Use Case Document: IoT Edge AI-Driven Predictive Maintenance and Quality Inspection System for Industrial Efficiency

Domain: Maintenances & Inspection

Use Case Name: IoT Edge AI-Driven Predictive Maintenance and Quality Inspection System for Industrial Efficiency

Use Case Description: This use case describes IoT devices are used to collect real-time data such as vibration and temperature from industrial equipment. This data is analyzed locally using Edge AI models to predict potential failures or detect quality issues. When anomalies are detected, the system automatically sends alerts to operators or managers. This enables them to take proactive actions to prevent equipment failures or address quality problems before they escalate, improving operational efficiency and reducing downtime.

Use Case Goal: To predict equipment failures and detect quality issues in real-time, ensuring industrial efficiency and minimizing downtime.

Actor: Industrial Operator/Manager

Pre-Conditions:

- IoT devices are installed on equipment to collect real-time data.
- AI models are trained on historical data to predict failures and detect anomalies.

Post-Conditions:

- Reduced downtime and increased industrial efficiency.
- Improved product quality and reduced waste.
- Cost savings through predictive maintenance and quality inspection.

Main Flow (Basic Path):

1. Data Collection: IoT devices collect real-time data from industrial equipment, such as temperature, vibration, and pressure readings.
2. Data Preprocessing: Collected data is cleaned, filtered, and formatted for analysis.
3. AI Model Analysis: AI models analyze the preprocessed data to predict potential failures or detect quality issues.
4. Anomaly Detection: AI models identify anomalies or patterns indicating potential issues.
5. Alert Generation: Alerts are generated and sent to operators or managers if issues are detected.
6. Proactive Action: Operators or managers take proactive measures to prevent failures or address quality issues.

7. Continuous Monitoring: The system continuously monitors equipment and updates AI models to improve accuracy.

Alternative Flows:
1. Manual Override: Allowing operators to manually intervene and correct AI-generated predictions or inspections.
2. Model Updates: Regularly updating AI models to incorporate new data, improve accuracy, and adapt to changing industrial processes.
3. Data Validation: Validating data quality and integrity to ensure accurate AI model predictions and inspections.
4. Alert Escalation: Escalating alerts to higher-level personnel or management if issues are detected and not resolved promptly.
5. Continuous Monitoring: Continuously monitoring system performance and adjusting parameters to optimize predictive maintenance and quality inspection.

Exception Handling:

- Data quality issues: Handling missing, incomplete, or inaccurate data from sensors or devices.
- Model errors: Managing errors in AI model predictions or classifications.
- Device failures: Detecting and responding to device or sensor failures.
- Network connectivity issues: Handling network disruptions or connectivity problems.
- Alert management: Managing alerts and notifications for predicted failures or quality issues.

Possible Test Cases:

Test Case ID	Description	Input Data	Expected Outcome
TP01	Sensor Data collection	Normal vibration and temperature readings	Sensor values are read and displayed correctly
TP02	Anomaly Detection	Abnormal vibration (e.g., spike in values)	System detects anomaly and triggers alert
TP03	Normal Condition	Stable sensor data within threshold	No alert is generated
TP04	Alert Generation	Abnormal sensor input	Alert is generated and logged
TP05	Alert Reception	Triggered alert event	Operator receives notification on UI or message

TP06	Sensor Failure	No data from sensor or 0 values	System logs error and notifies operator
TP07	Network Failure	Internet disconnected	Local processing continues; data stored locally
TP08	AI Model Failure	Corrupt model or forced crash	All events are recorded in local/cloud logs
TP09	Data Logging	Real-time data and alert events	System restarts and resumes from last known state
TP10	Power Failure Recovery	Sudden power loss	Alert is generated; operator reviews and flags it for model tuning
TP11	False Positive Handling	Normal data misclassified as anomaly	Data appears correctly on dashboard with graphs and status updates
TP12	Dashboard Visualization	Valid sensor data and alerts	Dashboard displays real-time values, graphs, and alert status correctly.

Technology Stack:

- Hardware: MCU, IoT sensors
- Software: Python, TensorFlow Lite, OpenCV, MQTT, Edge
- Communication: Wi-Fi, Bluetooth
- Dashboard: Web-based interface for alerts and analytics

Expected Outcome:

- Reduced operational downtime and maintenance costs
- Improved equipment reliability through early fault detection
- Enhanced product quality via real-time visual inspection
- Streamlined production with minimal human intervention

Expected Deliverables

1. Predictive maintenance insights
2. Real-time quality inspection results
3. Automated alerts for anomalies
4. Data-driven decision support
5. Improved efficiency and reduced downtime
6. Enhanced product quality
7. Scalable and secure system architecture
8. Integration with existing industrial systems
9. User-friendly interface for monitoring and analysis
10. Continuous model improvement and adaptation