Heavy Machinery Condition and Risk Monitoring System for Industrial Automation

Apoorv Kansal, Manan Gupta, GarimaSetia, Mohan Jagannath

Abstract*: This paper provides the design, implementation and analysis of heavy machinery condition and risk monitoring system which makes the machines more durable and effective by decreasing the damage caused to it due to excessive heating and detecting the risk of machine breakdown beforehand by monitoring the machine parameters. A webpage is created which serves as a handy tool for the workers and the admin to continuously monitor the load on which machine is working, its current temperature its current temperature and other parameters. It also provides the user an option to run the machine in automatic mode in which the load on the machine is varied according to its current temperature and also provide a cooling mechanism which gets activated when the machine temperature goes beyond a particular point and works more effectively as the temperature of the machine increases.

***Keywords* :Industry 4.0, Industrial Internet of Things (IIOT), Embedded System, Industrial Automation.**

I. INTRODUCTION

With the evolution of Industry 4.0 and digital transformation, conventional industries are adopting modern techniques utilizing the concepts of Industrial Internet of Things (IIoT). Due to this the investments made in this sector have scaled up in the past year [1].The Internet of Things (IoT) is a system of interconnected devices which communicate over the same network. These devices include mechanical components, sensors, actuators etc. This technique is widely used in various domains ranging from smart home solutions, self-driving cars as well as smart industries [2,3].

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* Correspondence Author
Apoorv Kansal*, B.Tech. (ECE) III Year Student, School of Electronics Engineering, Vellore Institute of Technology (VIT) Chennai Tamil Nadu 600127, India
Manan Gupta, B.Tech. (ECE) III Year Student, School of Electronics Engineering, Vellore Institute of Technology (VIT) Chennai, Tamil Nadu 600127, India
Garima Setia, B.Tech. (ECE) III Year Student, School of Electronics Engineering Vellore Institute of Technology (VIT) Chennai, Tamil Nadu 600127, India
Mohan Jagannath, Associate Professor, School of Electronics Engineering Vellore Institute of Technology (VIT) Chennai, Tamil Nadu 600127, India
Dr.Mohan Jagannath, Associate Professor, School of Electronics Engineering, Vellore Institute of Technology (VIT) Chennai, Tamil Nadu 600127, India

The proposed system mainly focuses on industrial automation which includes smart manufacturing as well as asset management. Smart manufacturing is defined as an approach to produce goods using machines which are fully-integrated and collaborative with the environment and respond actively to real time demands and customer needs[4].

This is primarily used for automation, digital transformation(as enabled by IoT), to develop industrial and manufacturing technologies, intensive use of data / analytics, industry and manufacturing challenges, to develop human wellbeing, economic and social development and demands and integration of information technology and operational technology (IT and OT) [5].This system is an advanced process management system controlled by Raspberry Pi which is a single board computer. The system is multi parameter based monitoring hardware system designed to avoid the breakdown of machines and detect risk in the working of a machine.The system parameters that can be monitored are temperature, humidity, power, vibrations and other customizable parameters of different machines.It is a closed loop feedback system as the load on the machine varies inversely with temperature. The intensity of cooling mechanism works in proportion to the machine temperature.

The difficulty in determining time-to-failure (TTF) of industrial machines is that the failure mode is not a linear progression. The progression of severity of a fault increases at a higher rate as the machine approaches failure[6]. Through experience, it is known that discrete frequencies in the vibrationspectra are associated with machine faults and will reach expected amplitudes at the point ofmachine failure. The data from each machine is gathered using different sensors like temperature, vibration sensor, humidity sensor to monitor the state of the machine in real time.

II. METHODS AND MATERIALS

A. Hardware Interface

Raspberry Pi: The Raspberry Pi is a credit card, single-board computer (microcontroller) which comes with different specifications in different models namely Raspberry Pi 2/3/3B/3B+/4 launched by Raspberry Pi foundation[7].It has a Broadcom BCM2835 chip comprising of an advanced RISC Machine 76JZF-S 700 MHz processor, video core IV GPU, and wasoriginally distributed with 256 megabytes of RAM, later it's improved and advanced models (B,B+ and 4) to 512 MB and further up to 1 GB.It does not contain any in build hard disk(HDD) or solid-statedrive(SSD), but it uses an SD card for booting andstorage which is attached at the back side and should be of memory capacity more than 8GB.

Raspberry Pi is a very delicate device and the chip gets heated when it works highly computational stuff for longer periods of time.

In the prototype of the proposed model, it is used to get the signals from various sensors, takes decisions on the basis of real time parameters and performs actuation. Fig. 1 shows the Raspberry Pi Model 3B used in this study.

Fig.1. Raspberry Pi Model 3B

DHT11 (Temperature Sensor): The DHT11 sensor module is a commonly used temperature and humidity sensor[8]. In the prototype, the sensor is used to read the real time temperature and humidity values of the actuating device and the surroundings. The sensor outputs an analogue voltage corresponding to the temperature which is then converted to digital using an on board analogue to digital converter (ADC). The sensor module comes with a 3-pin configuration namely V_{DD}, GND and Data pin. It is configured to the Raspberry Pi microcontroller using these 3 pins and the data is received periodically after each second.The sensor can measure temperature from 0°C to 50°C and humidity from 20% to 90% with a high accuracy. Fig. 2 shows the DHT11 sensor module which is used in the prototype of the proposed system.

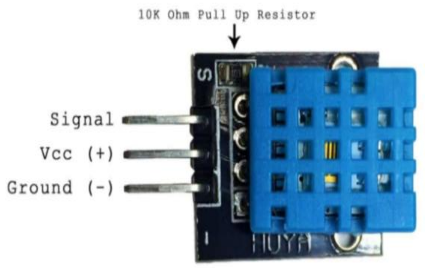

Fig.2. DHT11 Temperature and Humidity Sensor Module

DC Motor: It is used to mimic any machine operating in the industry. In the prototype, the load of the machine is shown as the revolution per minute (RPM) of the motor.
12V DC Fan: This fan is used as a cooling mechanism for the machine. In an advanced system, the fan can be replaced with a more sophisticated cooling mechanism such as liquid cooling techniques.
*L298N (Motor Driver):*The motor driver is basically used to give the signal to the motor or the fan that is provided by the microcontroller.

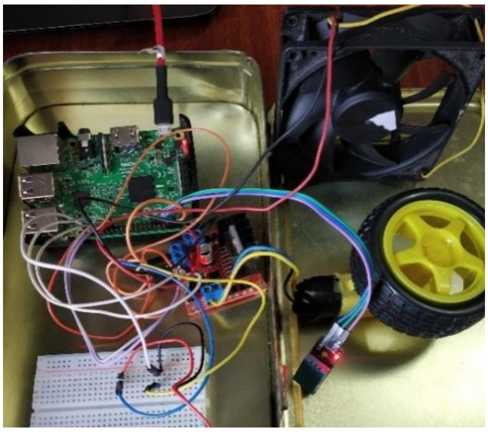

Fig.3. Hardware Interface of the Proposed System

Fig. 3 shows the hardware interface of the proposed system. More hardware components can be added to the system to gather maximum real time data of the machine so as to predict the risk efficiently.

B. Software Interface

Python: This high level programming language is used to program the Raspberry Pi to acquire the sensor reading and then upload it to the server. Various inbuilt libraries are used in the code such as https://www.python.org/:

- *General purpose input/ output (GPIO)*- To interface the sensors on the Raspberry Pi GPIO pins and get the sensor readings.
- *Requests* - To update the sensor readings to the server.

Webpage:

- *Express*: For developing backend of the website(https://nodejs.org/en/).
- *FS*: For file management and data management.
- *Body-Parser*: For handling the POST requests from the client side.
- *EJS*: For rendering the HTML webpages.

III. RESULTS AND DISCUSSION

The proposed system can be used effectively in industries which comprises of heavy duty machine which works round the clock and a heavy cost is attached to the breakdown of the machine. The main advantage of the system is that it can be used to run the industry in a risk free environment and can be used to detect any risks beforehand. Also, the system can be shifted from closed or open loop and vice versa as per our preference by a single click and it works efficiently in both the cases. The design of the system can be improved further by adding more components to monitor the parameters of a machine that leads to a risk of breakdown. Also, the system can be shifted from closed or open loop and vice versa as per our preference by a single click and it works efficiently in both the cases. Fig. 4 depicts the speed of the motor and fan in RPM. The donut chart updates automatically every second getting values from the system. Fig. 5 shows the time series readings of the temperature of the motor.The colour of graph changes according to the temperature.

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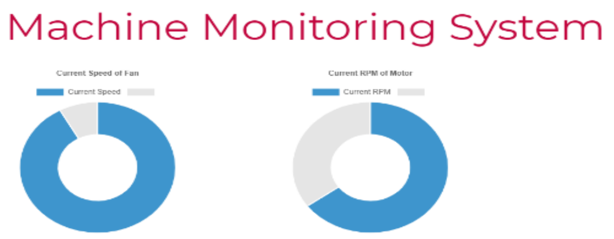

Fig.4. Webpage showing the speed of the motor and fan.

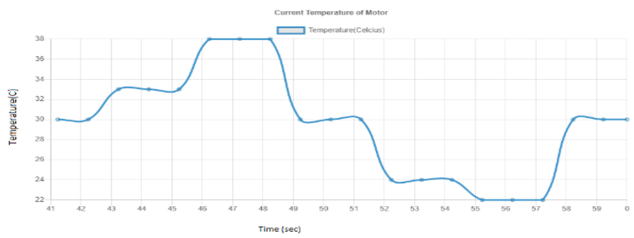

Fig.5. Time series reading of the motor temperature.

Raspberry Pi continuously gather values from sensors and the POST values to the server using API end point that are open. Pi updates the values once every second and similarly the webpage updates the value on the page once per second. Additionally, the user is provided an option on the webpage to

- Make the system automatic(closed loop)
- Manually control the values of the fan speed and load of the machine(open loop)
- To stop the system completely

A. *Automatic Mode:*

By default the system is running in this mode. This provides complete automation in the process. The motor RPM and fan speed and adjusted appropriately as the temperature is changed (Fig. 6).As soon as the temperature of the system goes above a certain point (25°), the cooling mechanism will get activated and the machine load will start to drop.

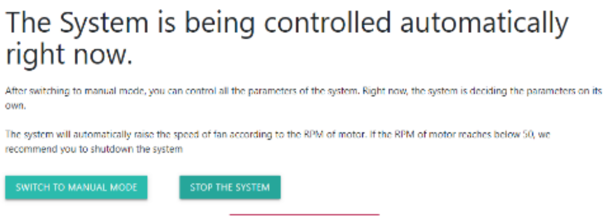

Fig.6.Automode: All the parameters are system controlled and system behaves as a closed loop system.

The intensity of the cooling mechanism and the drop in load of the machine is managed by a sigmoid function which is given in (1):

$$S(x) = \frac{100}{1+e^{-x+30}} \quad (1)$$

Where, *x* is the temperature of the motor and *s(x)* is the speed of the fan.

The original sigmoid function was shifted and stretched so that the middle point of sigmoid function must be at 30ºC and the function becomes saturated around 40ºC. The sigmoid function is also multiplied by 100. The sigmoid function outputs between 0-1. This modified function returns output between 0-100, which is the speed of the cooling fan.

Around 40ºC, we recommend user to shut down the system. The function and midpoint of function can be varied and changed according to the need of particular machine.So through the sigmoid function we realize the fan speed increases exponentially as the temperature of the motor changes. The rotation speedof the motor is also determined using same function and is given in (2).

$$Motor\ rpm = 100 - fan\ speed \quad (2)$$

This is also a simple method to determine the motor RPM from fan speed. This formula relies on temperature indirectly but we can standalone define the motor speed with the function of the temperature.Different functions can be chosen for different environments and the code can be altered accordingly.

B. *Manual Mode:*

There are many time when we would want to use the machine at its full potential, but the automatic system may decrease the motor RPM seeing the temperature rise. To fix, we have also given and option to freely chose different values and make the system as an open loop system (Fig. 7).This option gives the user freedom to run the machine and provide instructions to the machine online. The user can simply change the values of motor RPM and fan speed from the sliders provided on the website.Technicians can also use this mode to change the parameters for auditing the machines and thus checking whether machine is working correctly or not.

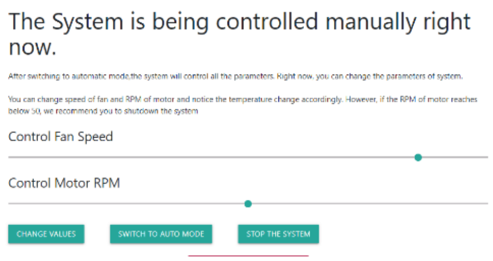

Fig.7. Manual Mode: User can change the motor RPM and fan speed and monitor the temperature changes

In this mode, the Raspberry Pi is continuously monitoring the change of the values on the server and then changes the real world values according. The delay in this process is no more than 1-2 seconds. The way ahead of the project is to predict the risk efficiently using machine learning on the real time data coming from multiple sensors[9]. This can be done in two ways:

Supervised Learning: A machine learning model or neural network is trained on the historical data of the machine which contains the process parameters and machine parameters which led to the breakdown of the machine in past and using that model to predict the risk in real time.

*Unsupervised Learning:*A machine learning model is trained using several clustering techniques so as to predict the risk on the real time data.

IV. CONCLUSION

This standalone system can be implemented in an industry to bring the whole industry down to a mobile device using an app with login facilities for the machine operators, engineers and supervisors. The app is customized for each type of login category as mentioned above and the authorized persons can login in anytime into the app to monitor as well as control the process parameters manually.They also have an option to switch the machine manual to automatic mode using the mobile app, similar to that provided on the website, which provides easier access to all the parameters.

The proposed system is also suitable for human and machine collaboration as it has a feature to automatically shut down the machine if any hindrance is detected in its motion,which is beneficial for the machine as well as for the safety of the humans working around the machines. If something gets stuck in the machine, the machine automatically stops rather than trying to break the object and thus potentially injuring any person present.

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AUTHORS PROFILE

Apoorv Kansal is studying third year Bachelor of Technology (Electronics and Communication Engineering) at Vellore Institute of Technology (VIT), Chennai, India. He is very much interested towards Raspberry Pi related projects. He is passionate about learning and mastering new skills to achieve greater heights in the field of automation technology.

Manan Gupta is studying third year Bachelor of Technology (Electronics and Communication Engineering) at Vellore Institute of Technology (VIT), Chennai, India. His interests are web development, sensor interface and product design. He has made several embedded systems Gismoz (using Arduino and Raspberry Pi).

Garima Setia is studying third year Bachelor of Technology (Electronics and Communication Engineering) at Vellore Institute of Technology (VIT), Chennai, India. Her interests includedata analytics, signal processing and sensor interface. She has made several Raspberry Pi based system for automation.

M. Jagannath is an Associate Professor in the School of Electronics Engineering at Vellore Institute of Technology (VIT), Chennai, India. Prior to joining VIT, he was serving the position of Senior Project Officer at the Industrial Consultancy and Sponsored Research at IIT Madras. He obtained his Ph.D. from IIT Madras in the year 2012. He received Best Academic Researcherof the Year 2017 from the Office of the Prime Minister of the Republic of India. He received Technical Icon of the Year 2012 from the Institution of Engineering and Technology, Young Professional Society (Chennai Network), UK. His research interests include sleep research, music research, biomedical instrumentation systems, signal and image processing.

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