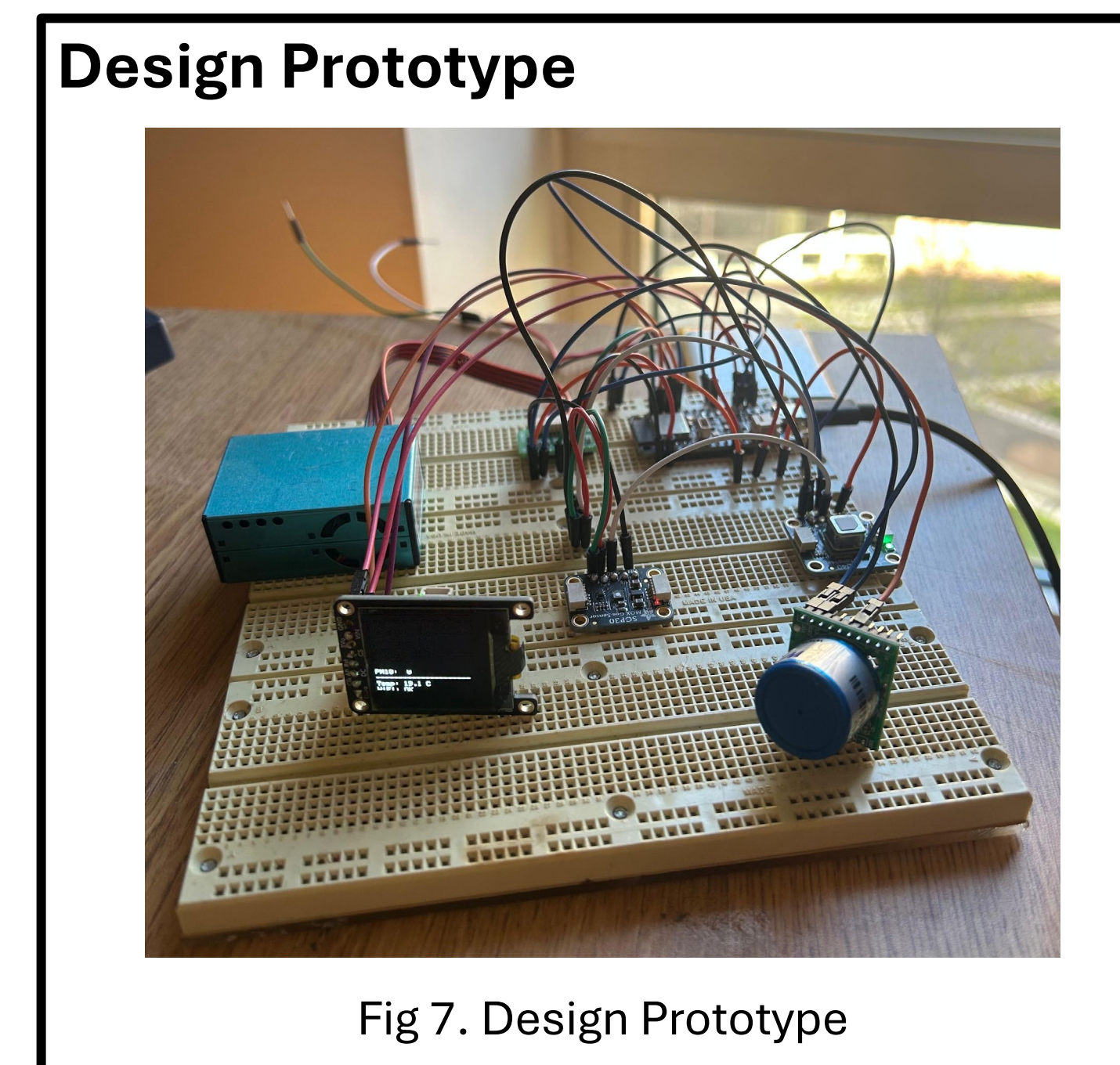
The Need: A low-cost, smart IoT monitor delivering actionable, context-aware feedback to improve human health.

The Air Oracle Objectives:

- Hardware < \$300 Multi-Sensor Array
- Edge AI TinyML Source Identification
- Interface OLED & Web Dashboard

Design Specifications

Stationary Power USB-C input (5V). Stationary installation for continuous operation.	Safety Standards Localized electrical safety. UL/CE compliant design practices.	TinyML Accuracy > 80% on-device pollutant source identification accuracy.	Connectivity IEEE 802.11n (2.4 GHz Wi-Fi). Stable network link required.
Environmental Tolerance Indoor range: 10C to 40C. Operating humidity: 20% to 80% RH.	System Integration MQTT-ready telemetry stack. API-friendly dashboard integration.	Budget Total hardware target < \$300. Low-cost sensor strategy maintained.	Timeline 2-semester execution plan. Milestone tracking via Gantt phases.



Final Design and Implementation

Hardware Design

Fig 1. Hardware Architecture

Software Design

Fig 2. Software Architecture (Arduino)

ML Design

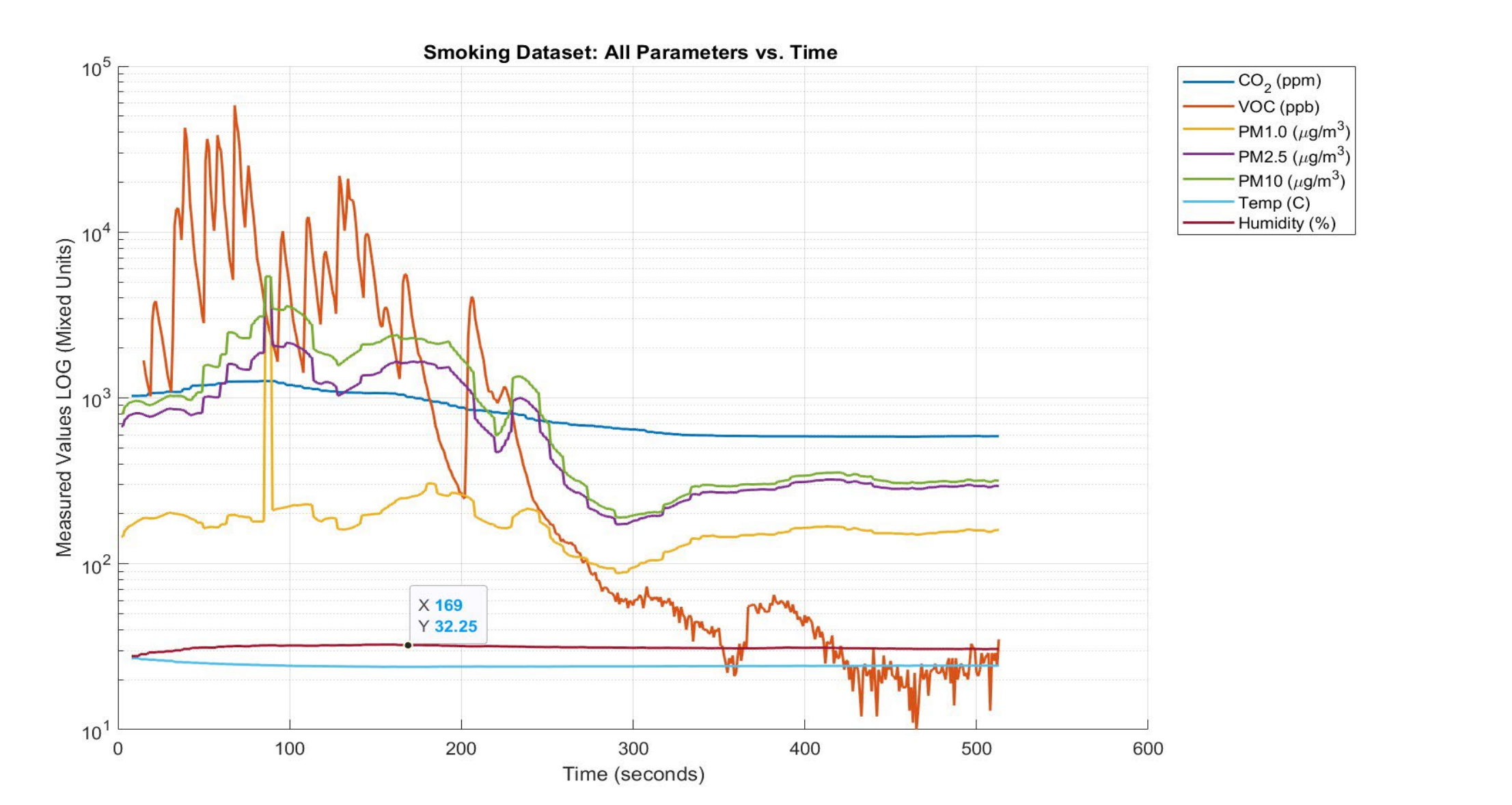
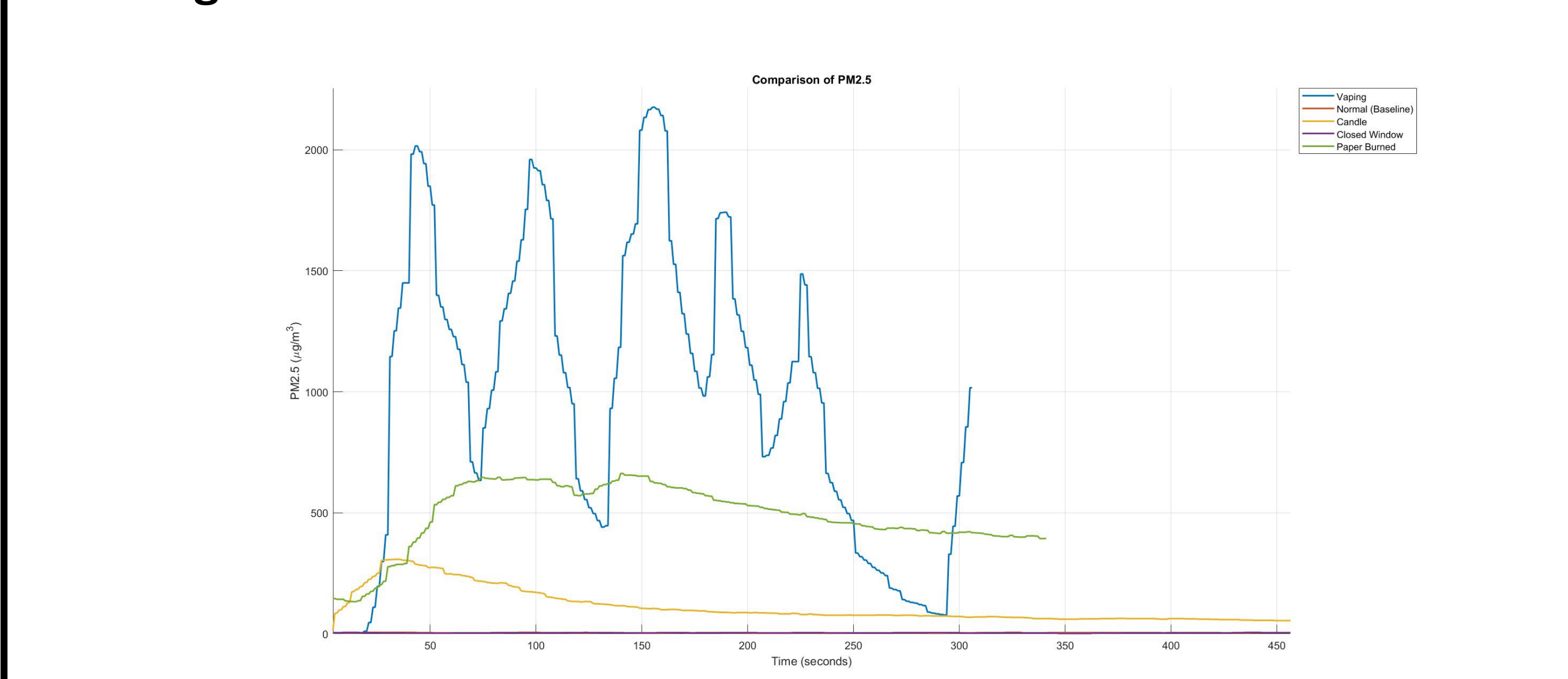
Fig 3. ML architecture

Air Scoring Model :

a) Prioritizing Real Threats: Weighting core pollutants (PM, VOCs) at 2.0x and ambient data (Temperature, CO₂) at 0.5x forces the AI to focus on true hazards rather than normal environmental shifts.

b) Eliminating False Alarms: a strict 70% confidence threshold prevents against false positive alerts triggered by environmental reasons

c) Guaranteed Accuracy: Because of the weighting ratio, reaching the 70% threshold mathematically guarantees that high-priority pollutant sensors must be at least 62.5% active for an event to be classified.



Design Alternatives

Hardware Design Alternatives

- Hardware UI: LED Status Lights, OLED Display Screen
- Firmware Power Logic: Interrupt-Driven Light Sleep Cycles, Continuous Always-On Execution
- CO Sensor: Metal Oxide (Heated), Electrochemical
- Processor Core: Single-Core, Dual-Core Processor

Software Design Alternatives

- Machine Learning Architecture: Cloud-Based Inference, Edge AI (TinyML)
- Telemetry & Data Logging: Local SD Card Storage, Real-Time MQTT over Wi-Fi
- Backend Database Infrastructure: Firebase Realtime Database, Supabase (PostgreSQL)
- Alerting Logic: Periodic Manual Dashboard Checks, Automated Threshold Alerts

Design Evaluation and Iterative Process

Power Supply Issue :

Initial Design: 3.7V LiPo Battery

Issue: PM Sensor Needs 5V

Iteration 1: Custom Step-Up Circuit

Issue: Highly Unstable Voltage

Iteration 2: MT-3608 Boost Module

Issue: Instability Under Peak Load

Final Resolution: Stationary Mains Power

ML Scope Refining

Initial Scope: LSTM Cloud Forecasting & Complex Signatures (Cooking)

Issue: Data Intensive & Fire Alarm Hazards

Scope Adjustment: Pivot to Edge AI & Safe Data Collection

Resolution:

Final Implementation: On-Device TinyML & 5 Accessible Signatures

Results and Discussion (Future Work)

System Category	Current Results & Validation	Discussion & Future Work
Prototype Validation	Currently built on a breadboard prototype, provides modularity and an easier prototyping stage.	Fabrication of custom PCB and vented 3D enclosure for enhanced durability
Sensor Responsiveness	PM Sensitivity: Validated with immediate spikes from cigarette smoke vs. gradual candle-based increases CO₂: Validated by human respiration and combustion tests. VOC: validated with instant spikes with Vape smoke	CO Sensors: Safe calibration and sensitivity validation of CO sensors without high-concentration fire hazards. VOC Calibration: Optimization of the SGP30 baseline to eliminate drift and ensure accuracy across different clean-air thresholds.
Machine Learning	Operational TFLite pipeline on ESP32 utilizing real-time Z-score normalization and parameter weighting	Public dataset integration to reduce "safe-air" bias and using a cloud-based LSTM model for predictive, short-term indoor air quality forecasting
IoT & User Interface	System development optimized at an estimated cost of \$210-\$257, well within the strict \$300 budgetary constraint.	Deploy a comprehensive web dashboard or mobile application with future predictions and historical trends.

References

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