MŰEGYETEM 1782

BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS

Masters in Construction Information Technology Engineering

BTC Week Documentation 15– 19 April 2024

ADAPTOSENSE

(BTC Week Project)

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ABSTRACT

AdaptoSense is an innovative environmental monitoring system developed during the BTC week internship, designed to predict missing sensor data using Artificial Neural Networks (ANN). Utilizing Arduino sensors to measure temperature, humidity, CO2, and light levels, the system collects and transmits data to the Arduino IoT Cloud. This data is then processed by a Python-based ANN to predict missing values, ensuring continuous operation and data integrity. The project successfully demonstrated high prediction accuracy and operational efficiency, offering a cost-effective and scalable solution for real-time environmental monitoring and analysis. Future enhancements will focus on expanding sensor networks, integrating advanced machine learning models, and improving user interfaces.

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INTRODUCTION

General Overview on BTC week

During the BTC week, our focus revolved around energy simulation and the effective utilization of sensors for smart building applications. Our main aim was to conceptualize and deploy sensor systems utilizing Arduino technology alongside a variety of sensors. Teams were formed, with each group choosing a specific room type within the facility to concentrate their efforts on.

Figure 1: BTC building Ground floor working location

Our group has chosen room three, which serves as a venue for lectures accommodating more than 20 people. This room features seating arrangements, whiteboards, a projector, and a partially glazed wall.

Our concept involves gathering data from sensors, and the system will forecast data for any malfunctioning or broken sensors until they are repaired.

ADAPTOSENSE PROJECT

Project Overview

AdaptoSense is an Artificial Neural Network (ANN)-based system designed to predict missing sensor data (temperature, humidity, CO2, light) in a room using internal and external weather data. The project was developed during our BTC week at Balatonfured.

Logo:

Figure 2: AdaptoSense Logo

Slogan: *Sensing, Adapting, and Predicting*

Objectives

1. **Data Collection**: Use Arduino sensors to measure temperature, humidity, CO2, and light levels in a room.
2. **Data Prediction**: Utilize an ANN to predict missing sensor values based on collected data.
3. **Continuous Operation**: Ensure the system operates continuously, even with missing data, by using predicted values.

Project Technical Details

1. **Hardware Setup**:
    - **Arduino MKR Wi-Fi 1010**: Central processing unit for data collection.
    - **Sensors Used**:
        - Digital Temperature Sensor
        - Photoresistor Sensor (Light measurement)
        - CO2 and Humidity Sensor
        - OPLA Weather Station for external weather data
    - **Prototype Shield**: Enabled wireless communication for data transmission.

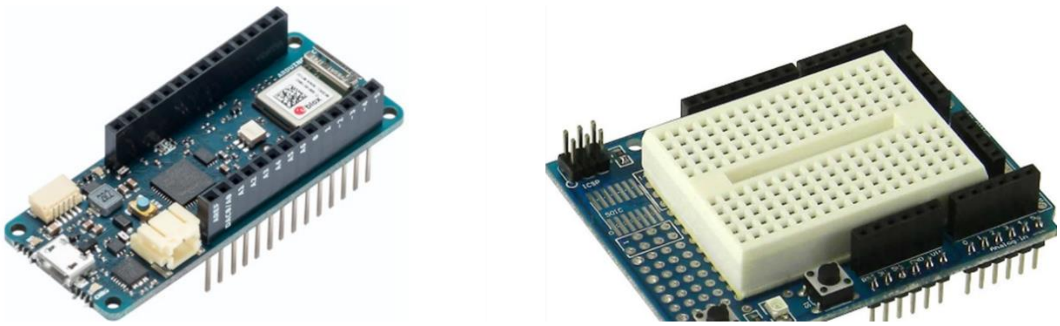

Figure 3: Arduino MKR and Prototype Shield

Figure 4: Sensors used in project

2. **Software Used**:
    - **Arduino Sketch IDE**: For programming the Arduino board.
    - **Python**: For developing and training the ANN, primarily using Google Colab.
    - **Excel**: For data management and creating CSV files for training the ANN.

ARDUINO

Figure 5: Software used in project

3. **Data Collection**:
    - Data was collected in 5-second intervals over several days.
    - External weather data was continuously logged from the OPLA weather station.

4. **Location:**
    - Conference Room Located on the ground floor BTC Building
    - Spacious lecture room with two external wall, one glasswall with doors, one internal wall with huge, wall-to-wall windows

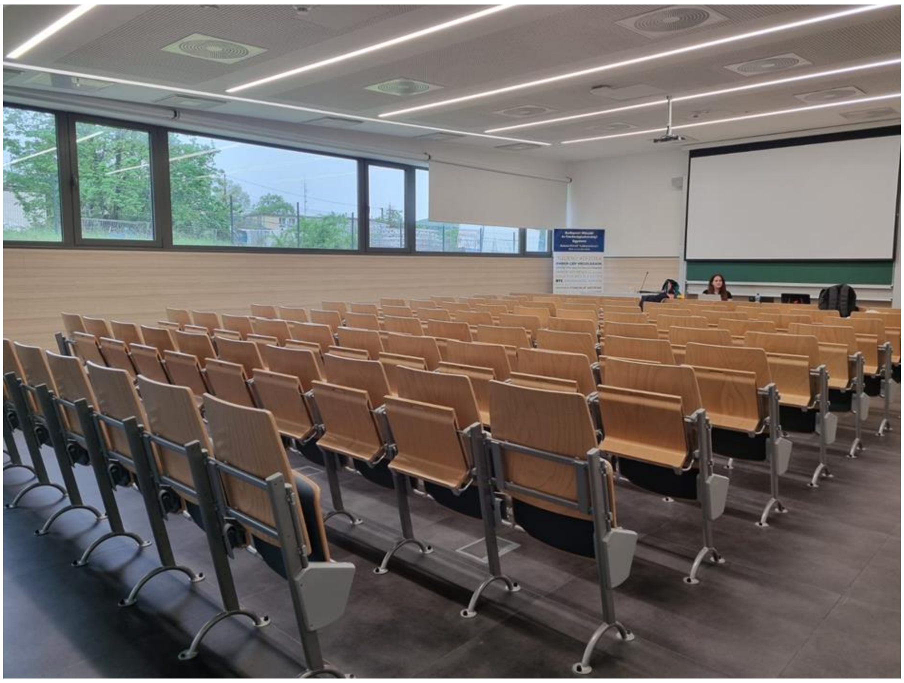

Figure 6: Location used for project; conference room

5. Project Overall Configuration

1. **Sensor Data Collection**:
    - **Hardware**: Arduino MKR Wi-Fi 1010 with various sensors (temperature, humidity, CO2, light).
    - **Process**: Sensors gather environmental data at 5-second intervals.
2. **Data Transmission**:
    - **Platform**: Arduino IoT Cloud.
    - **Process**: Sensor data is sent to the cloud for storage and remote access.
3. **Data Processing**:
    - **Software**: Python (Google Colab).
    - **Process**: Data is preprocessed and loaded into the Artificial Neural Network (ANN).
4. **Value Prediction**:
    - **Neural Network**: Trained ANN predicts missing sensor values based on collected data.
    - **Outcome**: Predicted values are used to maintain continuous operation and data integrity.

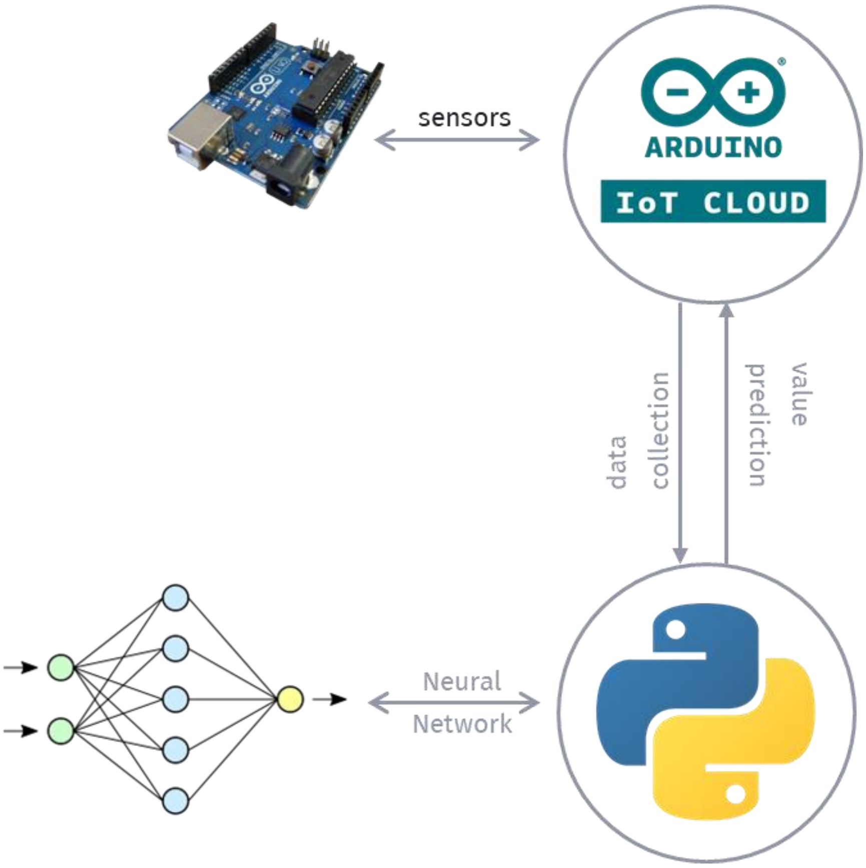

Figure 7: Project work process flow chart

6. **ANN Details**:

- Input Layer: 7 nodes (representing various sensor inputs).
- Hidden Layer: 70 nodes.
- Output Layer: 1 node (predicted value).
- Training involved 100 epochs using a sigmoid activation function and gradient descent for optimization.

AdaptoSense ANN Model

1. ANN Architecture

The ANN model consist of

1. **An Input Layer** (7 Nodes): can vary as per requirement
2. **A Hidden Layer** (Nodes =70): Can be vary as per requirement
3. **An Output Layer** (Nodes = 1): Can be vary as per requirement

    1. **No. of epoch:** 100 : can be changed

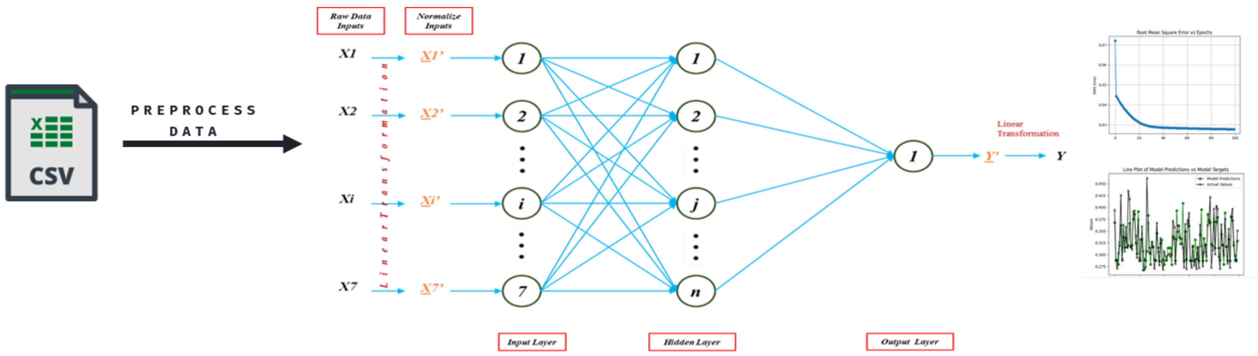

Figure 8: ANN Architecture

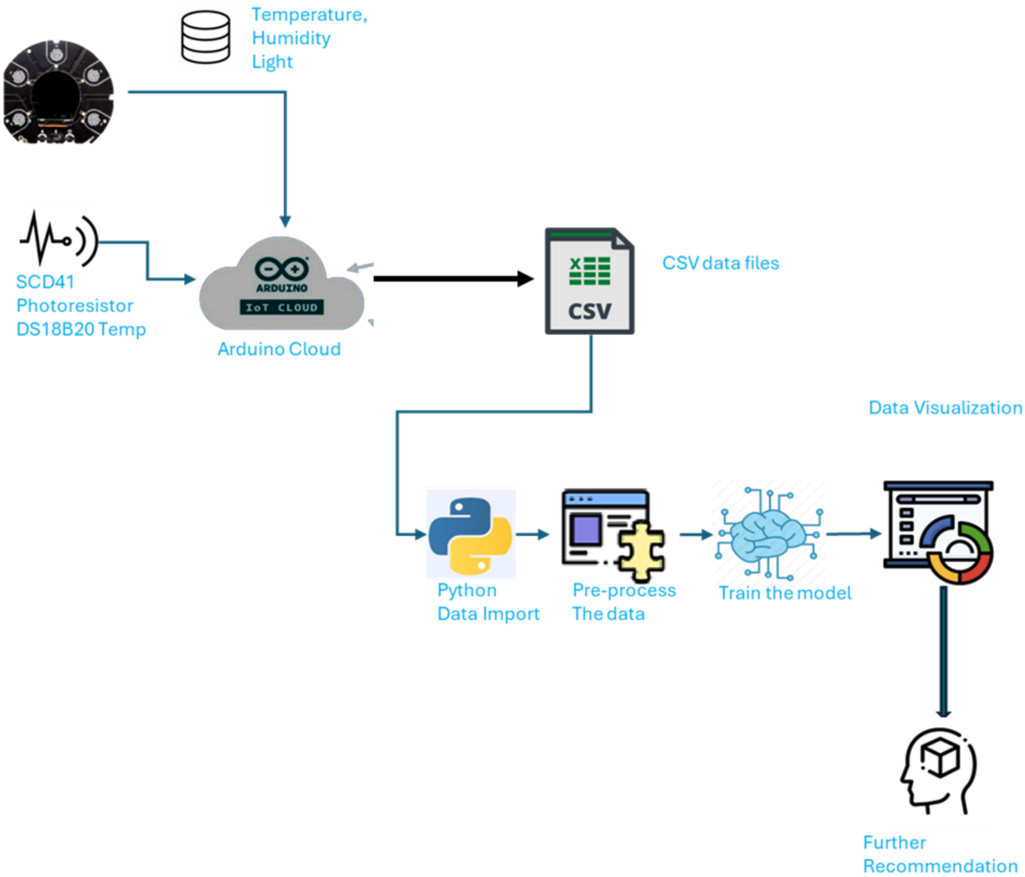

Figure 9: ANN workflow process

BTC WEEK WORK FLOW DETAILS

Day 1 – 15/04/2024

On our first day at BALATONFÜREDI TUDÁSCENTRUM (BTC), we simply arrived to explore the premises. The building features a ground floor, first floor, and a roof.

Figure 10: Balatonfüredi Tudáscentrum Building

Our attention will be directed towards the ground floor, as that is where our project will be located in the audience room.

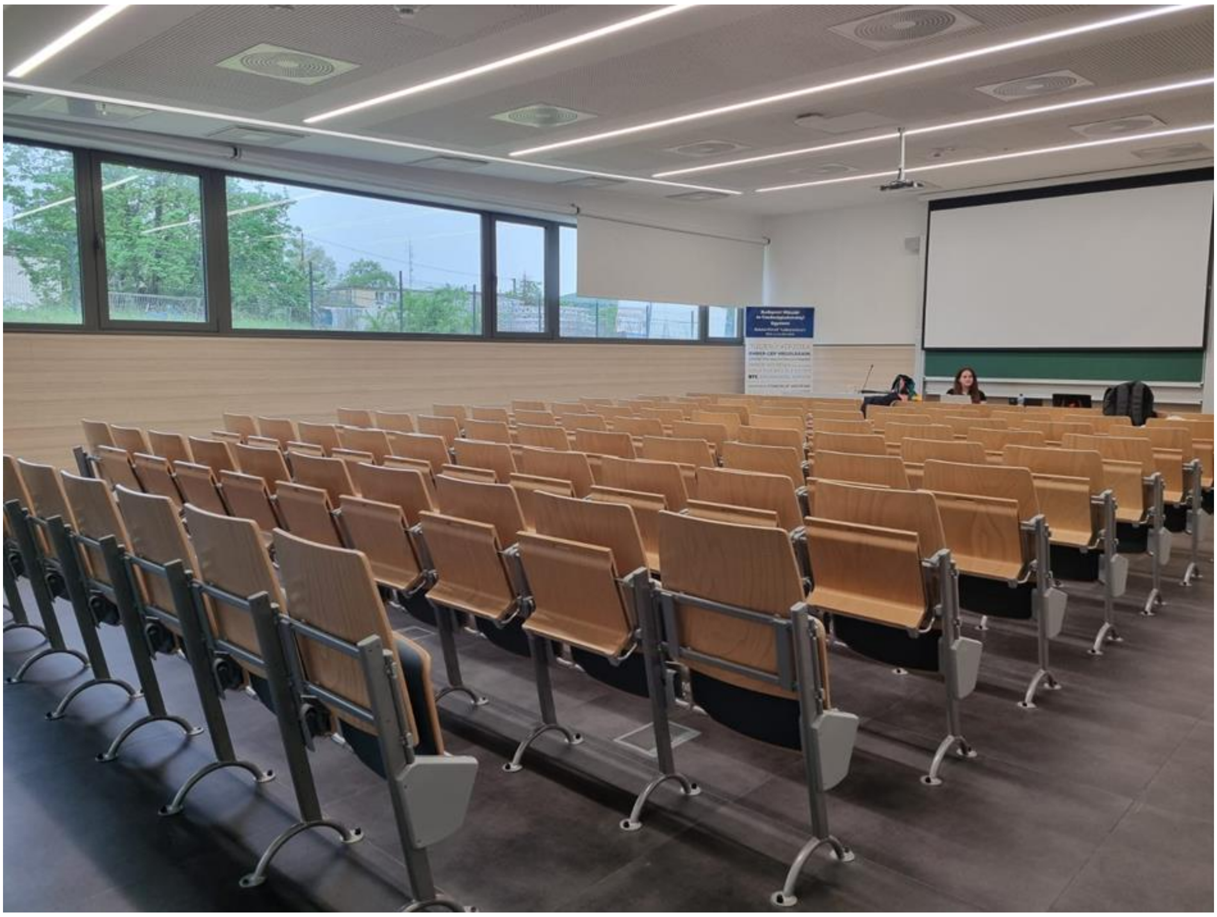

Figure 11: BTC Audience Room

Day 2 – 16/04/2024

On the following day, we commence the installation of sensors and wiring.

The components utilized in the project include:

- Arduino MKR Wi-Fi 1010
- Arduino UNO

Sensors:

- Digital temperature sensor :

Role: Measure ambient temperature.

- Photoresistor sensor:

Role: Measure ambient brightness.

- CO2 sensor:

Role: Measure the concentration of carbon dioxide in the air and the humidity of the air.

Figure 12: SCD41 Sensor, Photoresistor, Digital Temperature reader

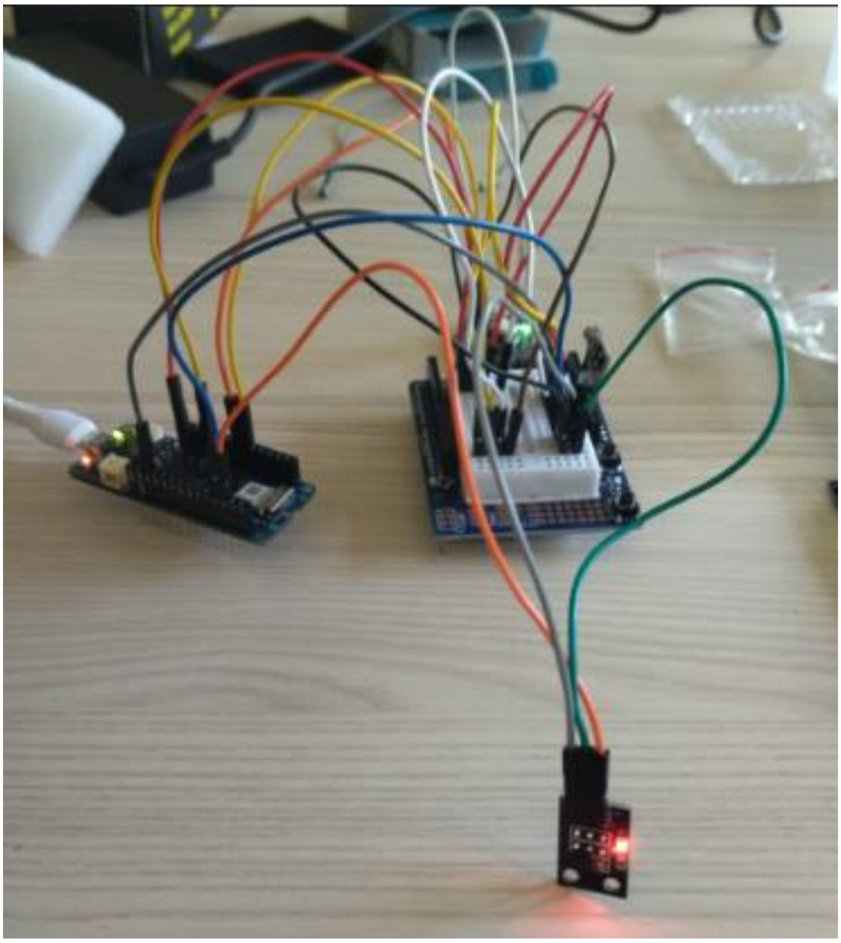

Figure 13: Circuit Connections

Overall, the combination of these different sensors offers a holistic approach to monitor and anticipate potential failures. By linking the data collected by each sensor, we can detect anomalies and unusual trends that may indicate a malfunction. For example, if a temperature and humidity sensor reports abnormal conditions but the other sensors record normal values, it could indicate a failure of the temperature and humidity sensor.

By using machine learning techniques and predictive modeling, we can leverage this relationship between sensors to predict the data of a failing sensor based on data from other sensors. This ability to extrapolate missing or corrupted data is essential for ensuring reliability and continuity of operations in various environments.

In conclusion, by integrating these sensors and exploiting their relationships, we can develop advanced monitoring systems capable of detecting failures, predicting breakdowns, and taking preventive measures, thus ensuring optimal performance and proactive maintenance of monitored equipment and environments.

Day 3/4 – 17/04/2024 - 18/04/2024

The idea involves developing a code that predicts the status of malfunctioning sensors. Here's how the process could work:

1. Initial data collection: Firstly, we gather data from all sensors under normal operating conditions. This provides us with a baseline for the correct functioning of the system.
2. Systematic deactivation of sensors: Next, we deactivate one sensor at a time while keeping the others active. The deactivated sensor is considered potentially faulty.
3. Data collection under each scenario: Under each configuration where a sensor is deactivated, we collect data. This gives us a view of how the system responds in the absence of that specific sensor.
4. Repetition for each sensor: We repeat this process for each sensor, deactivating them one by one.
5. Comparison of collected data: Once we have collected data for each scenario, we compare them. This allows us to determine if certain configurations have a significant impact on the system's performance. Configurations where the collected data differs significantly from the baseline may indicate an issue with the deactivated sensor.
6. Evaluation of system effectiveness: By analyzing the collected data, we evaluate the effectiveness of the system in predicting the status of malfunctioning sensors. If the system can effectively detect faulty sensors by analyzing the collected data in different deactivation scenarios, it confirms its utility and reliability.

In summary, this approach allows testing the resilience of the system by simulating individual sensor failures. It also provides data to train a sensor failure prediction model, thereby enhancing preventive maintenance and system reliability.

IMPLEMENTATION OF ADAPTOSENSE

Scenario 1 : All Sensor Working

Case:

Table 1: Scanerio 1 discription

Sensors	On	Off
Temp & humidity sensor	✕	
Photoresistor sensor	✕	
CO2 sensor	✕	
Yoda weather station	✕	

Observation:

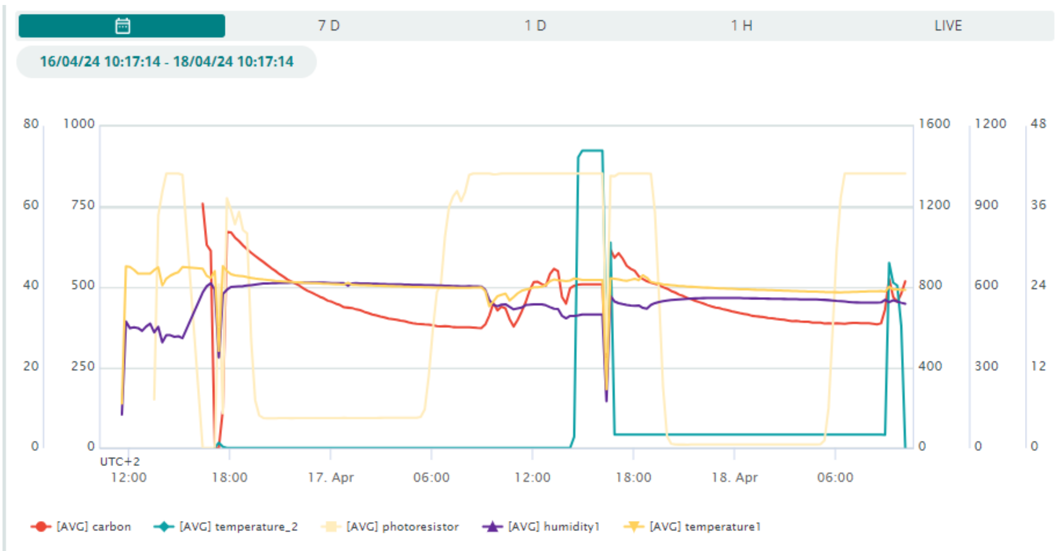

Figure 14: Adaptosense monitoring using Arduino Cloud

Remarks:

The system operates smoothly without any issues. All sensors are actively collecting data as intended, providing accurate information about the monitored parameters. This scenario represents the ideal state where the system is functioning as expected.

Scenario 2: CO2 Sensor Stopped Working

Table 2: Scanerio 2 discription

Sensors	On	Off
CO2 sensor		×
Photoresistor sensor	×	
Humidity sensor	×	
Temperature sensor	×	
Yoda weather station	×	

Observation:

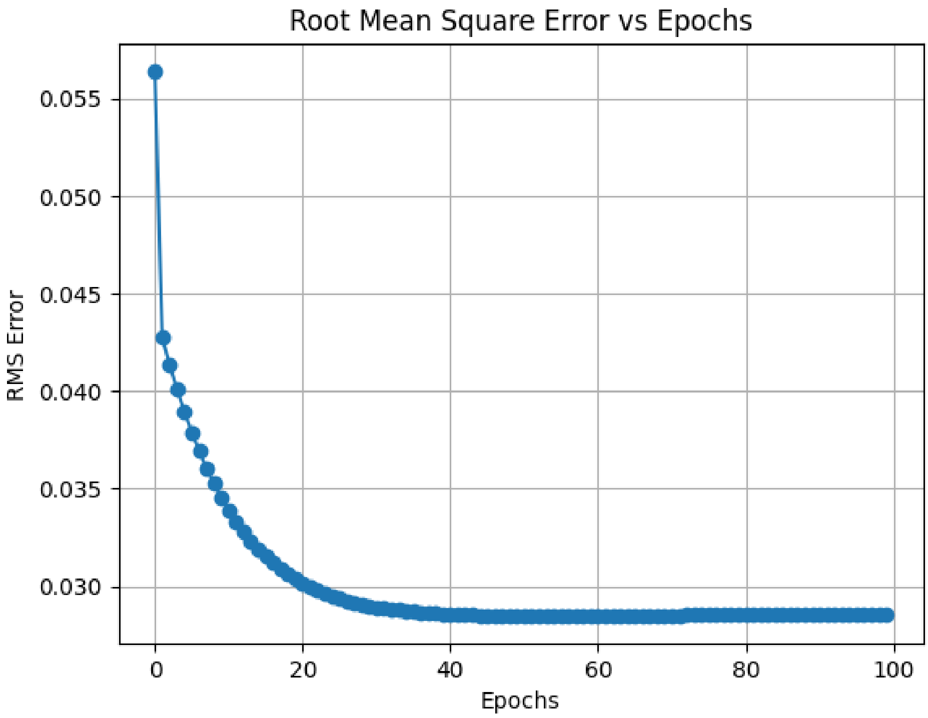

Figure 15: ANN Training Curve for Scanerio 2

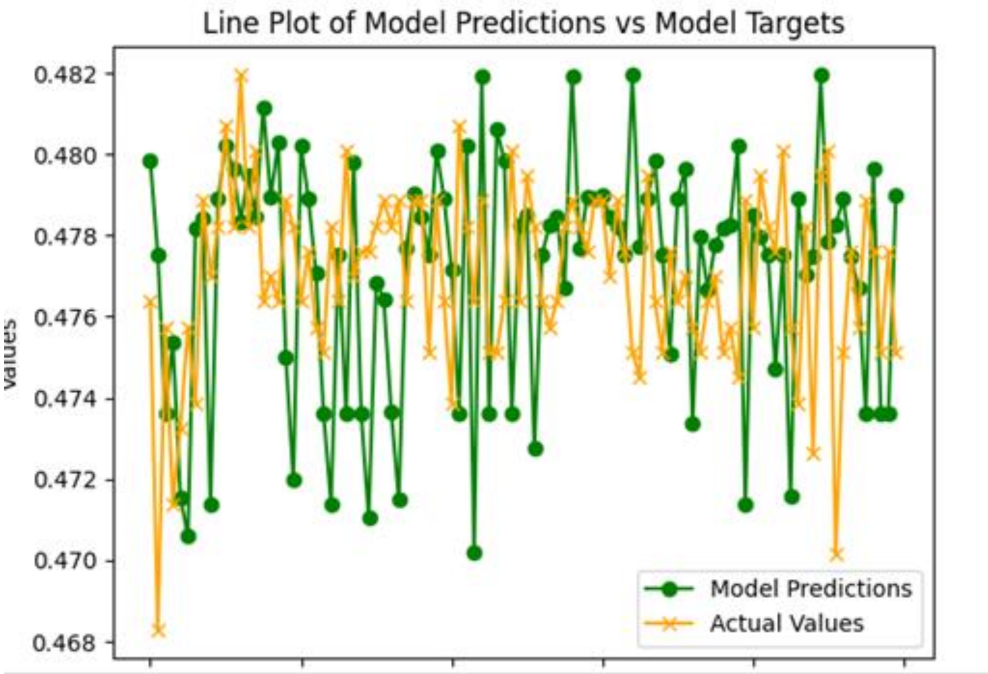

Figure 16: ANN Prediction curve for CO2 Scanerio 2

Remarks:

the code exhibits an impressive 95% accuracy in predicting sensor malfunctions, specifically demonstrated in Scenario 2 where only the CO2 sensor was deactivated. This outcome underscores the reliability of the solution, offering promising opportunities for enhancing preventive maintenance and system resilience.

Scenario 3: Photoresistor Sensor Stopped Working

Table 3:Scanerio 3 discription

Sensors	On	Off
CO2 sensor	✕	
Photoresistor sensor		✕
Humidity sensor	✕	
Temperature sensor	✕	
Yoda weather station	✕	

Observation:

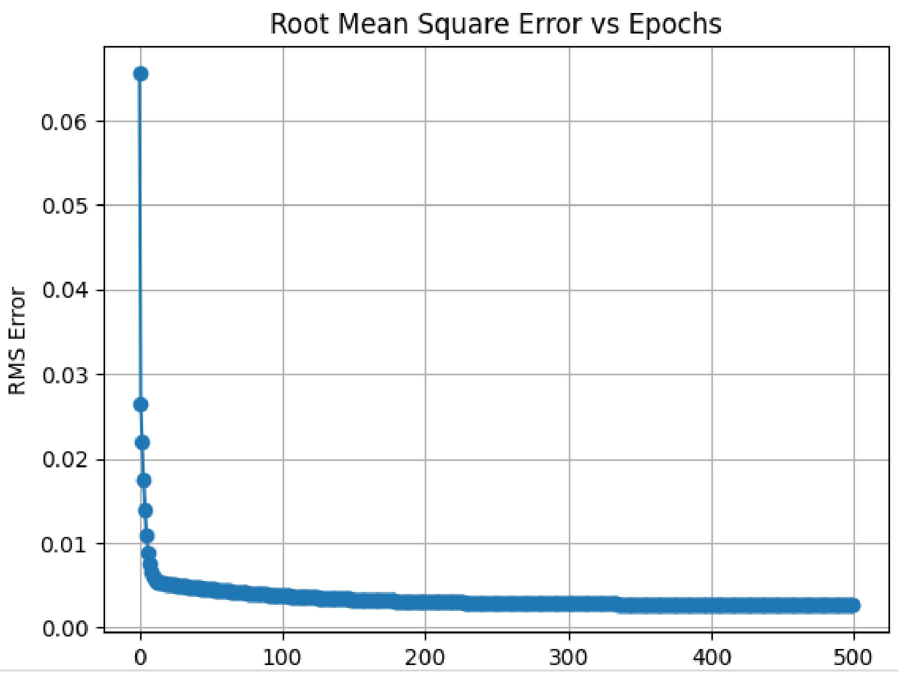

Figure 17: ANN training curve for scanerio 3

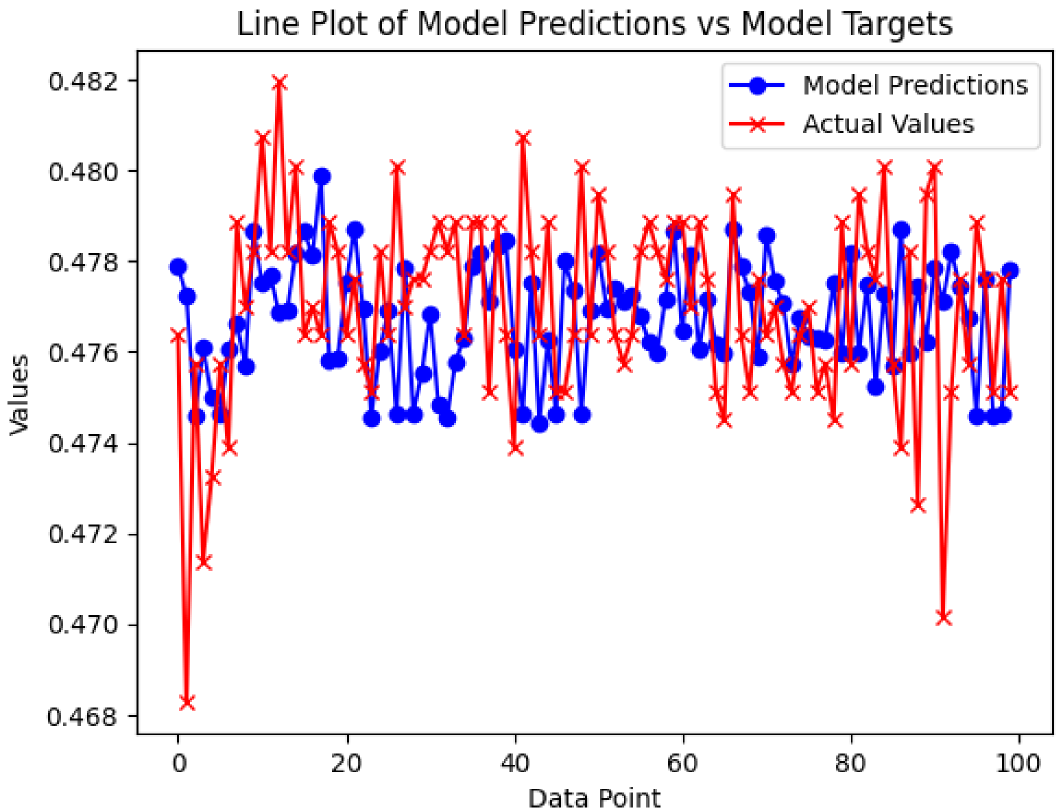

Figure 18: ANN Prediction Curve for Scanerio 3

Remarks:

The code showcases an impressive 95.9 % accuracy in predicting sensor malfunctions, as evidenced in Scenario 3 where the photoresistor sensor was deactivated. This successful outcome underscores the reliability of the solution, offering promising avenues for enhancing preventive maintenance and overall system resilience.

Scenario 4: Humidity Sensor Stopped working

Table 4:Scanerio 4 discription

Sensors	On	Off
CO2 sensor	✕	
Photoresistor sensor	✕	
Humidity sensor		✕
Temperature sensor	✕	
Yoda weather station	✕	

Observation :

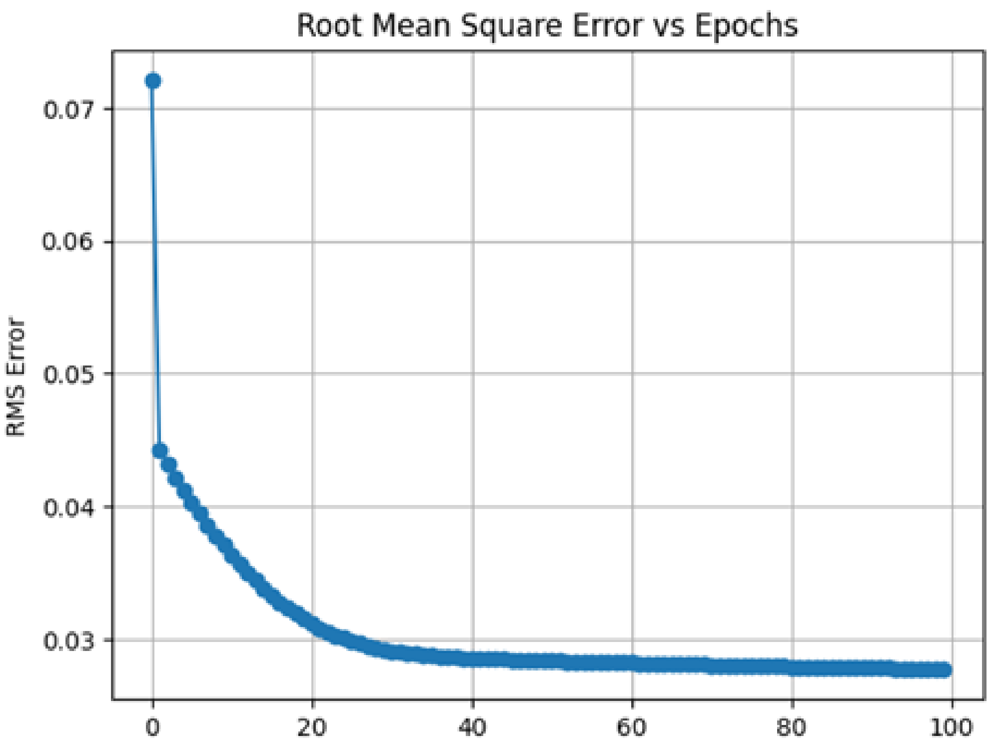

Figure 19: ANN Training curve for Scanerio 4

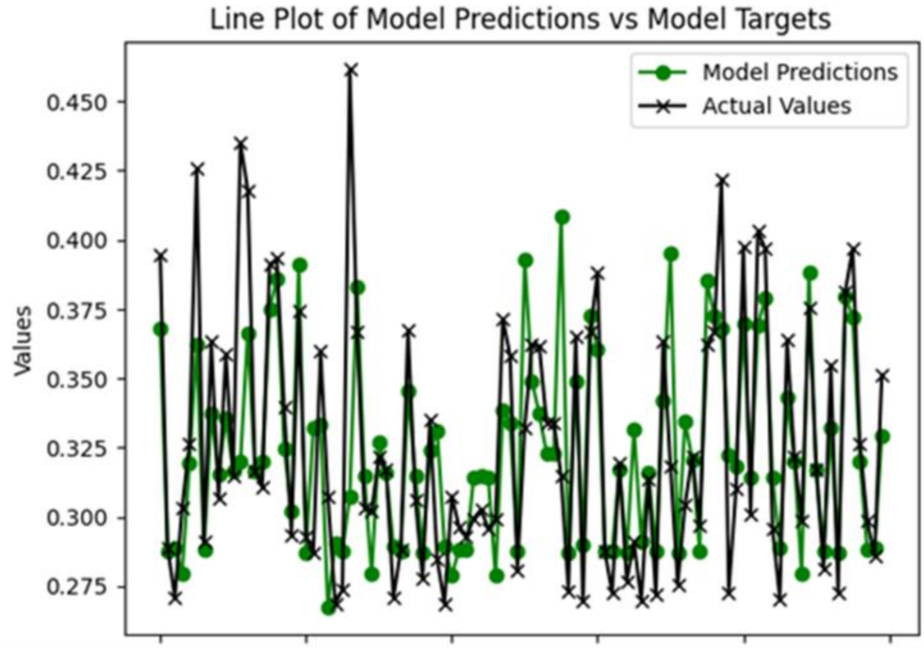

Figure 20: ANN prediction curve for Scanerio 4

Remarks:

The code exhibits an impressive 99.99% accuracy in predicting sensor malfunctions, as highlighted in Scenario 4 where the humidity sensor was deactivated. This robust performance underscores the reliability of the solution and its efficacy in identifying potential issues within the sensor network. Such results offer valuable insights for enhancing preventive maintenance strategies and fortifying the system's resilience against sensor failures.

Scenario 5: Temperature 2 Sensor Stopped Working

Table 5: Scanerio 5 discription

Sensors	On	Off
CO2 sensor	✕	
Photoresistor sensor	✕	
Humidity sensor	✕	
Temperature sensor		✕
Yoda weather station	✕	

Observation:

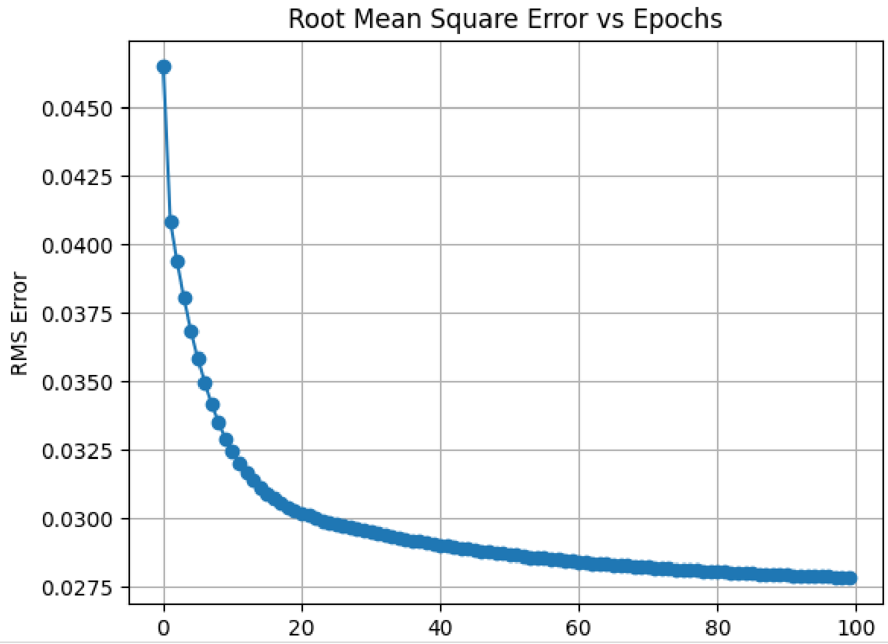

Figure 21: ANN Training curve for Scanerio 5

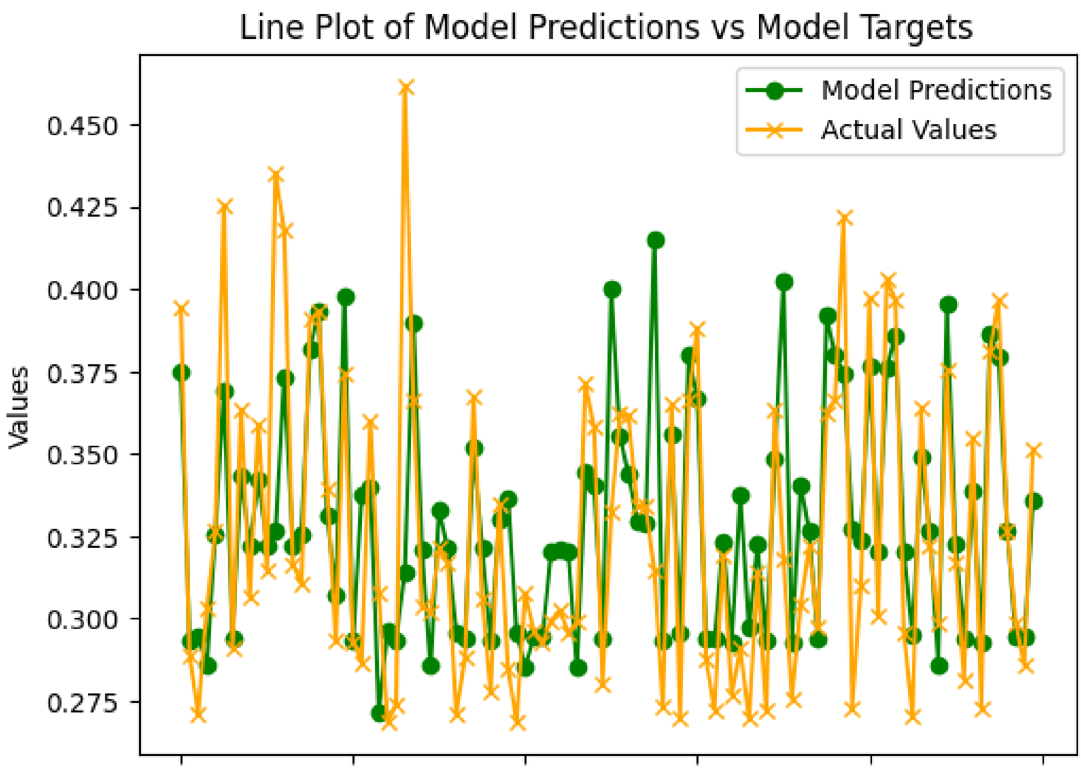

Figure 22: ANN prediction curve for scanerio 5

Remarks:

The code demonstrates a commendable 99.99 % accuracy in predicting sensor malfunctions, exemplified in Scenario 5 where the temperature sensor was deactivated. This successful outcome reaffirms the reliability of the solution and its capacity to effectively identify anomalies within the sensor array. Such findings hold promise for optimizing preventive maintenance protocols and bolstering the system's robustness in the face of sensor failures.

CONCLUSION

The AdaptoSense project demonstrated a successful integration of data collection with Arduino sensors and ANN-based prediction. The system effectively ensured data integrity and operational continuity, with the neural network learning to make predictions with up to 99% accuracy. The collaboration of Arduino Cloud and Python in Google Colab proved to be a robust solution for handling and analyzing sensor data.

CHALLENGES AND SOLUTION RECOMMENDATIONS

Challenges

1. **Sensor Accuracy and Calibration**:
   - **Issue**: Ensuring the accuracy of the sensors, particularly when dealing with different environmental conditions.
   - **Impact**: Inaccurate data can lead to incorrect predictions and compromised system reliability.
   - **Solution**: Regular calibration and validation with independent measurement tools.
2. **Data Transmission Reliability**:
   - **Issue**: Maintaining consistent and reliable data transmission to the cloud.
   - **Impact**: Network interruptions can cause data loss and affect the ANN's ability to make accurate predictions.
   - **Solution**: Implement redundant data storage and transmission methods.
3. **Neural Network Training**:
   - **Issue**: Training the ANN to achieve high accuracy requires large amounts of quality data.
   - **Impact**: Insufficient or poor-quality data can lead to lower prediction accuracy.
   - **Solution**: Collect extensive datasets and use advanced preprocessing techniques.
4. **Integration with Existing Systems**:
   - **Issue**: Integrating AdaptoSense with existing building management systems.
   - **Impact**: Compatibility issues can hinder seamless operation and data utilization.
   - **Solution**: Develop standardized interfaces and protocols for integration.
5. **Scalability**:
   - **Issue**: Scaling the system to monitor multiple rooms or buildings.
   - **Impact**: Increased complexity in data management and processing.
   - **Solution**: Use cloud-based solutions to handle large-scale data and processing needs.

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