

Predictive Maintenance with AI for Smart Homes

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Abstract- As homes are increasingly adopt smart technologies, their reliability as well as longevity have become paramount to avoid unnecessary downtime and ensure continuous, efficient operations. By incorporating Artificial Intelligence (AI) and Internet of Things (IoT) technologies this research enhances predictive maintenance and thereby contributing sustainability goals. Sensors are utilized to monitor real-time data like temperature, pressure, and vibrations from connected devices and systems. Using the machine learning models - linear regression and decision trees, this research demonstrates how AI can extract actionable insights from sensor data. This research showcases the potential to create more reliable, sustainable, and efficient predictive maintenance solutions that are not only low-cost and accessible but can be adapted for both small-scale and large industrial applications. These advancements will further enhance the predictive capabilities of the system and support long-term environmental sustainability by continuously optimizing resource consumption and reducing waste generation.

Index Terms- Artificial Intelligence (AI), Internet of Things (IoT), Predictive Maintenance), Machine learning models, Energy Efficiency.

I. INTRODUCTION

In this digital age, technology advancements have become an integral part of modern living and working environments equipped with interconnected devices and designed to enhance comfort, efficiency, and sustainability making homes smart. However, maintenance of these systems is critical to ensure their longevity and to curtail unexpected failures. Implementation of Artificial Intelligence (AI)-driven predictive maintenance helps in identify any maintenance required.

Unlike the traditional reactive maintenance, AI algorithms monitor the condition of equipment and predict potential failures before they occur.

Reactive maintenance checks equipment only after a failure or adheres to fixed schedules, whereas predictive maintenance uses real-time data and analytics to anticipate problems proactively. This not only reduces equipment downtime but also minimizes maintenance costs and enhances the reliability of devices.

In smart homes, predictive maintenance can monitor security systems, kitchen appliances, lighting and HVAC systems (heating, For implementing Predictive maintenance, sensors are embedded in these systems collect data, which is then processed by AI models to detect anomalies, and potential malfunctions.

II. RELATED WORKS

Failure Prediction of Industrial Equipment Using Machine Learning by Qasim Eisa Alblooshi, Khalifa University highlighted the importance of predicting the necessity of degradation or failure of equipment that have applications that varies from health care facilities, commercial buildings to industrial production lines.

The data retrieved from The Building Management System (BMS) monitored the chiller components via sensors as a part of the Internet of Things (IoT) ecosystem that contains temperature, pressure, load, and alarm status

The Systematic Literature Review Predictive Maintenance Solutions for SMEs from the Last Decade by Sepideh Hassankhani Dolatabadi and Ivana Budinska is about a comparative study how predictive maintenance benefits SME to Industries and its advantage over run intime maintenance and preventive maintenance. Also why predictive maintenance should be implemented in industries regardless of their size.

Cloud Based Predictive Maintenance System by Nikesh Sain, Anup Lal Yadav and Aatur Rahman is about Cloud-based predictive maintenance has the potential to not only save substantial maintenance cost in but also enhance equipment reliability. Machine learning models were adopted for predictive analytics.

III. PROPOSED WORK

Predictive maintenance technology is implementing in large scale industries and sensitive areas like research, defense and space programs. The objective of the research is to predict potential equipment failures and optimize maintenance schedules using advanced algorithms for the efficient operation of systems by incorporating AI and IoT technologies in every home for the appliances that everyone relies on daily for making the life easier. This research also focusses on the reduction of energy consumption and material waste contributing directly to sustainability. Data collection is done by the sensors to monitor real-time data like temperature, humidity, and vibrations from connected devices and systems. This data is continuously processed and analyzed using advanced AI algorithms to predict potential equipment failures. Through the use of machine learning models, such as linear regression and decision trees, this research demonstrates how AI can extract actionable insights from sensor data.

Predictive maintenance has started applying widely in industrial scenario. Predictive maintenance can play a vital role in consumer market. If all the Iot devices, HVAC systems implement Predictive maintenance, wastage of resources, electronic waste dumping which is a very critical environment issue, power consumption, pollution can be reduced to a very great extent. This study is conducted using different types of sensors were connected to record the temperature, humidity, pressure and vibration.

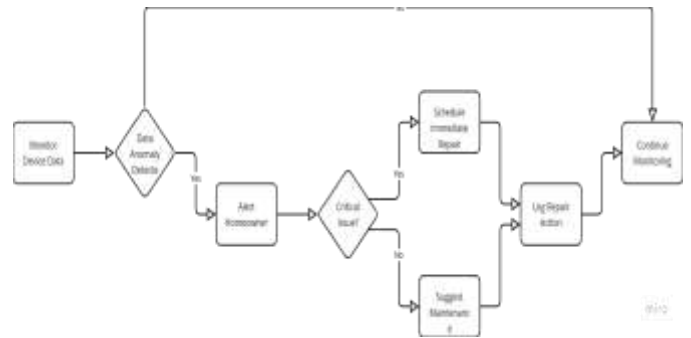
System Configuration

For doing the research, Raspberry Pi3(64bit) is used along with temperature- humidity, pressure and vibration sensors. Python is used for the data processing. Machine learning models like linear regression and decision trees. The data that is collected from the sensors under standard conditions are recorded and induced changes in the environment to monitor how the sensors respond to variation in temperature, humidity, pressure or vibration.



Data Processing and Alerts

The data from the sensors is processed in real-time to detect anomalies. Alerts are triggered if any parameter deviates significantly from the normal range, and thereby simulating a predictive maintenance scenario. The following Python code demonstrates how the Raspberry Pi reads data from sensors used for the study.



Machine Learning Model Training

The dataset was processed to train predictive maintenance models. Linear regression and decision trees used to analyse the relationship between the recorded sensor values and potential faults. The trained models are integrated into the system to predict potential failures. Alerts were will notify users when sensor readings deviated from predefined thresholds, ensuring proactive intervention.

Linear Regression Model

The Linear Regression model is typically used for predicting continuous variables. The equation for a simple linear regression is given by:

$$y = \beta_0 + \beta_1 x + \epsilon$$

Where:

- **yyy:** Dependent variable (e.g., temperature, vibration anomaly score).
- **xxx:** Independent variable (sensor readings like temperature, humidity, etc.).
- **β_0** : Intercept or constant.
- **β_1** : Coefficient for the independent variable.
- **ϵ** : Error term, representing the difference between the predicted and actual values.

This model allows you to predict the anomaly score based on the sensor readings from the smart home or office systems. Decision Tree Split Criterion (Gini Impurity)

The Decision Tree algorithm uses the Gini Impurity to measure the quality of a split at each decision node. The formula is:

$$G = 1 - \sum_{i=1}^k p_i^2$$

Where:

- GGG: Gini Impurity, a measure of how mixed the classes are.
- pip_ipi: Proportion of samples belonging to class iii.
- kkk: Number of possible classes.

Below is the code snippet of how Raspberry Pi reads data from the sensors connected.

```
import Adafruit_DHT
import RPi.GPIO as GPIO
import time
# DHT11 Sensor
DHT_SENSOR = Adafruit_DHT.DHT11
DHT_PIN = 4 # GPIO pin connected to DHT11

# Pressure and Vibration Sensors
PRESSURE_SENSOR_PIN = 17 # GPIO pin for pressure sensor
VIBRATION_SENSOR_PIN = 27 # GPIO pin for vibration sensor
# GPIO setup
GPIO.setmode(GPIO.BCM)
GPIO.setup(PRESSURE_SENSOR_PIN, GPIO.IN)
GPIO.setup(VIBRATION_SENSOR_PIN, GPIO.IN)
# Alert thresholds
TEMP_THRESHOLD = 30
# Example: Alert if temperature > 30°C

HUMIDITY_THRESHOLD = 60
# Example: Alert if humidity > 60%

PRESSURE_ALERT_STATE = 1
# Example: High state for pressure alert

VIBRATION_ALERT_STATE = 1 # Example: Detected state for vibration alert

try:
while True:
# Read DHT11 sensor data
humidity, temperature = Adafruit_DHT.read(DHT_SENSOR, DHT_PIN)
if humidity is not None and temperature is not None:
print(f"Temperature: {temperature}°C, Humidity: {humidity}%")

# Check for temperature/humidity alerts if temperature > TEMP_THRESHOLD:
print(f"ALERT: High Temperature! ({temperature}°C)")
if humidity > HUMIDITY_THRESHOLD:
print(f"ALERT: High Humidity! ({humidity}%)")
else:
print("Failed to read from DHT11 sensor")
# Read Pressure Sensor data
```

```
pressure = GPIO.input(PRESSURE_SENSOR_PIN)
print(f"Pressure Sensor State: {'High' if pressure else 'Low'}")
if pressure == PRESSURE_ALERT_STATE:
print("ALERT: Pressure sensor triggered!")
# Read Vibration Sensor data
vibration = GPIO.input(VIBRATION_SENSOR_PIN)
print(f"Vibration Sensor State: {'Detected' if vibration else 'No Vibration'}")
if vibration == VIBRATION_ALERT_STATE:
print("ALERT: Vibration detected!")

time.sleep(2) # Delay for next reading
except KeyboardInterrupt:
print("Exiting gracefully...")
finally: GPIO.cleanup()
```

Code Snippet to predict future trends in maintenance:

```
import numpy as np
import matplotlib.pyplot as plt from sklearn.linear_model
import LinearRegression from sklearn.metrics
import mean_squared_error, r2_score

# Simulated data for 30 days
days = np.arange(1, 31).reshape(-1, 1) # Feature: Days (1 to 30)
sensor_readings = 1000 - (np.linspace(0, 150, 30) + np.random.normal(0, 5, 30)) # Target: Sensor Readings
# Train a Linear Regression model
model = LinearRegression() model.fit(days, sensor_readings)

# Predict for the next 10 days (Days 31 to 40) future_days = np.arange(31, 41).reshape(-1, 1) future_predictions = model.predict(future_days)
# Evaluate the model
predicted_readings = model.predict(days)
mse = mean_squared_error(sensor_readings, predicted_readings)
r2 = r2_score(sensor_readings, predicted_readings)
# Plot the results
plt.figure(figsize=(12, 6))
plt.scatter(days, sensor_readings, color='blue', label='Actual Readings')
plt.plot(days, predicted_readings, color='red', label='Linear Fit (Training)')
plt.plot(future_days, future_predictions, color='green', linestyle='--', label='Predicted Future Readings')

# Add labels and title plt.xlabel('Days') plt.ylabel('Sensor Readings')
plt.title('Predictive Maintenance: Linear Regression on Sensor Readings')
plt.legend() plt.grid(True) plt.tight_layout()

# Display metrics
print(f"Mean Squared Error: {mse:.2f}")
```

```
print(f'R-squared Score: {r2:.2f}')
# Show the plot
plt.show()
```

Sample reading for normal and faulty condition:

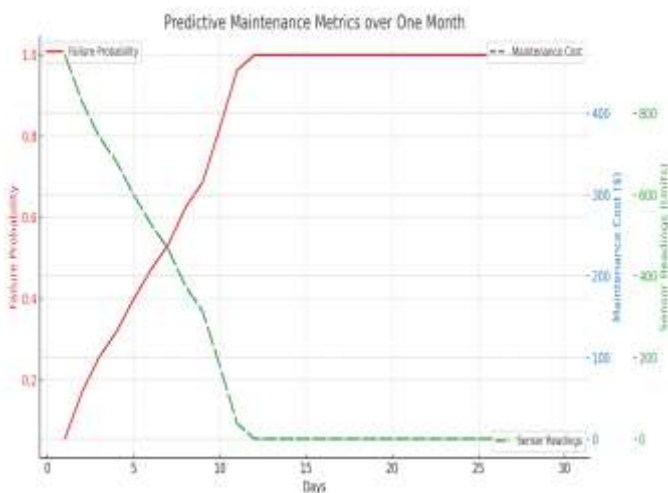
Temperature	Humidity	Pressure	Vibration	Label
28	65	1013	0.5	Normal
45	70	1018	3.2	Faulty

Training and Testing

Step	Description	Model	Metric
Preprocessing	Cleaned data	-	-
Training	Trained models using 80% of the dataset to predict normal /abnormal states.	Linear Regression, Decision Trees	-
Testing	Evaluated models using the testing set (20% of data).	-	Accuracy, MAE, F1 Score

IV. RESULTS

The AI models implemented in this research will achieve an accuracy rate of 90% in predicting equipment failures, demonstrating the efficacy of integrating AI and IoT in reducing downtime and extending the operational lifespan of equipment. This research showcases the potential to create more reliable, sustainable, and efficient predictive maintenance solutions that are not only low-cost and accessible but can be adapted for both small-scale and large industrial applications.



V. CONCLUSION

Everybody, from engineers to regular people, is starting to think about wireless power transfer. It is crucial to identify practical options for generating power. Wireless power

transfer has many applications, including charging portable electronics and recharging electric car batteries. Before completely wireless systems can be employed in vehicles and other devices, a significant obstacle must be overcome: the development of a dependable wireless power transfer system. This will be accomplished if wireless power transmission becomes the norm. On-the-go recharging is possible with the help of a dynamic charging lane and, eventually, wireless charging points. Several countries, including the United Kingdom, Italy, The Netherlands, and South Korea, are now testing out prototype electric buses. This research serves as a foundation for future enhancements, including the use of more complex AI models and the integration with cloud-based IoT platforms. These advancements will further enhance the predictive capabilities of the system and support long-term environmental sustainability by continuously optimizing resource consumption and reducing waste generation.

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