FACULTY OF ELECTRICAL AND ELECTRONICS ENGINEERING TECHNOLOGY

REPORT

BVI 3114

TECHNOLOGY SYSTEM OPTIMIZATION II

Problem-Based Learning Assessment:

IoT Sensor Data Forecasting System

No.	Student ID	Student Name	Section/Grp
1	VC22013	MUHAMMAD AKMAL HAIKAL BIN AZMI	01P/Group 3
2	VC22017	FARIS AZRI BIN FAISAL RIDZA	
3	VC22029	MUHAMMAD FAUZAN SYAFIQ BIN ROSLAN	

DATE OF REPORT SUBMISSION	19.0.2025

Contents

1.0 INTRODUCTION

Modern laboratories are highly sensitive environments where subtle changes in temperature, humidity, or unexpected obstacles can disrupt operations, compromise safety, and waste resources. Traditional monitoring methods are reactive and slow to address issues.

This project aimed to develop a predictive, automated monitoring solution using Internet of Things (IoT) technologies. By integrating real-time sensors with cloud analytics and mobile visualization, the system offers an intelligent, proactive approach to lab monitoring.

Core Components:

- **Sensing**: ESP32-based data collection from ultrasonic, temperature-humidity, light, and air quality sensors.
- **Cloud Integration**: Real-time data is transmitted to Google Sheets via HTTP POST using Google Apps Script.
- **Forecasting**: Short-term data prediction using Simple Moving Average (SMA) algorithms for environmental variables.
- **Dashboard Visualization**: Live metrics are displayed through a Google Looker Studio dashboard.
- **Mobile App**: A native Android application was built using Android Studio to provide portable real-time visualization.

2.0 SYSTEM DESIGN AND IMPLEMENTATION

2.1 Hardware and Data Flow

- **Microcontroller**: ESP32 Wi-Fi-enabled board
- **Sensors**: Grove ultrasonic and light sensors
- **Connectivity**: Wi-Fi + Google Apps Script Web App endpoint
- **Output**: Real-time logs in Google Sheets, analytics in Looker Studio, and app-based visualization

2.2 ESP32 Firmware

The ESP32 was programmed to:

- Connect to Wi-Fi
- Measure distance (and optionally light)
- Format and send data as JSON
- POST to a Google Apps Script endpoint every 10 seconds

✅ *Improved sampling interval from 10 minutes to 10 seconds for real-time tracking.*

2.3 Google Apps Script Backend

- Logs JSON payloads into a dedicated Google Sheet
- Automatically handles timestamps and data parsing
- Features a script-triggered forecast generator
- Supports menu-driven actions: Clear Data, Generate Forecasts

2.4 Forecasting Logic

Implemented in Apps Script using SMA:

- Generates 24-hour rolling forecasts
- Outputs forecast values with upper/lower bounds
- Automatically updates the “Forecasts” sheet

The ESP32 is programmed using Arduino IDE to send ultrasonic sensor data every 10 seconds via HTTP POST to a Google Apps Script endpoint. Full code provided in Appendix A.

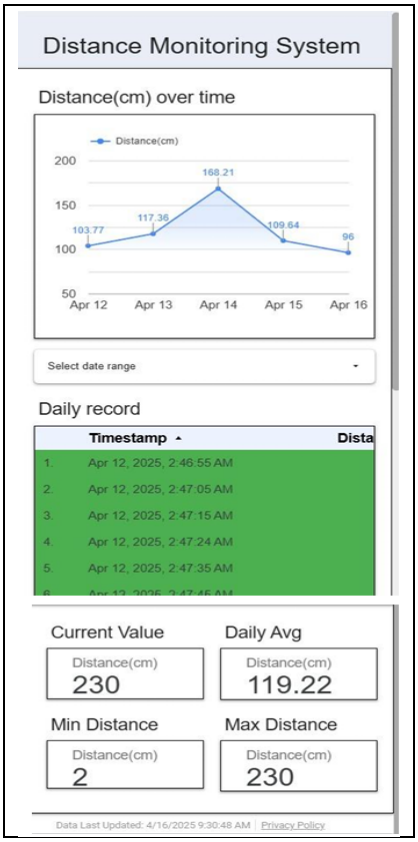
3.0 MOBILE APPLICATION

3.1 Overview

A lightweight Android app was developed using WebView to embed the real-time dashboard into a mobile-friendly layout.

3.2 Features

- Embedded Looker Studio dashboard
- Real-time readings
- Progress bar for UX
- Zoom and scroll enabled for responsive viewing



4.0 SYSTEM LINKS

📊 Google Sheets (Live Data): Google Sheets

📈 Looker Studio Dashboard: Looker Studio

5.0 SYSTEM SETUP & CHALLENGES

5.1 Sensor Configuration

- **Ultrasonic Ranger**:
  - VCC → 5V
  - GND → GND
  - SIG → GPIO 13 on ESP32

5.2 Enhancements & Modifications

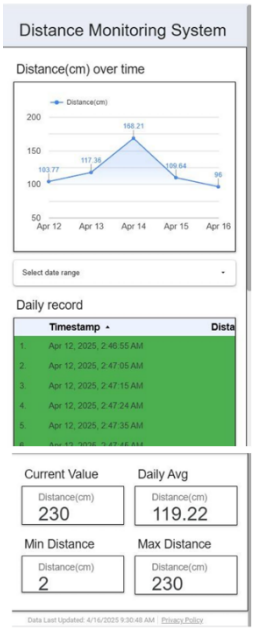
- Added light sensor integration with ultrasonic readings
- Developed web endpoint for Google Sheets using Apps Script

5.3 Common Issues & Fixes

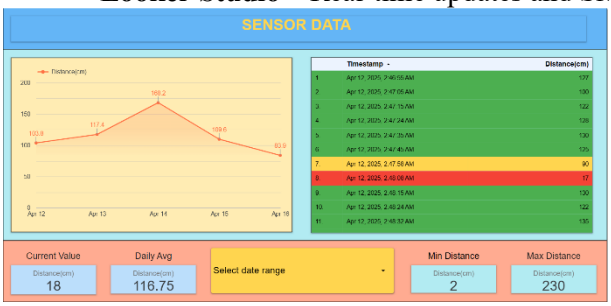
Issue	Resolution
Initial slow data updates	Reduced interval from 10 minutes → 10s
Data overflow in sheets	Added "Clear Data" menu in Apps Script
Mobile dashboard overflow issues	Used horizontal scroll and scaling

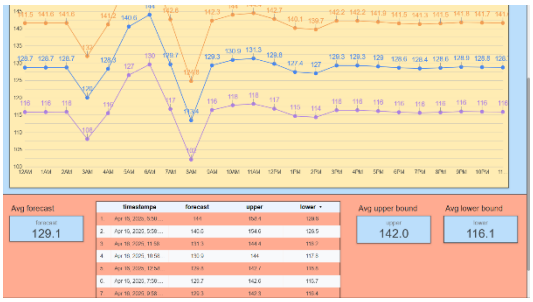
6.0 VISUAL PROOF OF SYSTEM

- **App Screenshots** – Showing embedded dashboard and refresh feature



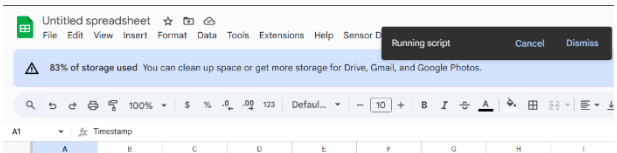
- **Looker Studio** – Real-time updates and SMA forecast





- **Google Sheets** – Live logging of sensor values

	A	B
1	Timestamp	Distance(cm
2	4/12/2025 2:46:55	127.00
3	4/12/2025 2:47:05	100.00
4	4/12/2025 2:47:15	122.00
5	4/12/2025 2:47:24	128.00
6	4/12/2025 2:47:35	130.00
7	4/12/2025 2:47:45	125.00
8	4/12/2025 2:47:58	90.00
9	4/12/2025 2:48:08	17.00
10	4/12/2025 2:48:15	130.00
11	4/12/2025 2:48:24	122.00
12	4/12/2025 2:48:32	135.00
13	4/12/2025 2:48:45	112.00
14	4/12/2025 2:48:55	11.00
15	4/13/2025 2:49:04	122.00
16	4/13/2025 2:49:16	123.00
17	4/13/2025 2:49:25	102.00
18	4/13/2025 2:49:35	108.00
19	4/13/2025 2:49:44	109.00
20	4/13/2025 2:49:55	112.00
21	4/13/2025 2:50:05	59.00
22	4/13/2025 2:50:15	12.00
23	4/13/2025 2:50:25	123.00
24	4/13/2025 2:50:34	124.00



7.0 CONCLUSION

This PBL project showcased how low-cost IoT solutions can significantly improve lab safety and monitoring through real-time sensing, cloud data management, and mobile visualization. Forecasting environmental trends allowed us to act proactively rather than reactively, setting the stage for scalable smart lab environments.

8.0 APPENDICES – FULL CODE LISTINGS

APPENDIX A – APPS SCRIPT CODE

```
// Script to receive sensor data from ESP32 and log it to Google Sheets
function doGet(e) {
return handleResponse(e);
}
function doPost(e) {
return handleResponse(e);
}
function handleResponse(e) {
// Process the incoming request
var lock = LockService.getScriptLock();
lock.tryLock(5000); // Wait 10 seconds for other processes to complete
try {
// Get the active sheet
var spreadsheet =
SpreadsheetApp.openByUrl("https://docs.google.com/spreadsheets/d/1jlimos4C4gYYEcMx9zxddugdrxA-
mfcRvSGrOPzSXEE/edit?gid=1020590958#gid=1020590958");
var sheet = spreadsheet.getSheetByName("Sheet1");
// Parse the incoming data
var payload;
if (e.postData && e.postData.contents) {
payload = JSON.parse(e.postData.contents);
} else if (e.parameter) {
payload = e.parameter;
} else {
return ContentService.createTextOutput(JSON.stringify({
'status': 'error',
'message': 'No data received'
})).setMimeType(ContentService.MimeType.JSON);
}
// Prepare data array for the sheet
var timestamp = new Date();
var data = [timestamp];
// Get sensor data based on what's available in the payload
// Add appropriate sensor values to the data array
if (payload.temperature !== undefined)
data.push(parseFloat(payload.temperature));
if (payload.humidity !== undefined)
data.push(parseFloat(payload.humidity));
if (payload.moisture !== undefined)
data.push(parseFloat(payload.moisture));
if (payload.light !== undefined) data.push(parseFloat(payload.light));
if (payload.motion !== undefined) data.push(payload.motion);
if (payload.distance !== undefined)
data.push(parseFloat(payload.distance));
// Insert data into the next row
sheet.appendRow(data);
// Return success response
return ContentService.createTextOutput(JSON.stringify({
'status': 'success',
'timestamp': timestamp.toString()
})).setMimeType(ContentService.MimeType.JSON);
} catch (error) {
// Return error response
return ContentService.createTextOutput(JSON.stringify({
'status': 'error',
'message': error.toString()
})).setMimeType(ContentService.MimeType.JSON);
```

```
} finally {
lock.releaseLock();
}
}
// Add menu to sheet
function onOpen() {
var ui = SpreadsheetApp.getUi();
ui.createMenu('Sensor Data')
.addItem('Clear All Data', 'clearData')
.addToUi();
}
// Function to clear all data except headers
function clearData() {
var sheet = SpreadsheetApp.getActiveSpreadsheet().getActiveSheet();
var lastRow = sheet.getLastRow();
if (lastRow > 1) {
sheet.deleteRows(2, lastRow - 1);
}
SpreadsheetApp.getUi().alert('All sensor data has been cleared!');
}
// Add this function to your existing Google Apps Script
// Function to generate forecasts (runs on time trigger or manual execution)
function generateForecasts() {
 var sheet = SpreadsheetApp.getActiveSpreadsheet().getSheetByName("Sheet1");
 var forecastSheet = SpreadsheetApp.getActiveSpreadsheet().getSheetByName("Forecasts");

 // If forecast sheet doesn't exist, create it
 if (!forecastSheet) {
 forecastSheet = SpreadsheetApp.getActiveSpreadsheet().insertSheet("Forecasts");
 // Add headers based on your sensor type
 forecastSheet.appendRow(["Timestamp", "Forecasted Value", "Upper Bound", "Lower Bound"]);
 }

 // Get historical data (last 24 hours or maximum available)
 var dataRange = sheet.getRange(2, 1, sheet.getLastRow()-1, sheet.getLastColumn());
 var values = dataRange.getValues();

 // Extract timestamps and sensor values
 var timestamps = [];
 var sensorValues = [];

 for (var i = 0; i < values.length; i++) {
 timestamps.push(values[i][0]); // Assuming timestamp is in column A
 sensorValues.push(values[i][1]); // Assuming sensor value is in column B
 }

 // Calculate forecasts using your chosen algorithm
 var forecasts = calculateForecasts(timestamps, sensorValues);

 // Clear previous forecasts
 if (forecastSheet.getLastRow() > 1) {
 forecastSheet.getRange(2, 1, forecastSheet.getLastRow()-1, 4).clear();
 }

 // Add new forecasts
 for (var i = 0; i < forecasts.length; i++) {
 forecastSheet.appendRow([
 forecasts[i].timestamp,
 forecasts[i].forecastValue,
 forecasts[i].upperBound,
```

```
 forecasts[i].lowerBound
 ]);
 }
}
// Implement your chosen forecasting algorithm
function calculateForecasts(timestamps, values) {
 var forecasts = [];

 // EXAMPLE: Simple Moving Average implementation
 // Replace with your chosen algorithm
 var windowSize = 6; // For 6-hour moving average

 // Generate forecasts for next 24 hours (at 1-hour intervals)
 var lastTimestamp = new Date(timestamps[timestamps.length - 1]);

for (var i = 1; i <= 24; i++) {
 var nextTimestamp = new Date(lastTimestamp.getTime() + (i * 60 * 60 * 1000));
 // Calculate forecast using rolling window
 var forecastValue = calculateSMA(values, windowSize);
 // Round to 2 decimal places
 forecastValue = Math.round(forecastValue * 100) / 100;
 // Add forecasted value to the values array for rolling updates
 values.push(forecastValue);
 // Add forecast with bounds
 forecasts.push({
 timestamp: nextTimestamp,
 forecastValue: forecastValue,
 upperBound: Math.round(forecastValue * 1.1 * 100) / 100,
 lowerBound: Math.round(forecastValue * 0.9 * 100) / 100
 });
}

 return forecasts;
}
// Example: Simple Moving Average implementation
function calculateSMA(values, windowSize) {
 if (values.length < windowSize) {
 windowSize = values.length; // Use all available data if not enough
 }

 var sum = 0;
 for (var i = values.length - windowSize; i < values.length; i++) {
 sum += values[i];
 }
 return sum / windowSize;
}
// Add button to sheet menu to generate forecasts manually
function onOpen() {
 var ui = SpreadsheetApp.getUi();
 ui.createMenu('Sensor Data')
 .addItem('Generate Forecasts', 'generateForecasts')
 .addItem('Clear All Data', 'clearData')
 .addToUi();
}
```

```
void loop() {
 unsigned long currentMillis = millis();

 // Check if it's time to send data
 if (currentMillis - previousMillis >= sendInterval) {
 previousMillis = currentMillis;

 // Read distance from ultrasonic sensor (in cm)
 long distance = ultrasonic.read();

 Serial.print("Distance: ");
 Serial.print(distance);
 Serial.println(" cm");

 // Send data to Google Sheets
 sendDataToGoogleSheets(distance);
 }
}
void sendDataToGoogleSheets(long distance) {
 // Check WiFi connection
 if (WiFi.status() != WL_CONNECTED) {
 Serial.println("WiFi not connected");
 return;
 }

 HTTPClient http;
 http.begin(scriptURL);
 http.addHeader("Content-Type",  "application/json");

 // Create JSON data
 StaticJsonDocument<200> doc;
 doc["distance"] = distance;

String jsonString;
 serializeJson(doc, jsonString);

 // Send HTTP POST request
 int httpResponseCode = http.POST(jsonString);

 if (httpResponseCode > 0) {
 String response = http.getString();
 Serial.println("HTTP Response code: " + String(httpResponseCode));
 Serial.println("Response: " + response);
 } else {
 Serial.print("Error on sending POST: ");
 Serial.println(httpResponseCode);
 }

 http.end();
```

APPENDIX B – ARDUINO CODE

```
#include <WiFi.h>
#include <HTTPClient.h>
#include <ArduinoJson.h>
#include <Ultrasonic.h>
// WiFi credentials
const char* ssid = "vivo V23 5G";
const char* password = "123456789";
// Google Script ID - deploy as web app and get the URL
const char* scriptURL =
"https://script.google.com/macros/s/AKfycbz8tL6KiAsTixmGAz9g8FlHeyxLuQrTqSXmqcvMtZV-
P2PpRFp7_V4ZFJyI7zOALtkV/exec";
// Ultrasonic sensor configuration
const int ultrasonicPin = 13; // Digital pin connected to ultrasonic sensor
Ultrasonic ultrasonic(ultrasonicPin);
// Data sending interval (in milliseconds)
const unsigned long sendInterval = 10000; // 10 seconds
unsigned long previousMillis = 0;
void setup() {
 // Initialize serial communication
 Serial.begin(115200);
 delay(1000);
 Serial.println("ESP32 Ultrasonic Ranger Data Logger");

 // Connect to WiFi
 WiFi.begin(ssid, password);
 Serial.print("Connecting to WiFi");
 while (WiFi.status() != WL_CONNECTED) {
 delay(500);
 Serial.print(".");
 }
 Serial.println();
 Serial.print("Connected to WiFi with IP: ");
 Serial.println(WiFi.localIP());
}

 unsigned long currentMillis = millis();

 // Check if it's time to send data
 if (currentMillis - previousMillis >= sendInterval) {
 previousMillis = currentMillis;

 // Read distance from ultrasonic sensor (in cm)
 long distance = ultrasonic.read();
2.0 PROCCES
void loop() {
 unsigned long currentMillis = millis();

 // Check if it's time to send data
 if (currentMillis - previousMillis >= sendInterval) {
 previousMillis = currentMillis;

 // Read distance from ultrasonic sensor (in cm)
 long distance = ultrasonic.read();

 Serial.print("Distance: ");
 Serial.print(distance);
```

```
 Serial.println(" cm");

 // Send data to Google Sheets
 sendDataToGoogleSheets(distance);
 }
}
void sendDataToGoogleSheets(long distance) {
 // Check WiFi connection
 if (WiFi.status() != WL_CONNECTED) {
 Serial.println("WiFi not connected");
 return;
 }

 HTTPClient http;
 http.begin(scriptURL);
 http.addHeader("Content-Type", "application/json");

 // Create JSON data
 StaticJsonDocument<200> doc;
 doc["distance"] = distance;

String jsonString;
 serializeJson(doc, jsonString);

 // Send HTTP POST request
 int httpResponseCode = http.POST(jsonString);

 if (httpResponseCode > 0) {
 String response = http.getString();
 Serial.println("HTTP Response code: " + String(httpResponseCode));
 Serial.println("Response: " + response);
 } else {
 Serial.print("Error on sending POST: ");
 Serial.println(httpResponseCode);
 }

 http.end();
```

APPENDIX C – ANDROID MainActivity.java

```
package com.example.distancemonitor;

import androidx.appcompat.app.AppCompatActivity;
import android.os.Bundle;
import android.view.View;
import android.webkit.WebSettings;
import android.webkit.WebView;
import android.webkit.WebViewClient;
import android.widget.ProgressBar;
import android.widget.Button;


public class MainActivity extends AppCompatActivity {
   private WebView dashboardWebView;
   private ProgressBar progressBar;

   @Override
   protected void onCreate(Bundle savedInstanceState) {
      super.onCreate(savedInstanceState);
      setContentView(R.layout.activity_main);

      dashboardWebView =
            findViewById(R.id.dashboardWebView);
      progressBar = findViewById(R.id.progressBar);
      Button refreshButton = findViewById(R.id.refreshButton);
      refreshButton.setOnClickListener(v -> dashboardWebView.reload());


      // Configure WebView settings
      WebSettings webSettings =
            dashboardWebView.getSettings();
      webSettings.setJavaScriptEnabled(true);
      webSettings.setDomStorageEnabled(true);
      webSettings.setLoadWithOverviewMode(true);
      webSettings.setUseWideViewPort(true);
      webSettings.setSupportZoom(true);
      webSettings.setBuiltInZoomControls(true);
      webSettings.setDisplayZoomControls(false);

      // Hide progress bar when page loads
      dashboardWebView.setWebViewClient(new
                                    WebViewClient() {
                                       @Override
                                       public void onPageFinished(WebView view, String
                                             url) {
                                          progressBar.setVisibility(View.GONE);
                                          super.onPageFinished(view, url);
                                       }
                                    });
      // Replace with your actual Looker Studio dashboard embed URL
      String dashboardUrl = "https://lookerstudio.google.com/embed/reporting/33854f6a-849e-4a8f-85da
868509b91880/page/cr8GF";
      dashboardWebView.loadUrl(dashboardUrl);

   }
```

```
    @Override
    public void onBackPressed() {
        if (dashboardWebView.canGoBack()) {
            dashboardWebView.goBack();
        } else {
            super.onBackPressed();
        }
    }
}
```

APPENDIX D – activity_main.xml

```
<?xml version="1.0" encoding="utf-8"?>
<androidx.constraintlayout.widget.ConstraintLayout
    xmlns:android="http://schemas.android.com/apk/res/android"
    xmlns:app="http://schemas.android.com/apk/res-auto"
    xmlns:tools="http://schemas.android.com/tools"
    android:layout_width="match_parent"
    android:layout_height="match_parent"
    tools:context=".MainActivity">

    <Button
        android:id="@+id/refreshButton"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:text="Refresh"
        android:layout_margin="16dp"
        app:layout_constraintTop_toTopOf="parent"
        app:layout_constraintEnd_toEndOf="parent" />

    <!-- HorizontalScrollView wrapping WebView -->
    <HorizontalScrollView
        android:id="@+id/horizontalScrollView"
        android:layout_width="0dp"
        android:layout_height="0dp"
        android:fillViewport="true"
        android:scrollbars="horizontal"
        app:layout_constraintTop_toBottomOf="@id/refreshButton"
        app:layout_constraintBottom_toBottomOf="parent"
        app:layout_constraintStart_toStartOf="parent"
        app:layout_constraintEnd_toEndOf="parent">

        <WebView
            android:id="@+id/dashboardWebView"
            android:layout_width="wrap_content"
            android:layout_height="match_parent" />
    </HorizontalScrollView>

    <ProgressBar
        android:id="@+id/progressBar"
        style="?android:attr/progressBarStyle"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        app:layout_constraintBottom_toBottomOf="parent"
        app:layout_constraintEnd_toEndOf="parent"
        app:layout_constraintStart_toStartOf="parent"
        app:layout_constraintTop_toTopOf="parent" />

</androidx.constraintlayout.widget.ConstraintLayout>
```

APPENDIX E – Android Manifest

```
<?xml version="1.0" encoding="utf-8"?>
<manifest
   xmlns:android="http://schemas.android.com/apk/res/android"
   package="com.example.distancemonitor">

   <uses-permission
      android:name="android.permission.INTERNET" />

   <application
      android:allowBackup="true"
      android:icon="@mipmap/ic_launcher"
      android:label="@string/app_name"
      android:roundIcon="@mipmap/ic_launcher_round"
      android:supportsRtl="true"
      android:theme="@style/Theme.SensorDashboard">
      <activity
         android:name="com.example.distancemonitor.MainActivity"
         android:exported="true">
         <intent-filter>
            <action
               android:name="android.intent.action.MAIN" />
            <category
               android:name="android.intent.category.LAUNCHER" />
         </intent-filter>
      </activity>
   </application>
</manifest
```