

## ENHANCING PREDICTIVE MAINTENANCE IN COMPUTER-AIDED MANUFACTURING THROUGH IOT AND BIG DATA ANALYTICS

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### ABSTRACT

This study investigates the integration of Internet of Things (IoT) and Big Data analytics in Computer-Aided Manufacturing (CAM) systems to facilitate predictive maintenance. By leveraging real-time data collection and advanced analytics, the research aims to minimize equipment downtime, optimize maintenance schedules, and improve overall equipment efficiency (OEE). Analytical data collected from a six-month deployment on CNC machines demonstrates significant improvements in operational efficiency and reliability, validating the potential of these technologies in modern manufacturing environments.

**Keywords-** Computer-Aided Manufacturing (CAM), Predictive Maintenance, Internet of Things (IoT), Big Data Analytics, Equipment Efficiency, CNC Machines, Operational Efficiency.

### 1. INTRODUCTION

In the rapidly evolving field of manufacturing, maintaining high equipment uptime and operational efficiency is paramount. Traditional maintenance strategies, such as reactive and preventive maintenance, often lead to unplanned downtimes and inefficient resource utilization. This paper explores the application of IoT and Big Data analytics in CAM systems to enable predictive maintenance, which anticipates equipment failures before they occur, thus optimizing maintenance activities and enhancing production efficiency.

### 2. LITERATURE REVIEW

**2.1 Maintenance Strategies in Manufacturing-** Maintenance strategies have evolved from reactive (fix after failure) to preventive (scheduled maintenance) and now to predictive maintenance, which uses data-driven insights to foresee and mitigate potential equipment issues.

**2.2 IoT and Big Data Analytics-** IoT technology enables real-time data collection from manufacturing equipment, while Big Data analytics processes this data to extract actionable insights. Studies by Lee and Bagheri (2015) and Wang and Xu (2017) highlight the transformative potential of these technologies in predictive maintenance, showing significant reductions in downtime and maintenance costs.

### 3. METHODOLOGY

**3.1 IoT Implementation-** IoT sensors were installed on CNC machines to monitor parameters such as temperature, vibration, spindle speed, and power consumption. Data was continuously transmitted to a cloud-based platform for storage and analysis.

**3.2 Data Collection and Storage-** Over a six-month period, data from the sensors was collected and stored in a Hadoop Distributed File System (HDFS) to handle the large volume and variety of data.

**3.3 Big Data Analytics-** The data was analysed using Apache Spark for real-time processing and applying machine learning algorithms (e.g., Random Forest, Support Vector Machines) to predict equipment failures. Key analytical processes included:

- **Data Preprocessing:** Cleaning and normalizing data to ensure accuracy.
- **Feature Extraction:** Identifying critical features that influence equipment performance.
- **Model Training and Validation:** Using historical data to train predictive models and validating them against actual outcomes.

### 4. EXPERIMENTAL SETUP

**4.1 Equipment and Environment-** The experimental setup involved five CNC machines in a manufacturing facility. IoT sensors collected data at one-minute intervals, resulting in over 2 million data points over six months.

**4.2 Performance Metrics-** Key performance metrics included mean time between failures (MTBF), maintenance cost savings, and overall equipment effectiveness (OEE).

## 5. RESULTS AND DISCUSSION

### 5.1 Analytical Data and Findings

The implementation of IoT and Big Data analytics significantly improved predictive maintenance outcomes:

- **Reduction in Downtime:** Predictive models identified potential failures up to five days in advance, reducing unplanned downtime by 40%.
- **Optimized Maintenance Schedules:** Maintenance activities were scheduled based on predictive insights, reducing maintenance costs by 25%.
- **Improved Equipment Efficiency:** OEE improved from 78% to 90%, reflecting better utilization and performance.

### 5.2 Data Analysis

**Table 1** summarize the performance improvements.

Metric	Before Implementation	After Implementation	Improvement (%)
Mean Time Between Failures	150 Hours	210 Hours	40%
Maintenance Costs (per month)	\$10,000	\$7,500	25%
Overall Equipment Effectiveness	78%	90%	15%

### 5.3 Discussion

The data indicates that predictive maintenance enabled by IoT and Big Data analytics not only reduces downtime and costs but also enhances equipment efficiency. The predictive models were particularly effective in identifying anomalies and potential failures, allowing for timely interventions. The use of machine learning algorithms, such as Random Forest, proved robust in handling the complex and high-dimensional data generated by IoT sensors.

## 6. CONCLUSION

This research demonstrates the efficacy of integrating IoT and Big Data analytics into CAM systems for predictive maintenance. The significant improvements in downtime reduction, maintenance cost savings, and OEE highlight the potential of these technologies to transform manufacturing operations. Future research should focus on refining predictive algorithms and exploring their scalability across diverse manufacturing environments and equipment types.

## 7. REFERENCES

- [1] Lee, J., & Bagheri, B. (2015). "Cyber-Physical Systems for Predictive Maintenance Using Big Data Analytics," *Journal of Manufacturing Science and Engineering*, 137(4), 1-10.
- [2] Wang, K., & Xu, Y. (2017). "IoT and Cloud Computing Based Predictive Maintenance for Smart Manufacturing," *IEEE Transactions on Industrial Informatics*, 13(6), 3063-3074.
- [3] Zhang, L., & Zhang, Y. (2019). "Big Data Analytics in Smart Manufacturing: A Review," *Journal of Manufacturing Systems*, 49, 120-130.
- [4] Choi, S., & Kang, D. (2020). "Application of Machine Learning Algorithms for Predictive Maintenance in Smart Manufacturing," *International Journal of Advanced Manufacturing Technology*, 108, 1537-1554.