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AI-Based Smart Digital Twin for Industrial Predictive Maintenance

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Abstract- Predictive maintenance has become an important application of Artificial Intelligence in modern industries. Traditional maintenance techniques often lead to unexpected machine failures and increased operational costs. This research proposes an AI-based smart digital twin system that monitors machine performance and predicts possible failures before they occur. The digital twin model replicates the physical machine in a virtual environment using sensor data and machine learning algorithms. The system analyzes temperature, vibration, and operational parameters to detect abnormal patterns. Experimental results show that the proposed model can effectively identify potential faults and reduce downtime. This approach improves maintenance efficiency, increases equipment life, and reduces operational costs.

Keywords – Digital Twin, Predictive Maintenance, Machine Learning, Industrial IoT, Artificial Intelligence.

I. INTRODUCTION

Industries rely heavily on machines for continuous production. Unexpected machine failure can cause production loss and financial damage. Traditional maintenance approaches such as reactive maintenance and scheduled maintenance are not efficient in modern industrial systems.

Predictive maintenance uses Artificial Intelligence and machine learning techniques to analyze machine data and predict possible failures before they occur. Digital twin technology creates a virtual model of a physical system that continuously receives real-time data from sensors.

This research focuses on developing an AI-based digital twin system that can monitor machine conditions and predict failures using machine learning algorithms.

II. LITERATURE REVIEW

Several researchers have studied predictive maintenance using machine learning techniques. Previous studies show that data-driven models can effectively detect anomalies in industrial equipment.

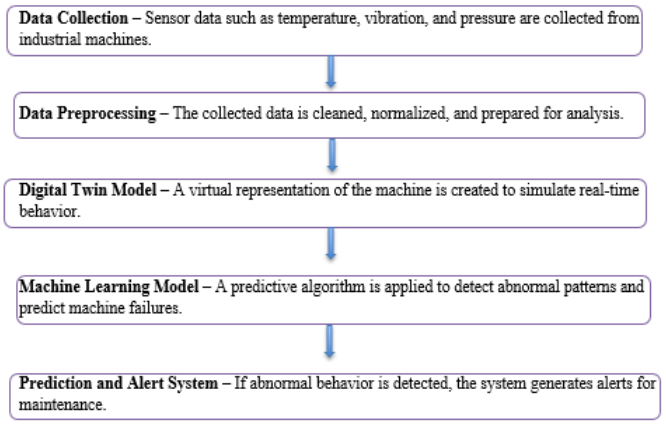
Researchers have used algorithms such as decision trees, neural networks, and deep learning models for fault prediction. Digital twin technology has also been widely used for simulation and monitoring of industrial systems.

However, many existing systems lack real-time monitoring and efficient prediction models. This research attempts to integrate digital twin technology with machine learning to improve predictive maintenance performance.

III. METHODOLOGY

The proposed system uses a digital twin architecture combined with machine learning models.

Steps involved:



System Architecture:
Industrial Machine → Sensor Data → Data Preprocessing → Machine Learning Model → Digital Twin Model → Monitoring Dashboard & Alert System

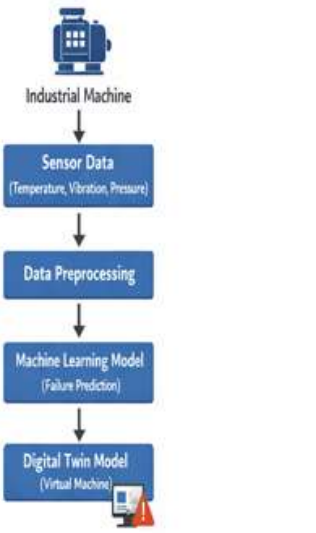


Figure 1: Architecture of AI-Based Digital Twin Predictive Maintenance System

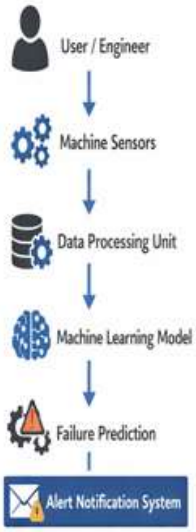


Figure 2: Data Flow Diagram of Predictive Maintenance System

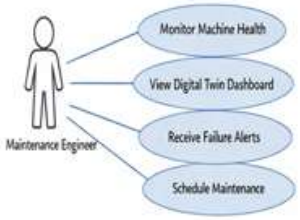


Figure 3: Use Case Diagram of Digital Twin Maintenance System

IV. RESULTS AND DISCUSSION

The proposed system was tested using machine sensor data. The machine learning model analyzed operational parameters and detected patterns indicating potential failure. The digital twin simulation helped visualize machine behavior and predict faults earlier than traditional maintenance methods.

The experimental results showed improved prediction accuracy and reduced unexpected machine downtime. This system demonstrates the effectiveness of combining digital twin technology with machine learning algorithms for predictive maintenance.

V. CONCLUSION

This research presented an AI-based digital twin system for predictive maintenance in industrial environments. The system continuously monitors machine data and predicts failures before they occur. The proposed approach improves maintenance planning, reduces operational costs, and increases machine reliability.

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