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Predictive Maintenance of Industrial Machines Using IoT

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ABSTRACT

In modern digital manufacturing, nearly 79.6% of the downtime of a machine tool is caused by its mechanical failures. Predictive maintenance (PdM) is a useful way to minimize the machine downtime and the associated costs. Thus, early fault detection is highly desired to increase the product quality, expedite the progress of unscheduled maintenance, and shorten the machine downtime. It was a device designed for the Industrial machines (Like CNC Machine tools), which monitors and predicts the performance and condition of equipment during normal operation to reduce the likelihood of failures.

Keywords: Predictive Maintenance, Internet of Things, Downtime, Sensors, Predictive Analysis, Induction Motor, Machine Learning.

1. INTRODUCTION

In the early days of the Industrial Revolution, machines were not too complex and that meant fewer breakdowns. As we have entered in to the 2^{nd} and 3^{rd} wave of the Industrial Revolution, with the assembly line and rapid automation through Programmable Logic Controllers (PLCs) respectively, the scenario had changed. There was less of manual labor and more of automation through complex machinery. To remain competitive, factories started measuring and closely tracking various performance metrics including production output, overall equipment effectiveness, personnel productivity etc. Maintenance, which was seen as an activity to be undertaken only when there was a breakdown, became much more important. The strategy of regularly scheduled, preventive maintenance became popular. This periodic inspection of the machinery helped identifying issues early so that breakdowns could be minimized and production stoppages reduced. As we enter the 4^{th} wave of the Industrial Revolution also known as Industrial Internet of Things (IIoT) or Industry 4.0, there is a greater focus on equipment utilization, operational cost, worker productivity etc. Industrial IoT is all about connecting low-cost sensors to gather machine data and using advanced analytics to draw meaningful insights. It is estimated that Industrial IoT will allow manufacturers to increase their productivity by 30%. The maintenance strategy that employs advanced analytics to predict machine failures is known as Predictive Maintenance.

In a survey carried out by the World Economic Forum (WEF), the most widely cited application of the Industrial IoT is predictive maintenance and rightly so. Predictive maintenance allows manufacturers to lower maintenance costs, extend equipment life, reduce downtime and improve production quality by addressing problems before they cause equipment failures.

2. ANALYSIS

a. Existing System

Existing analysis methods of these complex and diverse data are inefficient and time-consuming. Manufacturers have been practicing a time-based approach to the equipment maintenance. They used to take the age of machinery as the factor for planning the maintenance routine. The older the equipment the more frequent maintenance procedures need to be carried out.

b. Proposed System

One of the challenges with Predictive Maintenance is the early fault detection under time-varying operational conditions, which means mining sensitive fault features from condition signals in long-term running.

This device is used for early fault detection under time-varying conditions. In this, a deep learning model is constructed to automatically select the impulse responses from the vibration signals from past data. Then, dynamic properties are identified from the selected impulse responses to detect the early mechanical fault under time-varying conditions.

c. Requirement Specification

i. Hardware Requirements

System hardware is the collection of physical parts of the project module. It includes various modules like controllers, sensors and relay circuits.

1. Arduino UNO

Arduino microcontroller collects the information from various sensors that are connected to the machine. It is programmed to sense the sensor data, which is indirectly the machine condition. The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. Figure 3.1 shows the Arduino board.

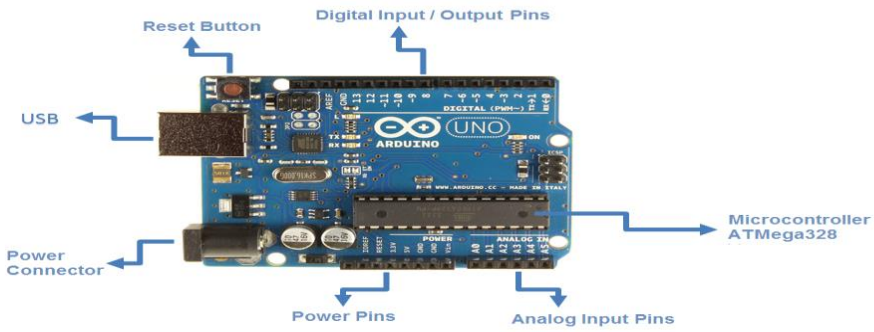

Figure 1. Arduino Uno Board

2. Relay

Relay means the act of passing something from one thing to another, the same meaning can be applied to this device because the signal received from one side of the device controls the switching operation on the other side. So relay is a switch which controls (open and close) circuits electromechanically. The main operation of this device is to make or break contact with the help of a signal without any human involvement in order to switch it ON or OFF. It is mainly used to control a high powered circuit using a low power signal. In this project, relay is connected to motor to control its switching operation.

Figure 2. 5V 2 Channel Relay Module 10A

3. DC Motor

DC motors were the first form of motor widely used, as they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. Small DC motors are used in tools, toys, and appliances. The universal motor can operate on direct current but is a light weight brushed motor used for portable power tools and appliances. Larger DC motors are currently used in propulsion of electric vehicles, elevator and hoists, and in drives for steel rolling mills.

Figure 3. DC Motor

4. Vibration Sensor

The Vibration Sensor is based on piezoelectric transducer. It is well known that piezo electric materials responds to strain (deflection) changes or applied force by generating a measurable output voltage. This output voltage is proportional to the strength of shock or vibration. So you can measure and characterize the vibration.

Figure 4. OEM Vibration Sensor

5. Current Sensor

A current sensor is a device that detects electric current in a wire, and generates a signal proportional to that current. The generated signal could be analog voltage or current or even a digital output. The generated signal can be then used to display the measured current in an ammeter, or can be stored for further analysis in a data acquisition system, or can be used for the purpose of control.

Figure 5. ACS712 Current Sensor

6. Voltage Sensor

A voltage sensor can determine, monitor and can measure the supply of voltage. It can measure AC level or/and DC voltage level. The input to the voltage sensor is the voltage itself and the output can be analog voltage signals, switches, audible signals, analog current level, frequency or even frequency modulated outputs. In voltage sensors, the measurement is based on the voltage divider.

Figure 6. Voltage Sensor

7. Temperature Sensor

LM35 is a temperature measuring device having an analog output voltage proportional to the temperature. It provides output voltage in Centigrade (Celsius). It does not require any external calibration circuitry. The sensitivity of LM35 is 10 mV/degree Celsius. As temperature increases, output voltage also increases.

Figure 7. LM35 Temperature Sensor

ii. Software Requirements

The system software is the interface between hardware and user applications. A computer program, that is designed to run a computer's hardware and application programs.

1. Arduino IDE

Arduino IDE is an open source software that is mainly used for writing and compiling the code into the Arduino Module. It is an official Arduino software, making code compilation too easy that even a common person with no prior technical knowledge can get their feet wet with the learning process. It is easily available for operating systems like MAC, Windows, Linux and runs on the Java Platform that comes with inbuilt functions and commands that play a vital role for debugging, editing and compiling the code in the environment. A range of Arduino modules available including Arduino Uno, Arduino Mega, Arduino Leonardo, Arduino Micro and many more. Each of them contains a microcontroller on the board that is actually programmed and accepts the information in the form of code. The main code, also known as a sketch, created on the IDE platform will ultimately generate a Hex File which is then transferred and uploaded in the controller on the board. The IDE environment mainly contains two basic parts: Editor and Compiler where former is used for writing the required code and later is used for compiling and uploading the code into the given Arduino Module. This environment supports both C and C++ languages.

2. Microsof Azure IoT Accelator

It is mainly useful for the implementation of common Internet of Things (IoT) scenarios like remote monitoring, industrial Internet of Things (IIoT), predictive maintenance and device simulation. It helps to get all the required cloud-based services you need—including all required application code—for a successful, efficient and streamlined build and deployment.

3. Microsoft Azure Machine Learning Platform

Microsoft Azure Machine Learning Studio is a collaborative, drag-and-drop tool you can use to build, test, and deploy predictive analytics solutions on your data. Machine Learning Studio publishes models as web services that can easily be consumed by custom apps or BI tools such as Excel.

3. IMPLEMENTATION

i. Module Description

This Project is divided into 2 Modules. They are Hardware Module using Arduino and Software Module using Microsoft Azure Machine Learning Studio.

Each Module has its own Purpose. Hardware Module is for connecting sensors to the Machine, which is used for predicting failures. And Software Module is for training the datasets using different algorithms for prediction.

Hardware

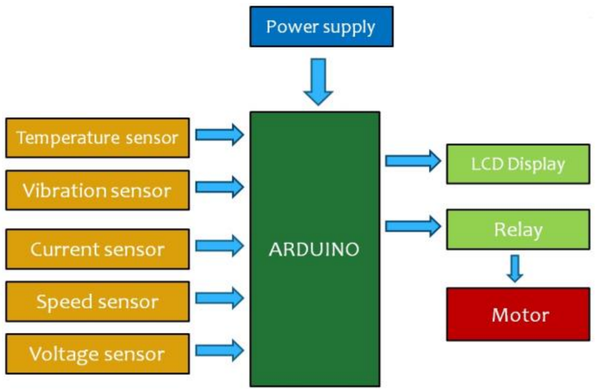

Figure 8. LM35 Temperature Sensor

The power supply is turn ON , the Arduino and all the interface components get the required supply. Sensor unit senses the corresponding motor parameters and feed to the Arduino. Arduino reads the data from various sensors and analyses according to the given instructions, Then sends the sensor information to LCD and network gateway through WiFi. In Parallel, Arduino reads the commands from internet and provides control signals to the relay via contactor, which will control the induction motor. The sensor information's are displayed visually in server. The Induction motor control is based on the sensed parameters and in manual mode the control is based on alert messages received from the web. The control is done by relay and contactor circuit. The motor is turn ON/OFF when abnormal value is detected.

1. Software

In this Module, using Microsoft Azure Machine Learning Studio, we get the sensor data from the hardware connections connected to our machine (DC Motor) and also we use the different time series datasets related to our machine like failure dataset. Initially, For preprocessing the data, different techniques like removing extra spaces and removing unnecessary columns are done using r programming. Now, using these datasets from present and past, we try to train the model using different machine learning algorithms, here we used decision tree algorithm.

But, Predictive maintenance can be formulated in one of the two ways:

Classification approach - predicts whether there is a possibility of failure in next n-steps.

Regression approach - predicts how much time is left before the next failure. We call this Remaining Useful Life (RUL).

Ex: svm model, logistic regression, Decision Tree Algorithm etc.

i) Decision Tree Algorithm:

Decision tree builds regression or classification models in the form of a tree structure. It breaks down a dataset into smaller and smaller subsets while at the same time an associated decision tree is incrementally developed. The final result is a tree with decision nodes and leaf nodes. A decision node (e.g., Outlook) has two or more branches (e.g., Sunny, Overcast and Rainy), each representing values for the attribute tested. Leaf node (e.g., Hours Played) represents a decision on the numerical target. The topmost decision node in a tree which corresponds to the best predictor called root node. Decision trees can handle both categorical and numerical data. The core algorithm for building decision trees called ID3 by J. R. Quinlan which employs a top-down, greedy search through the space of possible branches with no back tracking. The ID3 algorithm can be used to construct a decision tree for regression by replacing Information Gain with Standard Deviation Reduction.

4. TEST CASES

In this project, we tried to obtain the Remaining useful life of a machine. So, test cases are based on the different values of Number of Cycles of a machine.

Here, the threshold value of Total Number of Cycles for DC Motor is 192.

S.No.	TestCases	Expected	Obtained	Result
1.	80	112	112	Success
2.	196	Negative Value	Negative Value	Success
3.	192	0	0	Success

5. SCREENSHOTS

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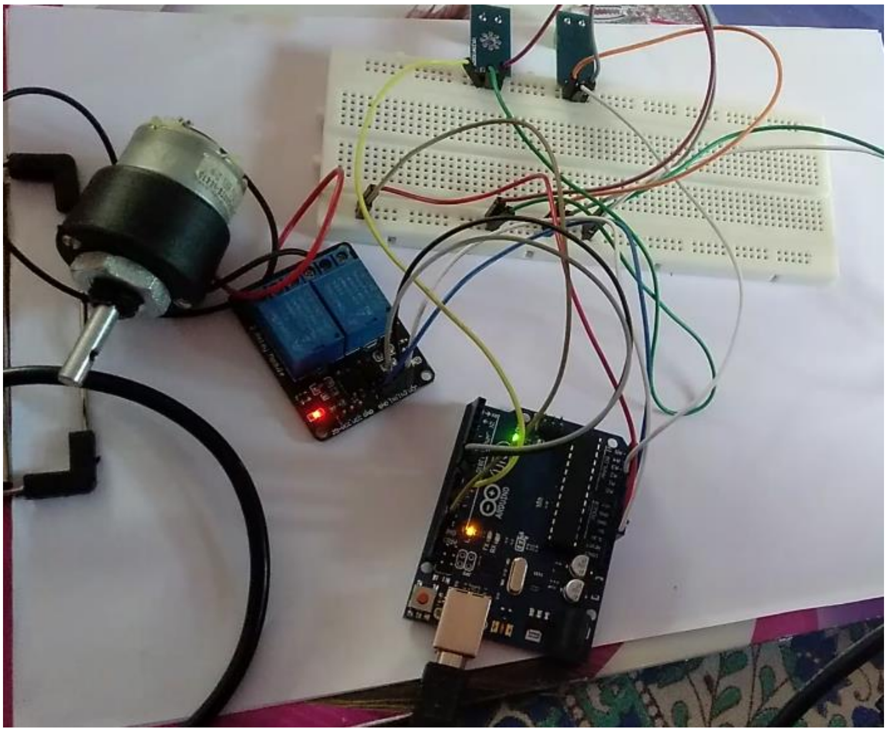

Figure 9. Hardware Connections with DC Motor

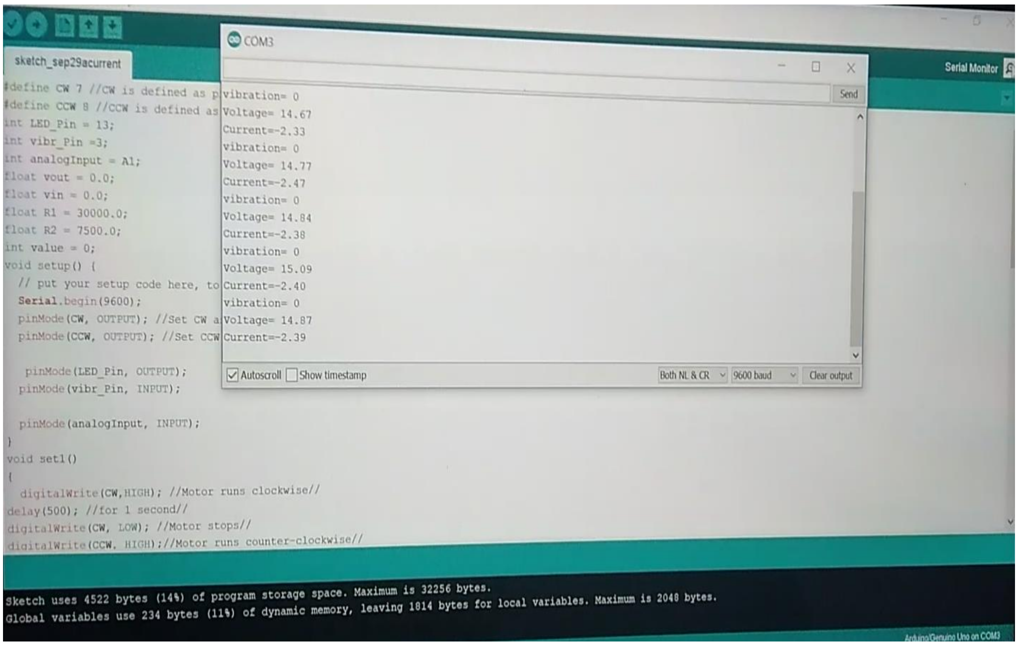

Figure 10. Sensor Values on Serial Monitor

rows	columns
20631	14

id	cycle	setting1	setting2	setting3	s1	s2	s3	s4	s5
1	1	-0.0007	-0.0004	100	518.67	641.82	1589.7	1400.6	14.62
1	2	0.0019	-0.0003	100	518.67	642.15	1591.82	1403.14	14.62
1	3	-0.0043	0.0003	100	518.67	642.35	1587.99	1404.2	14.62
1	4	0.0007	0	100	518.67	642.35	1582.79	1401.87	14.62
1	5	-0.0019	-0.0002	100	518.67	642.37	1582.85	1406.22	14.62
1	6	-0.0043	-0.0001	100	518.67	642.1	1584.47	1398.37	14.62
1	7	0.001	0.0001	100	518.67	642.48	1592.32	1397.77	14.62

Figure 11. Machine Failure Dataset

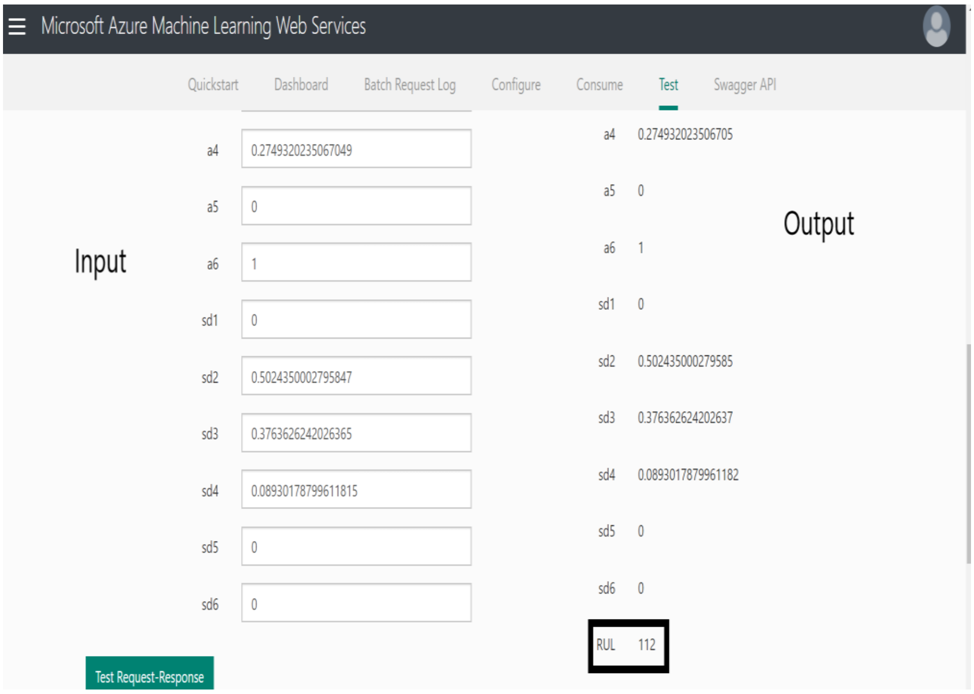

Figure 12. RUL(Remaining Useful life) Prediction obtained in Azure ML Studio

6. CONCLUSION

In this project the concept of Internet of Things for early detection and monitoring of motor system failures remotely. The system has the ability to combine various sensed parameters in real time and improve accurate detection of different faults occur in motor. The monitoring of the motor system presents the measurement of different parameters namely vibration of the motor, temperature, supply voltage and motor current. Thus, compared to other conventional methods this system has more number of fields which enables alarm, alert messages and quick controlling. The concept of IoT is presented here for remote monitoring and controlling the motor. By using predictive maintenance, the data received from the controller node is trained and used for early prediction of failures .The data is also displayed serially. The work is updated to extra fields for precious control. The application of the system is needed today for every electrical system (i. e EV vehicle and automation of industries where greater safety is needed). The system has the specific advantage less maintenance, easy and quick controlling and accessing of data remotely. Experimental results confirm the feasibility of the implementation of the system.

And, For Future Improvements, we can add more number of sensors that can work for different machines failures. For more accurate prediction, more number of real time datasets with accurate values can be used.

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