IoT based Breakdown Analysis of Equipments

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Abstract - *For years now, manufacturers have been using a time-based approach for equipment maintenance. But only a few pieces of equipment have failed due to its age, while other failures occur randomly. Smart manufacturing uses Industrial Internet of things (IIoT) technology using different IoT sensors that are fitted on physical assets to enhance manufacturing processes. The ordinary maintenance after the failure may involve unintended resources, time, cost, and partially or completely interrupt the remaining tasks. Multivariate analysis is used for gaining information about the equipment's health status and later analysis is performed to determine the operational situation before unexpected failure. This paper aims to focus on the Internet of Things (IoT) based Predictive Maintenance (PdM) model to predict early failure of equipment. As prediction relies on data, the real-time collected data is used by the Predictive Maintenance model for notifying whether Preventive Maintenance (PM) is required or not and also involves classification of equipment based on health status.*

***Key Words*: Predictive Maintenance (PdM), Preventive Maintenance (PM), Internet of Things (IoT), Smart Manufacturing, Industry 4.0.**

1.INTRODUCTION

Lately, with the appearance of Industry 4.0, Machine Learning, Artificial Intelligence, and Predictive Maintenance (PdM) methods have been enormously applied in industries for managing the health status of machinery. The construction industry faces higher annual budgets for repairing machinery. Interferences in the course of heavy machinery can stop the entire construction process. To make sure that equipment and machinery respond appropriately in the future, maintenance is necessary.

This paper provides information about the maintenance of equipment in the construction industry. Because of digital alteration towards Industry 4.0 (I4.0), collecting immense amounts of data is feasible and involves processing the data generated from diverse segments of equipment and harvesting the collected data for making an automated error identification and examination to cut down breakdown time. Companies have started trying different techniques for the analysis of predictive maintenance as a solution that will eventually reduce the costs and unnecessary requirements of maintenance activities. These smart techniques use IIoT (Industrial Internet of Things) technology where IoT sensors are installed on top of physical assets. These sensors are capable of autonomously interchanging information that will help the company to make accurate business decisions to minimize unexpected device downtime, improving the quality of services and thereby extending the equipment lifecycle. IIoT Industry is continuously growing and using Latest Technology. Trends for automating the tasks and making their software efficient for the customer.

Nowadays various business organizations want to enhance their production, employee security, operational efficiency, and make huge financial outcomes. With increasing competition in a cooperative environment, a company's success depends on the size of production and services provided to their client. The main factor for satisfying the clients and improving productivity is the effective maintenance of the equipment. It plays a major role not only for the clients but also for the company's success. The objective of this paper is to demonstrate how the Machine Learning model is used for predicting the maintenance cost of equipment.

Section 2 describes the maintenance types that have been followed in the industry while section 3 deals with the study of research in the domain. Section 4 outlines the proposed methodology for the case study and Section 5 presents the evaluation metrics of the Predictive Model for prediction, Section 6 concludes the paper.

2.MAINTENANCE APPROACHES:

This section gives descriptions about reactive, preventive and predictive maintenance. It also talks about the advantages and disadvantages of each of the maintenance.

2.1] REACTIVE MAINTENANCE:

This maintenance follows the approach of repairing the parts of the equipment or equipment only after the breakdown or failure of equipment. As the assets are used up to their limits, this maintenance offers maximum utilization and in turn, maximum production output. This approach is useful till the asset is working fine. The repairing cost of the equipment is accordingly more than the production value. In advance, efforts are not taken but as soon as the breakdown of the asset occurs, this asset is unused for some amount of time which ultimately leads to immense losses if our organization's business is largely dependent on this asset.

2.2] PREVENTIVE MAINTENANCE:

This maintenance is also called planned maintenance because the planning of repair or optimization of the performance is done on a regular and timely basis. This maintenance does not take into consideration the machine failure in between the calculated time for the maintenance, so again the same problems of reactive maintenance are faced by this maintenance strategy. The primary goal of this maintenance is to increase productivity, decrease equipment downtime, enhance efficiency and save on time. In this, the parts of the equipment are still replaced even when they have up-to-the-mark lifespan remaining in them which again increases the cost required for fitting the new spare parts. In this, the fully functioning asset is taken down for doing its maintenance which also leads to disrupting the operation of that asset.

2.3] PREDICTIVE MAINTENANCE:

As the name suggests, the maintenance of the equipment is only done after predicting the requirement of the maintenance. Predictive maintenance evaluates the performance of the equipment as the health status data of the asset/equipment which is known via the sensor installed on top of the equipment. The advantage of this maintenance is that the issue is fixed by the maintenance team before the breakdown occurs. Rather than doing the time-based maintenance of the equipment which results in stopping the functioning of the asset or repairing the asset only after its failure, this maintenance focuses on repairing the asset only when it is necessary hence increasing the production value. This method avoids downtime and repair costs due to unexpected failures and also costs with loss of production caused by unnecessary preventive maintenance.

3. LITERATURE REVIEW

Machines are an important part of the construction industry and need to be maintained all the time to ensure quality working. To make effective use of industrial machinery, few kinds of research were carried out in the industrial domain on Predictive maintenance.

3.1 BACKGROUND OF DOMAIN

It was analyzed that Radio-frequency identification (RFID) was observed as a prerequisite for the IoT at that point. If all objects and people were equipped with identifiers, computers could manage and inventory them.

The evolution of IoT can be stated in 5 stages: First, the pre-internet period where it was only human to human interaction. The second being the Internet of content i.e., IT platform and services. Third, the Internet of services where the Web 2.0 was named used for E-productivity and E-commerce. Fourth, the Internet of People, the technology used in Social media, and lastly, the IoT where identification, tackling, monitoring, and metering of data is done from Machine to Machine. The basic concept is that: the Internet of things is a network of physical objects or things; embedded with sensors, software, which enables a computer to exchange and collect data without interacting with humans. The "Things" in IoT usually refer to IoT devices that can have a unique identity and can perform using remote signals and also have the capability of remote monitoring. IoT involves extending internet connectivity beyond standard devices like desktops, laptops, and tablets to different traditional non internet devices. Embedded with technology, these devices have the ability to communicate and interact over the internet which remotely monitors and control.

Raydu Parpala. et al(2017) introduced the latest easy approach for predictive maintenance and as well as for online monitoring over the machinery used in manufacturing industries[2]. This approach was based upon the unification of machines along with the software. For translating distinct industrial equipment language into web protocols this procedure was used. For high-rise furnished elements, the operating parameters of an automatic polishing and Sanding Machine were monitored and tracked, and also a threshold alert was elucidated. The communication framework is the major disadvantage in integrating a production system with IoT dedicated platforms, speaking the latest communication protocols which are implemented on IoT-based platforms are incompatible with the primary industrial communication protocols. In these circumstances, for online monitoring and predictive maintenance of industrial equipment, the current paper puts forward a brand new and easy approach. This particular approach has two characteristics of connected manufacturing. One of these characteristics is process monitoring which ensures assurance of constant quality, the another is condition monitoring to prevent accidental breakdowns.

Shikhil Nangiaa, Makkarb, Hassan(2020) proposed work that discusses IoT-based predictive maintenance and implements it using a case from the manufacturing industry[1]. The paper proposed by them initially discusses Industry 4.0 and an interconnected IoT-based Sensor ecosystem. The Data from sensors collected is leveraged by the manufacturing units and used to predict the failure. They stated a model which was created using advanced analytics software, which meant to simplify the process.

In an agreement with the McKinsey report, it was observed that equipment's life is extended if we implement IoT-based predictive maintenance. Traditional time-based maintenance routine is banished by about 30 % by using this type of maintenance and it also decreases equipment breakdown by 50%. The IoT-based solution was considered to be more reliable throughout the architecture. Overall equipment effectiveness which is abbreviated as OEE is defined as one such performance-measuring tool that measures distinct kinds of production losses and specifies sectors of process enhancement. An analysis is done majorly on how Overall equipment effectiveness (OEE) has evolved resulting in several different tools which include an effective performance of entire total equipment, the effectiveness of production equipment, overall effectiveness of factory, overall effectiveness of plant, and overall effectiveness of asset.

4.PROPOSED METHODOLOGY:

The system is segregated into layers and the first layer is a Device layer where different IoT Devices are in different locations. So, on each Site, there are distinct equipment and for each equipment, there are distinct materials and for each material, there are distinct quantities. In the master data, there is already cost for the materials column but for distinct locations, the cost is also distinct. So, here many to many relationships are established for data. The main objective in the prediction is to find the required quantity in the future so that it can be multiplied with cost to get the predicted cost.

The second layer is Server where data is collected from the device layer through an API Authentication in SQL database and then Analytics is carried out. Rule's engine sets out rules for each parameter in the dataset for equipment. For example, the temperature of the engine cannot be more than 90^0 Celsius. An analysis is done in python scripts and then a report is generated on the localhost.

4.1] DATA COLLECTION:

Data sensing is done using the RMS which is installed on each piece of equipment and sent to an API that performs Authentication, Authorization, and Accounting (AAA). Authentication identifies the user for accessing the services based on the credentials like username and password. The authorization ensures that the user can access allowed resources and perform particular operations only and accounting, monitors how long the user has access to the network. It then sends the data to the database in the required format.

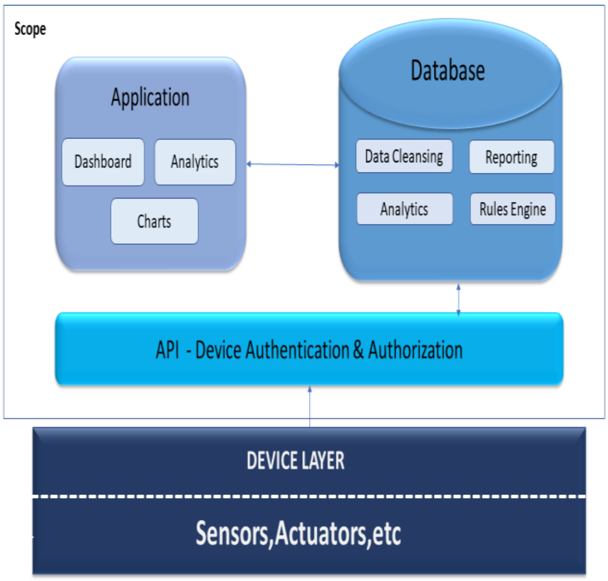

Fig -1: System Architecture

Site No.	Equipment No.	Material No.	Run Hours	Difference in run hrs	Threshold
1	19731	205335	2045	561	118
1	19731	205341	2100	86	118
2	20350	352488	1900	123	65
3	51190	175644	3248	845	78
3	51191	182533	1156	426	78

Table -2 : Sample dataset

The above table shows sample data of the system where equipment numbers are the unique numbers given to equipment like JCB, Gensets, and other industrial machinery. Each equipment has different materials like Tyre, Bolt, Nut, etc. which is represented by 'Material No.'.

4.2] DATA WAREHOUSING:

The main purpose of data warehousing is the combination of data from different sources. For this case study, datasets presented in excel like Maintenance tables, Equipment detail, Material detail, Log data, and Reservation tables. All of these data will be imported to Microsoft SQL Server. At this stage, more than 10000 records were imported. After collecting datasets, all of them will be merged into one Master Sheet using SQL to obtain data in a required format for processing. During joins, a lot of duplicate data will be generated and need a data cleansing process to proceed with the operation.

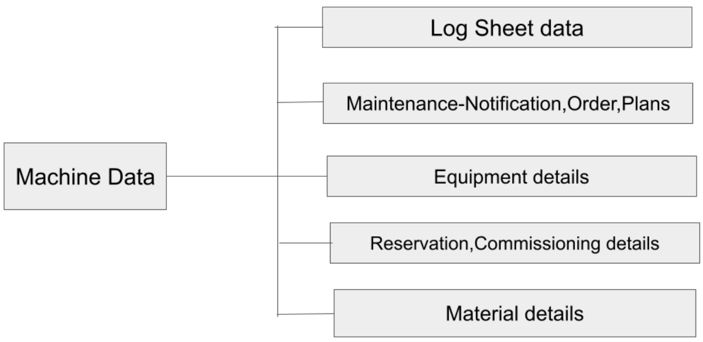

Fig -2: Data Format

4.2] DATA CLEANSING:

Data cleansing is an operation that is performed on the incoming data from different materials to remove anomalies and obtain the data which is an accurate and unique representation. 4NF will be used to normalize Master data in stream-based analytics. This master data has maintenance information, Equipment information, Log data, etc. Data is continuously collected from different sensors in the defined format, so there is a possibility of receiving irrelevant data, incorrectly formatted data, missing values, etc. When these data are combined from multiple sources there is a possibility of data duplication which will be removed during the data cleansing process.

Data cleansing steps followed are:

- **Remove duplicate or irrelevant observations**

  When data sets are combined from multiple places, departments, scrape data, there are possibilities to create duplicate data. Normally, data is received from different clients that can lead to data duplication while joining those data. Hence it is needed to remove those irrelevant observations from data using some tool to make the process efficient or monitor the entire data.

- **Removing unwanted columns**

  The analysis part requires only a few important factors for making predictions. So irrelevant columns are removed that don't play any role in prediction otherwise the algorithm can take more time for processing the logic.

- **Scaling of data**

  Data normalization should be performed across the dataset. The data types of the fields should be consistent and validation is required e.g., a numeric value can't be a Boolean or string. Since scaling of data is an important step in machine learning algorithms, the following points need to be considered :

  - Data fields having numeric values should be kept as Numeric in the columns.
  - Check if numeric can take a string value. If yes, it is incorrect.
  - The default value 'NA' should be entered if a specific value can't be converted.

- **Handle missing data**

  Missing data from a dataset cannot be ignored because the missing values will not be accepted by algorithms for performing analysis. There are different ways to treat missing data in Data mining. Default values like '0' or null can be used in place of missing data or alter the way the data is used to effectively traverse NULL values. Missing values are replaced with appropriate values based on other observations.

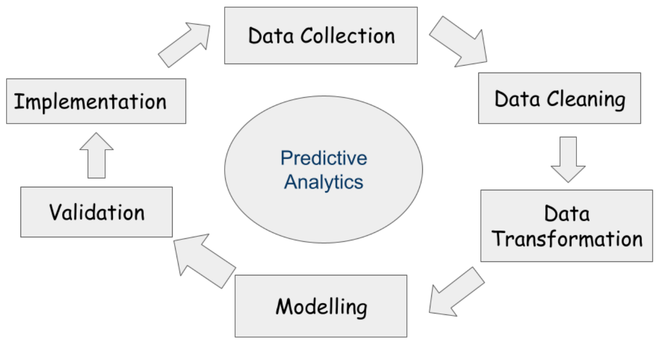

Fig -3: Generic Predictive Analytics Process

4.3] DATA ANALYSIS:

Algorithms that were compared for the precision of results are Linear Regression and Decision Tree. But the best result was given by Decision Tree because its precision is more than 93% while the precision of other algorithms was about 90%. Five attributes considered for predicting maintenance cost and quantity required for future analysis is:

1)Equipment Number
2)Material Number
3)Run Hour
4)Site Number
5)Difference in Run Hour

All these data are numerical. The most important step in building a prediction model using data mining techniques is to decide the splitting of the dataset into two parts, training and testing. This case study divides the dataset into a 70:30 ratio which means 70% of data will be used for training and 30% of data will be used for testing.

4.4] DECISION TREE:ID3

This paper uses the decision tree Iterative Dichotomiser Algorithm(ID3) for the prediction Model. ID3 is a supervised learning algorithm that builds a decision tree from a defined set of training samples using the Mean squared error method. A decision tree is usually built from the root node with a top-down greedy approach involving the partitioning of data into subsets having similar values. The generated decision tree has depth 36 and 6349 leaves for predicting cost and depth 44 with 3923 leaves for predicting quantity.

5. EVALUATION OF THE MODEL

Models are evaluated with different evaluation criterion which will be further discussed in this section with experimental results.

5.1] EVALUATION METRICS:-

Many different sources on the internet use different methods as their criterion for splitting the data. Sklearn uses mean squared error while other sources use standard deviation, variance reduction, root mean square error and the sum of squared residuals. This case study is using mean squared error in the python Sklearn function for evaluation of the model. By default decision tree regression uses the Mean square error method(MSE) method to generate the entire tree in python. But other methods are also available like the Mean absolute error(MSA), Friedman MSE, and Poisson method. Mean squared error tells how close the regression line presents from data points by calculating distances. So the model evaluates for each variable of each parameter. It is needed to choose the variable on splitting such that the two groups should be as different as possible.

$$\mathrm{MSE} = \frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y}_i)^2$$

Using the above formula, mean squared error is calculated for each node and good split is decided by the weighted average of the mean squared errors of the two groups that create. Entire process of creating a decision tree will stop when leaf nodes only have one thing that means no further split is possible.

Table -2: Accuracy with various criterion methods

criterion	mse	friedman_mse	mae	poisson
COST	90%	88.02%	88.76%	66.93%
QUANTITY	83.11%	88.72%	58.12%	88.25%

5.1] EXPERIMENTAL RESULTS:-

Predicted cost and quantity was most accurate with decision tree when compared with linear regression.Run hours with predicted cost of an equipment after decision tree regression model applied is shown in the figure 4.

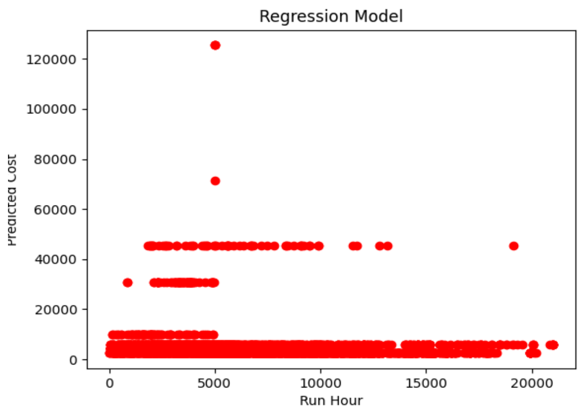

Fig -4: Predicted Cost vs Run Hour

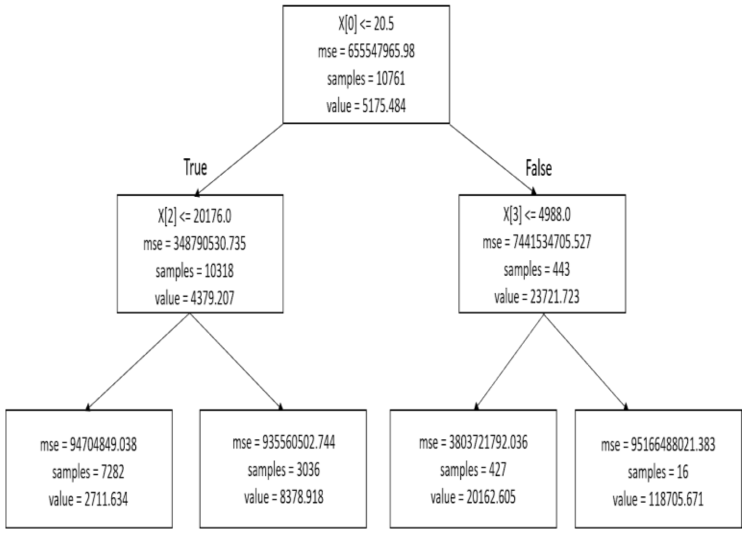

Fig -5: Visualization of Decision Tree

6. CONCLUSION AND FUTURE SCOPE:

The proposed research work discusses the Internet of Things (IoT) based predictive Maintenance implemented on the case of the manufacturing unit's equipment. The Proposal initially discusses Industry 4.0 and then moves its focus towards the use of IoT Interconnected using sensors to the ecosystem which helps in sharing and exchange of data amongst each other. The data gathered from the sensors can further be leveraged by the manufacturing organizations to predict Machine failure. This tells us that Opportunities in IoT and implementation of Predictive maintenance in industries will be huge. The ability to predict failure in advance will help organizations increase productivity, reduce equipment costs, improve working conditions and work environment safety, better product quality, reduced waste in terms of consumables and energy savings. A model is created using advanced analytics software, which tends to simplify the process. A successful Implementation of Industrial PDM would involve any organization to scale across multiple assets. A model having thousands of IoT sensors would generate huge volumes of data.

The future scope involves implementing a Prescriptive Maintenance-based solution that uses data modeling and forecasting to test the likely outcome of different actions based on the data. Predictive maintenance is the answer to questions like “What will happen and when?”.It learns from the historical maintenance data to predict the occurrence of a specific event in the future. So, indirectly it provides recommendations for decision-making about the failure of particular equipment at runtime. Prescriptive maintenance answers the question “How can we make it happen?. Predictive analytics is the best method when it comes to deciding whether the equipment fails in the future or not and how to do maintenance.

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