اونيۏرسيتي مليسيا قهڠ السلطان عبد الله
UNIVERSITI MALAYSIA PAHANG
AL-SULTAN ABDULLAH

PROBLEM BASED LEARNING

BVI 3114 TECHNOLOGY SYSTEM OPTIMIZATON II

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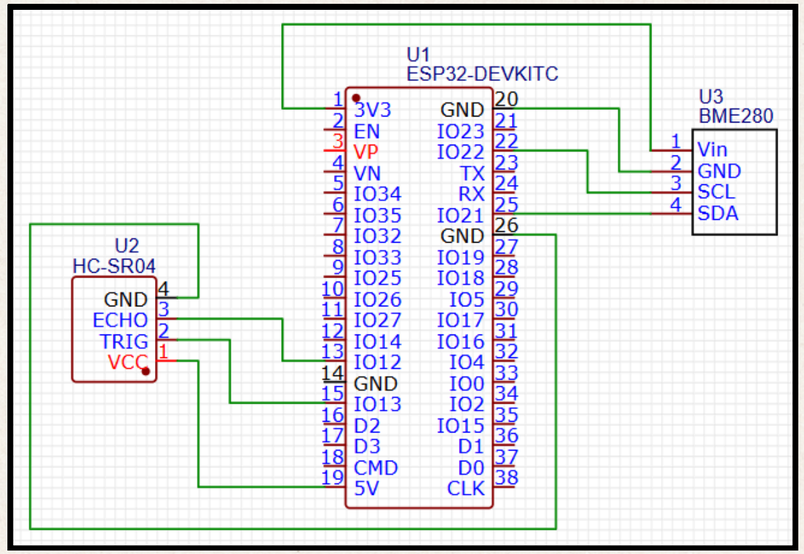
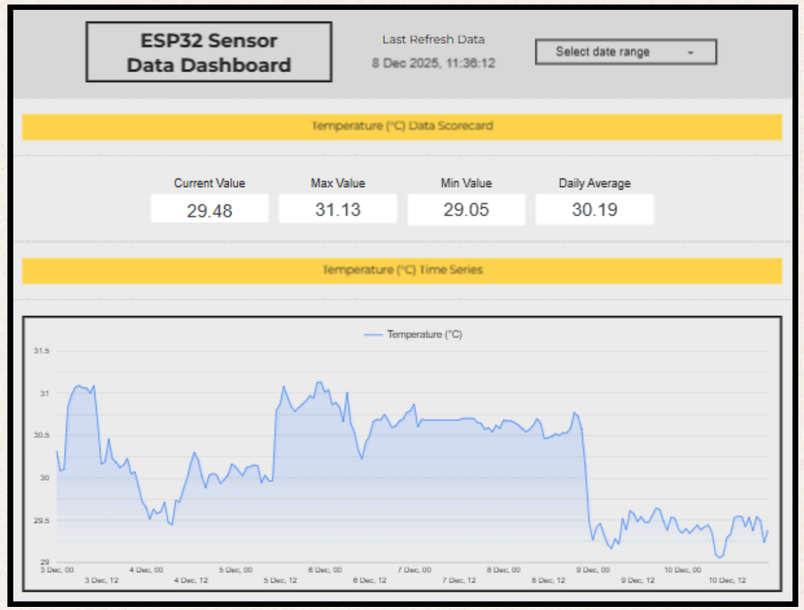




Executive Summary

This project developed an IoT based real time sensor data collection and forecasting system using an ESP32 integrated with Google Sheets and Looker Studio. Temperature, humidity, pressure and distance data were collected using BME280 and HC-SR04 sensors and stored for processing and analysis. Forecasting algorithm was implemented using Google Apps Script with the Holt-Winters method to generate 24 hour forecasts and confidence bounds. The system features an interactive dashboard embedded in a mobile app, providing reliable monitoring with potential for future AI based enhancements.

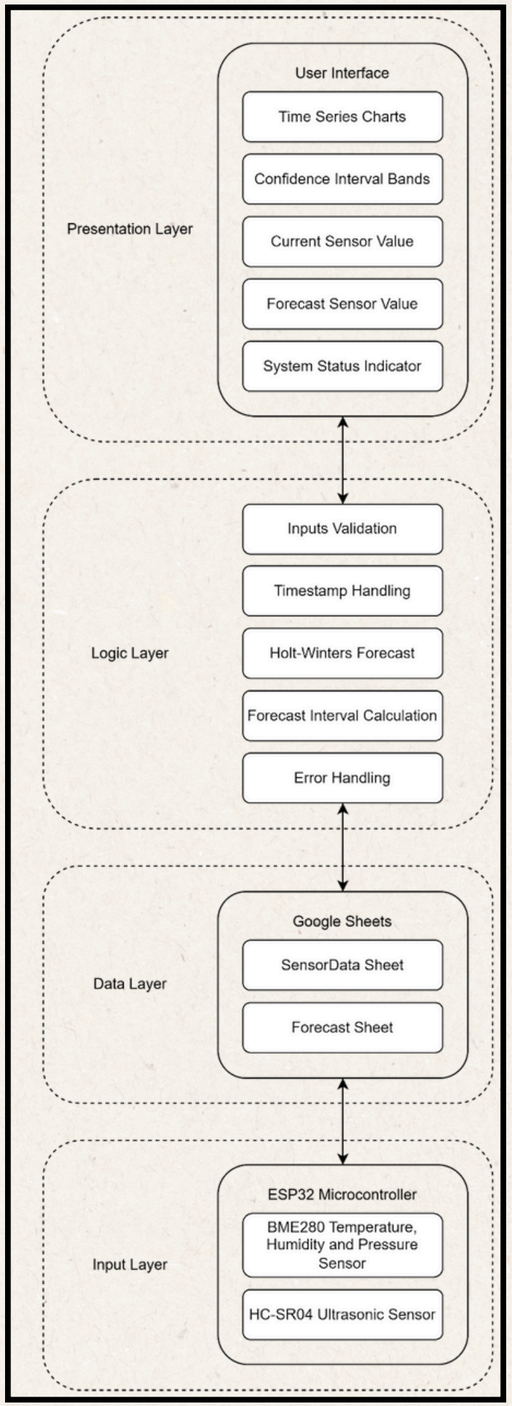
System Architecture Diagram

1. Presentation Layer
   - User Interface
     - Time-series charts
     - Confidence interval bands
     - Current sensor values
     - Forecast sensor values
     - System status indicator

2. Logic Layer
     - Input validation
     - Timestamp handling
     - Holt-Winters forecast
     - Forecast interval calculation
     - Error handling

3. Data Layer
   - Google Sheets
     - SensorData sheet
     - Forecast sheet

4. Input Layer
   - ESP32 Microcontroller
     - BME280 Temperature, Humidity and Pressure sensor
     - HC-SR04 Ultrasonic sensor



Forecasting Algorithm Explanation

01 Exponential Moving Average (EMA)

a. Basic Principle

A time series smoothing technique that gives more weight to recent data while still considering older observations. The EMA reacts faster to sudden changes because the weighting decreases exponentially over time.

b. Strengths

- Fast reaction to new change.
- Low computational cost.
- Good noise filtering.
- Reduce random spikes in sensor readings.
- Works well with streaming data.

c. Limitations

- Cannot detect trends or seasonality.
- Heavily dependent on the alpha value.
- Not suitable for long term forecasting.

d. Sensor Suitability

Highly suitable for HC-SR04 Ultrasonic sensor because the distance readings often contain noise and sudden spikes.

$$EMA_t = \alpha \cdot x_t + (1-\alpha) \cdot EMA_{t-1}$$

02 Holt-Winters Method

a. Basic Principle

Also known as Triple Exponential Smoothing is forecasting technique for seasonal time series, by adding seasonal component which use 3 smoothing equations for Level (L), Trend (T) and Seasonality (S) that controlled by alpha, beta and gamma parameters.

$$L_t = \alpha(x_t - S_{t-m}) + (1-\alpha)(L_{t-1} + T_{t-1})$$

$$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1}$$

$$S_t = \gamma(x_t - L_t) + (1-\gamma)S_{t-m}$$

$$F_{t+h} = L_t + hT_t + S_{t-m+h}$$

b. Strengths

- Captures data trend and seasonality.
- More accurate for a long term forecasts.
- Smooths the data while forecasting.
- Effective for daily environmental sensor data.

c. Limitations

- More computationally heavy.
- Not always suitable for low end microcontrollers.
- Requires storing multiple past values.

d. Sensor Suitability

Highly suitable for BME280 Temperature, Humidity and Pressure sensor because environmental data shows daily temperature cycles, pressure trends and humidity fluctuations with patterns.

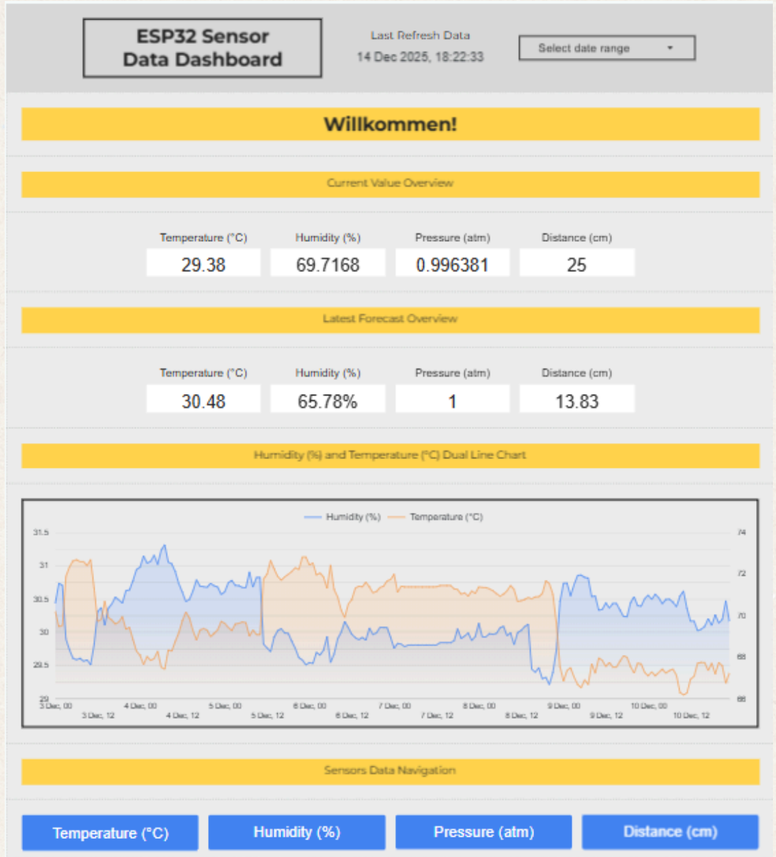
Results

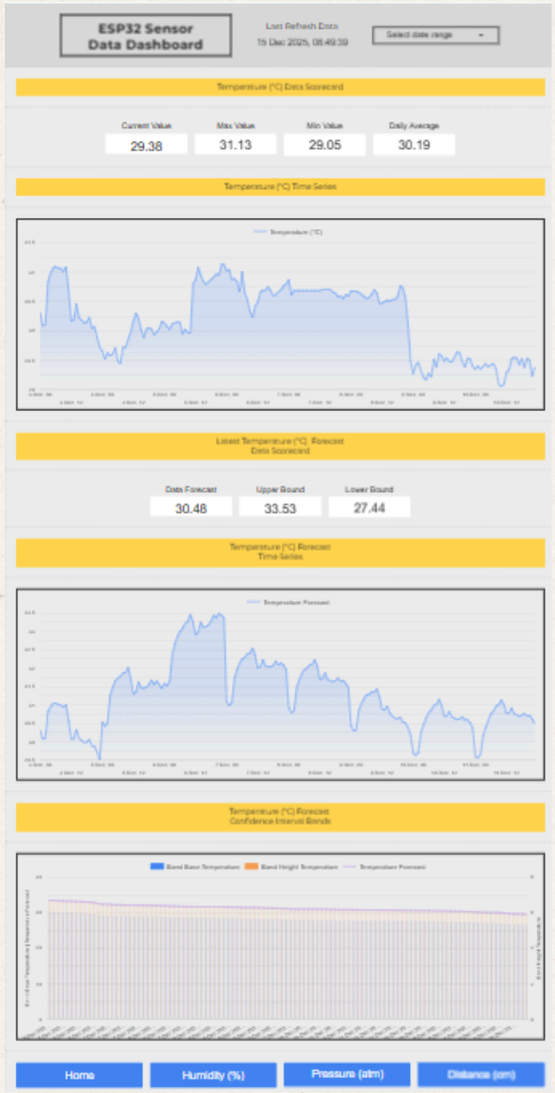
1. Forecast Sheet

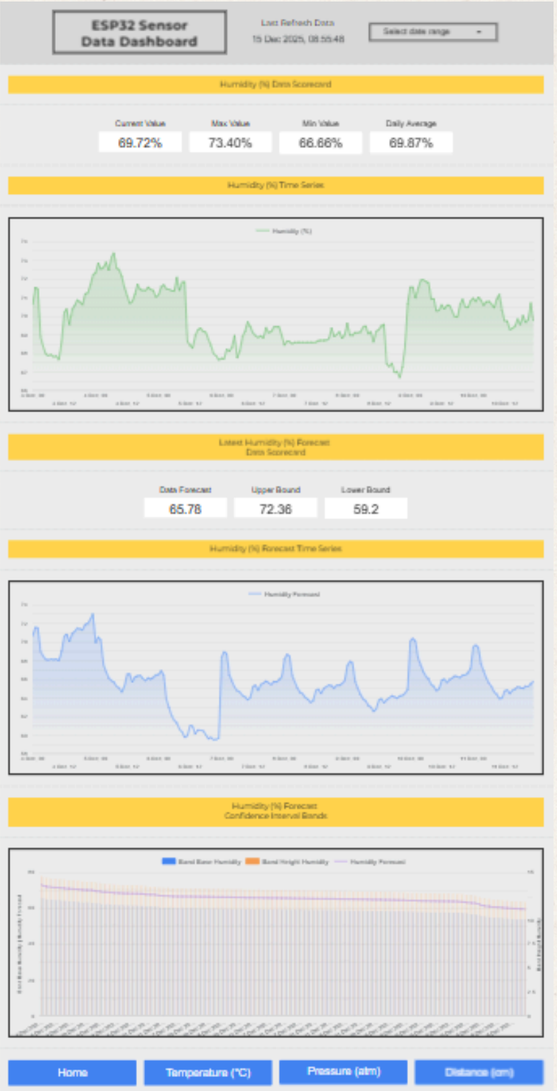
Timestamp	Temperature Forecast	Temperature Upper	Temperature Lower	Humidity Forecast	Humidity Upper	Humidity Lower	Pressure_atm Forecast	Pressure_atm Upper	Pressure_atm Lower	Distance Forecast	Distance Upper	Distance Lower
04/12/2025 00:00:47	30.29	33.32	27.26	70.66	77.72	63.59	1.00	1.1	0.9	21.15	23.27	19.04
04/12/2025 01:00:47	30.06	33.07	27.06	71.61	78.77	64.45	1.00	1.1	0.9	63.6	69.95	57.24
04/12/2025 02:00:47	30.08	33.09	27.07	71.52	78.67	64.37	1.00	1.1	0.9	17.83	19.61	16.05
04/12/2025 03:00:47	30.81	33.89	27.73	68.96	75.85	62.06	1.00	1.1	0.9	20.66	22.73	18.59
04/12/2025 04:00:47	30.95	34.04	27.85	68.47	75.32	61.62	1.00	1.1	0.9	23.93	26.32	21.54
04/12/2025 05:00:47	31.03	34.13	27.92	68.09	74.9	61.28	1.00	1.1	0.9	27.52	30.27	24.77
04/12/2025 06:00:47	31.04	34.14	27.93	68.05	74.86	61.25	1.00	1.1	0.9	24.33	26.76	21.9
04/12/2025 07:00:47	31	34.1	27.9	68.17	74.98	61.35	1.00	1.1	0.9	32.29	35.52	29.06
04/12/2025 08:00:47	30.99	34.09	27.89	68.06	74.87	61.25	1.00	1.1	0.9	33.34	36.68	30.01
04/12/2025 09:00:47	30.92	34.01	27.83	68.17	74.99	61.35	1.00	1.1	0.9	27.45	30.2	24.71
04/12/2025 10:00:47	31	34.1	27.9	67.98	74.78	61.18	1.00	1.1	0.9	43.58	47.94	39.22
04/12/2025 11:00:47	30.56	33.61	27.5	69	75.9	62.1	1.00	1.1	0.9	43.71	48.08	39.34
04/12/2025 12:00:47	30.05	33.05	27.04	70.62	77.68	63.56	1.00	1.1	0.9	48.82	53.7	43.94
04/12/2025 13:00:47	30.07	33.08	27.06	70.85	77.94	63.77	1.00	1.1	0.9	49.91	54.9	44.92
04/12/2025 14:00:47	30.33	33.36	27.3	70.03	77.04	63.03	1.00	1.1	0.9	49.96	54.96	44.97
04/12/2025 15:00:47	30.08	33.09	27.07	70.9	77.99	63.81	1.00	1.1	0.9	47.98	52.78	43.18
04/12/2025 16:00:47	30.03	33.03	27.03	71.13	78.24	64.02	1.00	1.1	0.9	52.96	58.26	47.66
04/12/2025 17:00:47	29.96	32.96	26.97	71.5	78.65	64.35	1.00	1.1	0.9	42.9	47.19	38.61
04/12/2025 18:00:47	29.98	32.98	26.99	71.39	78.53	64.25	1.00	1.1	0.9	45.81	50.39	41.23
04/12/2025 19:00:47	30.06	33.06	27.05	71.28	78.41	64.16	1.00	1.1	0.9	48.68	53.55	43.81
04/12/2025 20:00:47	29.86	32.84	26.87	71.91	79.11	64.72	1.00	1.1	0.9	58.52	64.37	52.67
04/12/2025 21:00:47	29.88	32.87	26.89	71.97	79.17	64.78	1.00	1.1	0.9	120.33	132.36	108.3
04/12/2025 22:00:47	29.69	32.66	26.72	72.46	79.7	65.21	1.00	1.1	0.9	58.11	63.92	52.3
04/12/2025 23:00:47	29.5	32.45	26.55	73.03	80.33	65.73	1.00	1.1	0.9	63.87	70.26	57.48

Results

2. Looker Studio Visuals

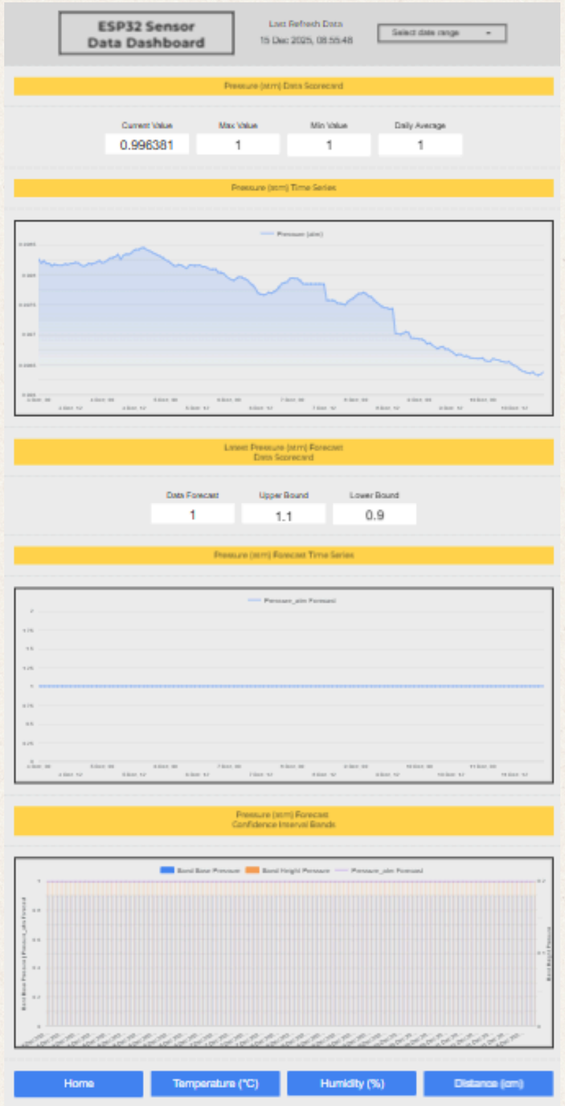


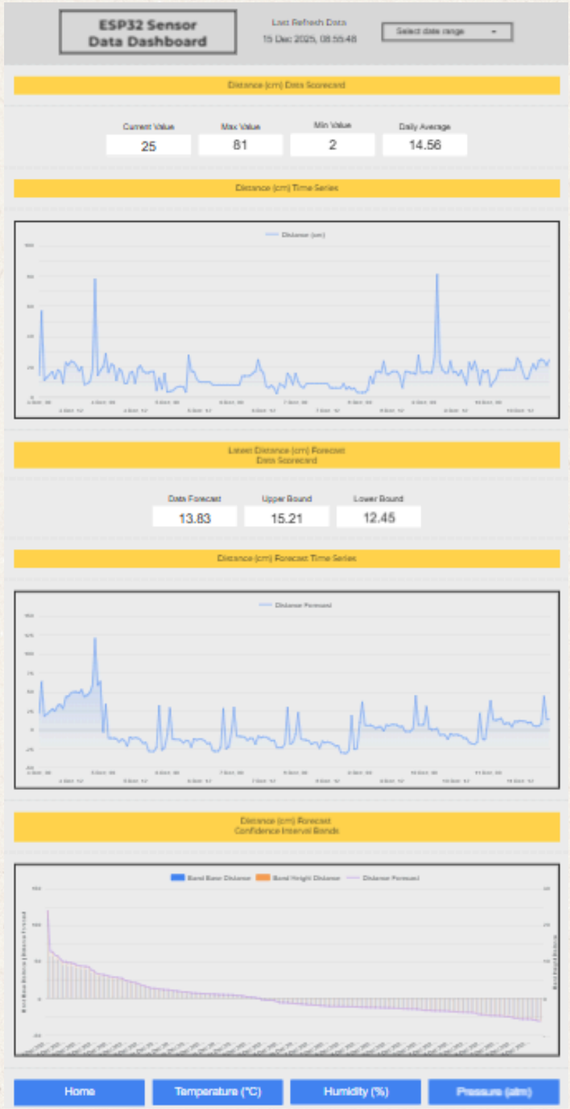




Results

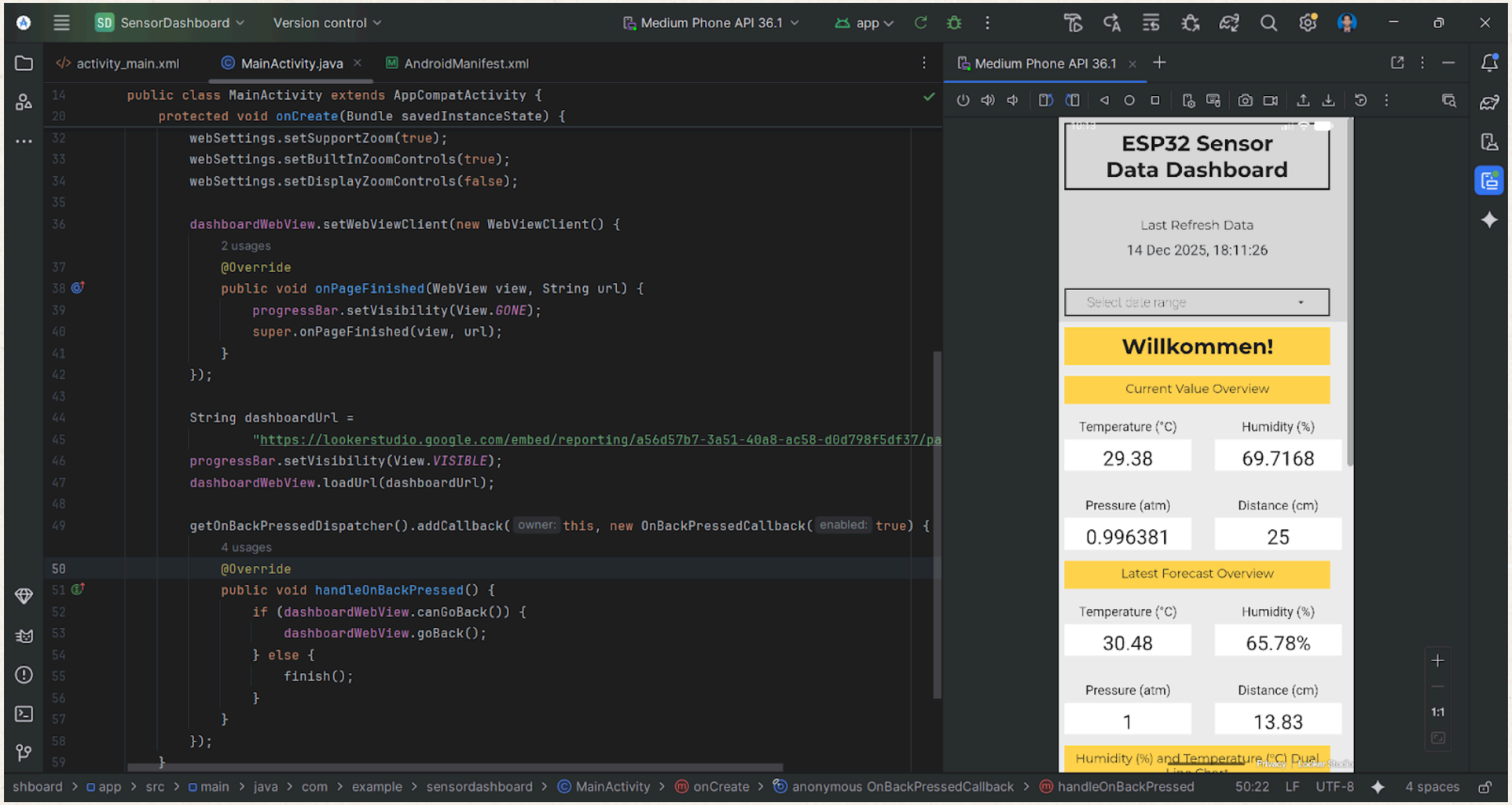
2. Looker Studio





Results

3. Android Studio



Future Improvements

1

Integration of Gemini AI to generate automated summaries and insights from sensor data. Gemini AI can analyze hourly or daily trends, detect important patterns, and produce clear, human-readable reports.

2

implementation of Exponential Moving Average (EMA) forecasting for distance sensor data. EMA helps smooth sudden spikes while remaining responsive to recent changes.

Thank you