Machine Monitoring System

A PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this project report **"MACHINE MONITORING SYSTEM"** is the Bonafide work of **"AKSHARA K B (715517104007), SARATH R (715517104309) and SHILPA DASS R (715517104310)"** who carried out the project work under my supervision.

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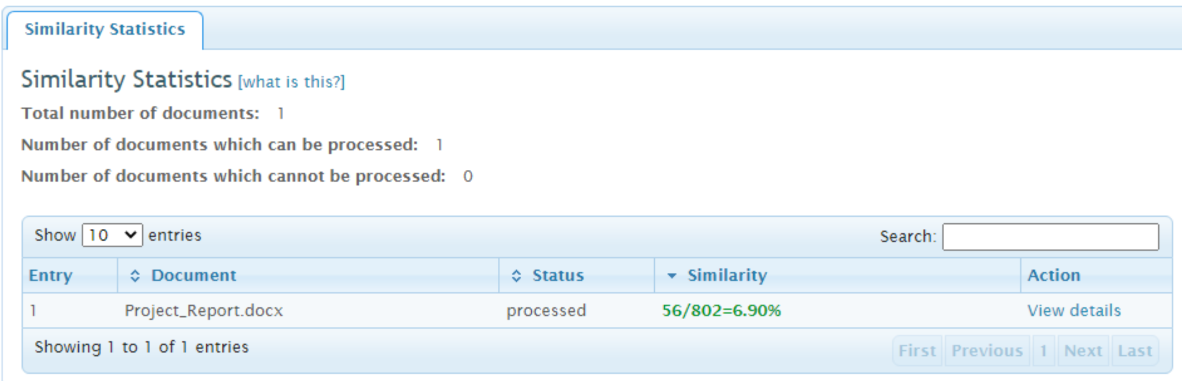
VERIGUIDE ANALYSIS REPORT



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ABSTRACT

Internet of Things is the new arising innovation. Sensors are utilized to consistently screen industry apparatuses which are exceptionally difficult to be monitored by people. With the utilization of sensors, the whole actual framework of an industry can be quickly checked and actions can be made rapidly if there should be an occurrence of breaking down. These sensors will be associated with the web to share the various sorts of information acquired. The information acquired can be viewed either a phone or on PC and can produce alert signals and aid in quick relief measures. The project is aimed at implementing an Industrial Monitoring System alongside thread cut detection utilizing Thingspeak™ platform and reaction-based framework. The project is employed by installing carious sensors at crucial points in the machine. A continuous monitoring is done and the date is constantly being checked for any outbound values. Once any such detection is observed, warnings are raised which is helpful to prevent further damages to the machine. In the case of thread breakage detection, image comparison method is utilized to detect a missing thread. With the utilization of this framework, the efficiency of the machines can be drawn out and furthermore productivity can be guaranteed in the working of the business

Keywords: Thingspeak™, MATLAB®, Fiber optic sensing

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LIST OF ABBREVIATIONS

ABBREVIATION	EXPANSION
IoT	Internet of Things
FBG	Fibre Bragg grinding
RGB	Red Green Blue
AC	Air Conditioner
ERP	Enterprise Resource Planning
IR	Infrared
DCS	Digital Combat Simulator
Wi-Fi	Wireless Fidelity
MQTT	Message Queuing Telemetry Transport
HTTP	Hyper Text Transfer Protocol
API	Application Programming Interface

CHAPTER 1
INRODUCTION

1.1 MACHINES

A machine (or mechanical device) is a mechanical structure that uses power to apply forces and control movement to perform an intended action. Modern machines are complex systems that consist of structural elements, mechanisms and control components and include interfaces for convenient use. So vast and vital is the usage of machines, that we need ways to increase the efficiency of the machine. One way is early prediction of when defects can occur in the machine.

1.2 OBJECTIVE

The main objective is to develop a system with the usage of sensors and a microcontroller, which can continuously monitor the machines and raise warnings when the machine tends to go into defects.

1.3 PROBLEM STATEMENT

Machines are used everywhere. Usually defects and faults in the machines are detected only when the machine is damaged and it stops working. Here the aim is to develop a system using which can continuously monitor the different parameters of the working machine. This can be used to predict when a machine can go into fault, thus saving a lot of time and money for the owner

1.4 PROJECT OVERVIEW

1.4.1 System Architecture

First, data has to be continuously obtained from the machine. For this purpose, sensors are positioned near the components as shown in Figure 1.1, from which the data can be monitored. The sensors cannot act on the data obtained. Hence, they are fed into the raspberry pi microcontroller.

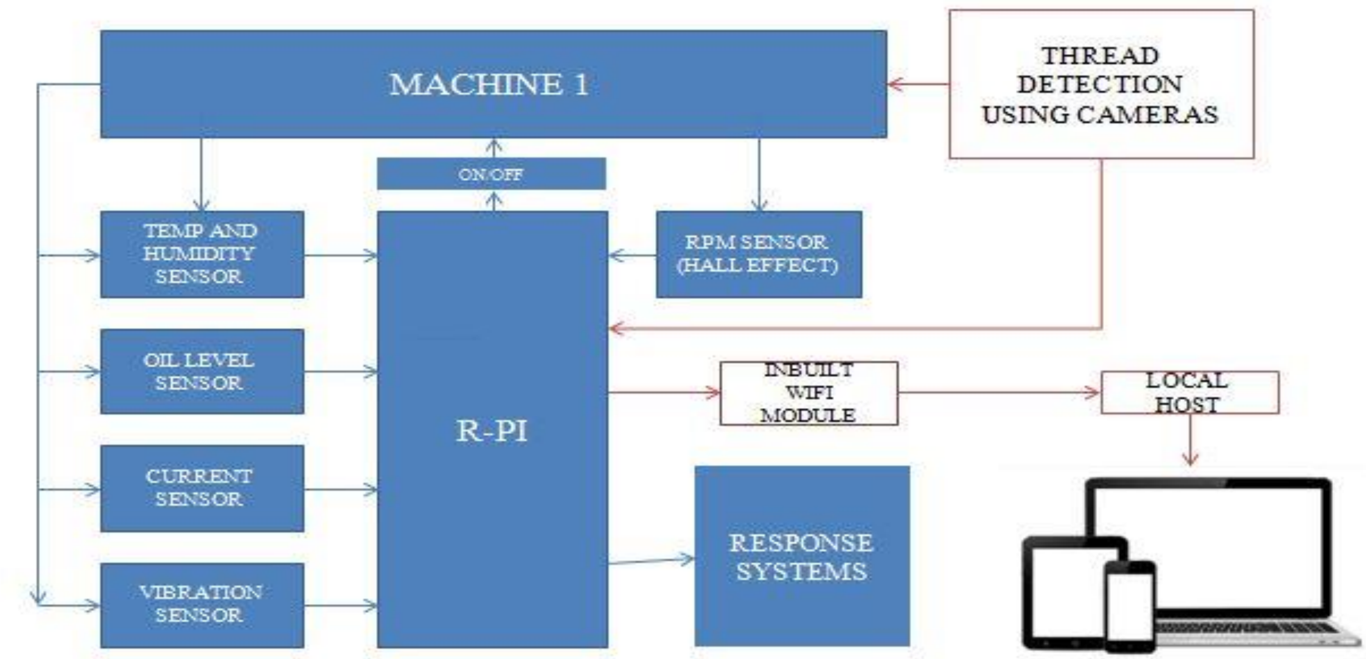

Figure 1.1 Sensor Connection

1.4.2 Data-Collection

The microcontroller receives the data from the sensors. It sends the values to an application so that we can have a continuous monitoring over the readings.

1.4.3 Feature extraction

There are many attributes present in the dataset, out of these only a few attributes have significant impact on the device. These attributes have to be identified and only they have to considered for improving the efficiency of the machine.

1.4.4 Defect Prediction

The microcontroller compares the values which it receives, with the threshold values allowed. Based on the comparison it either allows the machine to continue working or it stops the machine and raises warnings. The flowchart depicting the entire process is depicted below.

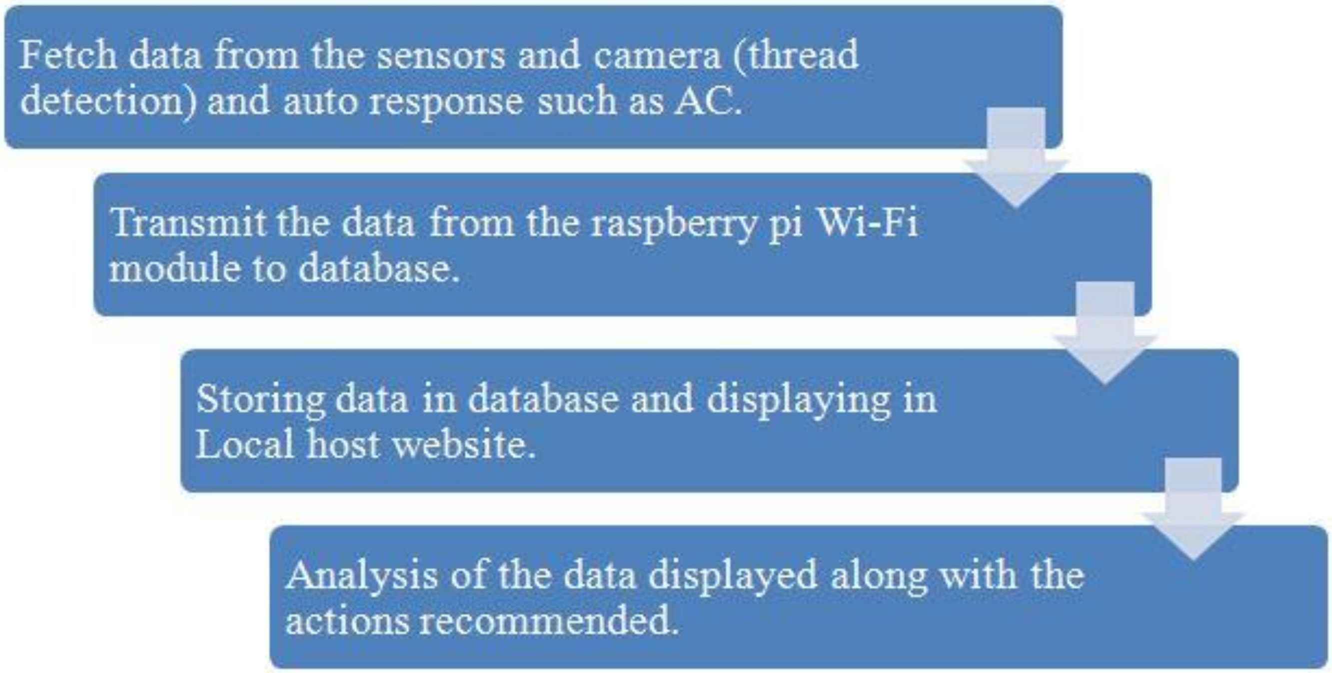

Figure 1.2 Flowchart

1.4.5 Scope and Motivation

The main objective of this project is to predict when the machine can go into defects, thus reducing the cost for the owner as well as improving the overall efficiency of the machine. Here the readings obtained from various parameters of the machine are compared with the desired values which can help in early prediction. Also, this system has a very wide scope usage in the sense that the data obtained can be used for several research and behavioral understanding purposes. The overall steps involved in this project is demonstrated through the flowchart in Figure 1.2

1.4.6 Role of sensors (IoT)

Internet of Things (IoT) is a network of connected devices such as sensors, electronic equipment, cameras, and many more. They are programmed in such a way that IoT provides automation for the devices that are connected. We just need to give commands to these devices using our smartphone application for operating them. This is all possible by smartly integrating technologies and equipment together to form an IoT product. Further, due to the advancements in the field of AI and Machine Learning, the future scope of IoT has impressively increased.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provides an in-depth analysis of the various methods that have been deployed to monitor the health conditions of the machine. Each methodology has its own advantages and disadvantages. A combination of positive features in all the methodologies have been integrated in this project. **Mohammed and S. Djurović, [1]** wanted to develop a system to reduce cases of burning of induction motors and the consequent downtime and cost. Increased burning of three-phase induction motors windings were reported. The initial symptoms before the burning of the windings were an increase in operating current and a temperature rise. The induction motor protection and control system was designed, developed, and constructed to reduce the problem of burnt winding by early detection and disconnection of supply if the problem persists. It was found to be reliable and very efficient in early predictions. The system is a boost to Nigerian industrialists as it will. The system is cheap and easy to repair and maintain because the parts and components used in the design are available locally. This success has influenced the construction of new systems for various different machines in the real world

2.2 FIBER BRAGG GRINDING METHODOLOGIES

M. Fabian, D. M. Hind, C. Gerada, T. Sun and K. T. V. Grattan [23] have utilized the Fiber Bragg grinding (FBG) sensors for monitoring the machine. In the proposed technique , simultaneous extraction of thermal and mechanical information on the bearing operational status for health monitoring and fault diagnosis purposesis carried out. Here, FBG array sensors are fitted to the drive-end bearing of an operating inverter driven induction motor and tests are then undertaken to evaluate the sensing scheme's performance under healthy and faulted bearing conditions. The results demonstrate that the information, can clearly differentiate to enable understanding of the examined motor bearing's thermal only and mechanical only operating conditions. Also the readings obtained in fault conditions are shown to contain clearly defined time and frequency domains fault signatures, which can enable unambiguous fault diagnosis and trending.

To detect electrical faultsin wound coils , **Mohammed and S. Djurović [5]**constructed a prototype to test coils housed in a purpose built steel core section. The FBG thermal sensors are embedded between copper conductors in multiple positions within the coil structure and in close proximity of the known hot spots of interest. The examined coils are designed to enable creation of hot regions similar of those that would be expected to arise during winding fault events. Various experiments were conducted in order to characterize the various potential defects that could arise. The final report demonstrate the potential of the proposed in-situ thermal sensing scheme to enable monitoring and recognition of coil internal thermal stress induced at various stages of emulated electrical fault

D. S. Vilchis-Rodriguez, S. Djurović, P. Kung, M. I. Comanici and A. C. Smith[8] investigated the use of fibre Bragg grating (FBG) accelerometers for vibration monitoring . The sensor performance is assessed in a series of experiments on a laboratory machine operating in healthy conditions and with fault. The fibre optic sensor effectiveness in measurement of wide band fault signatures in the vibration signal is compared with that of a commercial piezoelectric based solution. The potential and limitations of the investigated FBG accelerometer design are evaluated for use in condition monitoring applications.

2.3 CONDITIONAL MONITORING OF MACHINES

P. Tavner [25]did a research to get results from conditional monitoring of the machines. Condition monitoring involves taking minimum measurements from a machine so that a condition can be rapidly inferred, giving a clear indication of incipient failure modes. The current state of the art is reviewed in the following ways: survey developments in condition monitoring of machines, mechanically and electrically, over the last 30 years; put that work in context alongside the known failure mechanisms; review those developments which have proved successful and identify areas of research which require attention in the future to advance the subject.

P. Zhang, Y. Du, T. G. Habetler and B. Lu [26], monitored the wavelets in a vector controlled induction motor for monitoring the various AC and DC current voltages. **P. P. Kulkarni, M. Patil, S. Shibi, M. Patle and R. Kale [27],**used online monitoring as an effective way to observe factual data. Internet of things [IoT] based online monitoring can be used to access data remotely. IoT is used to observe different parameters on real time scale and can be used to measure and sense different sources like energy, voltage, current, temperature, power factor and frequen. This paper reviews suitability of IoT based online monitoring system for electrical equipment

2.4 THREAD BREAKAGE DETECTION

Wenyuan Wang, Ping Zhou and Xiangyu Lin [31], wanted tosave the cost of textile enterprises. In a spinning mills yarn breakage cannot be detected in a timely manner, and this proves to be expensive in the long run. Their paper presents a software system based on computer vision for real-time detection of yarn breakage. Running on the Tablet PC, software system is designed to collect yarn and location information for analysis and processing. And will be processed after the information through the Wi-Fi and http protocol sent to the cloud server to store in the Microsoft SQLdatabase. In order to follow up on the yarn break information query and management. Finally sent to the local display on time display, and remind the operator to deal with broken yarn. The experimental results show that the system of missed test rate not more than 5%o, and no error detection.

Liu Zhao;ZHANG Ling;WU Zhen-tian;HUO Ming-wu;YAO Jun-hong [32] , invented a system be find the large number of fuzzy yarns produced during spinning process of the spinning machines. They designed a test car for this process and it is composed of the servo motor, which is intelligent to detect the yarn break and raise alarm. Such car has advantages of good sensitivity, highaccuracy, convenient to be operated, high working efficiency and low cost, and has good application prospect.

CHAPTER 3
IOT BASED MONITORING OF MACHINES

3.1 OBJECTIVES

An essential assembling objective is to keep up high item quality. For some endeavors, this target actually appears to be not really reachable. Over and over again, item quality issues are revealed just when an item falls flat in testing, or more regrettable, when a client makes a return or triggers a review. A typical reason behind decreased item quality is defects in hardware, which has not been as expected kept up or aligned. Makers are progressively going to IoT-driven machine condition observing, which uncovers hardware gives that can influence the nature of items so they can be fixed before things deteriorate.

The IoT-driven approach to product quality control: Condition observing empowers item quality control by distinguishing blends of hardware wellbeing, for example, shaft vibration recurrence, motor temperature, cutting rate, and encompassing boundaries, like temperature and dampness. Joined, these boundaries can cause decay in the nature of an item yield. A verifiable informational collection that contains gear condition records assembled through a time span (say, a year) is joined with the information session item quality deviations and setting information (for instance, hardware upkeep history) from either ERP, PIMS, or DCS frameworks.

The joined informational index is then taken care of into cutting edge AI calculations, which would then be able to identify causal connections in the approaching information records. Uncovered connections are reflected in prescient models, which are then used to recognize mixes of hardware condition and ecological boundaries that can prompt item quality issues.

3.2 BENEFITS IOT-DRIVEN CONDITION MONITORING

- Compared to customary creation quality control procedures (for instance, test looks at conveyed toward the finish of a creation cycle), IoT-driven gear condition observing allows clients to pinpoint quality issues at the creation stage, when an issue can in any case be alleviated.
- The examination capacities of IoT-driven condition observing arrangements establish a framework for enhancements in item quality. For instance, consolidating recorded information from vibration sensors joined to the processing moves' orientation with the information about past quality misfortunes, makers infer that a 8% increment in a roller bearing's vibration causes a metal sheet's left side be 0.1 inch thicker than the correct side. Makers would then be able to utilize these experiences to improve the nature of the yield items.

3.3 FACTORS TO CONSIDER

Opting for an IoT platform vendor has the following advantages:

- Lower implementation cost;
- Simpler integration with enterprise and shop floor management systems;
- More comprehensive upgrades.

However, going for the collaboration with a single IoT platform vendor, enterprises are unlikely to get the best-of-breed functionality, as they often get locked up in the vendor's solution ecosystem with limited options to test alternative solution components that may be a better fit.Collaborating with an IoT integrator, on the other hand, offers the possibility to 'build' an IoT solution from the components tailored to the enterprise's needs. Still, the cost of implementation will rise, as enterprises have to buy separate individual modules from multiple vendors and partner with an integrator to bring these modules together.

Despite the fact that IoT-based condition checking makes ready to enhancements underway quality, such a methodology has certain constraints, as information about machine conditions might be insufficient for balanced quality affirmation. Observing the state of machines, for example, can't recognize issues emerging from the utilization of damaged or misidentified segments, or inappropriate material taking care of. Controlling the nature of items by observing the state of machines, on which they are made, assists with driving yield improvement, lessen scrap, and limit revamp. Contrasted with other quality confirmation strategies (for instance, in view of reviewing parts and semi-completed items as they travel through the creation cycle), the condition checking based methodology may offer less separation as far as quality control scope, yet it recognizes quality issues at their early stage and anticipate likely ones.

3.4 ALTERNATIVES TO IOT WII NETWORKS AND CONNECTIVITY

The Internet of Things (IoT) is all about seamless network connectivity that works on its own. The introduction of Alexa and Google Nest has shown how easy it is to connect one’s devices. But it’s not just consumer products that are making the leap: IoT technology is transforming with the implementation of trackers, sensors and devices.WiFi connectivity for IoT devices seems like an obvious choice, but it’s not the only IoT wireless connectivity option—nor is it necessarily the best.The three things we typically tend to reference when sizing up a good IoT network are

- Power consumption. Many IoT devices are battery-powered and not hardwired. Keep this in mind when choosing a network, as you won't want something too power-hungry if you're looking for longevity.

- Coverage range. If your devices span a fair distance, you'll want to keep coverage range in mind when choosing an IoT network.
- Bandwidth. Some IoT devices can consume a lot of data. You'll need to choose an IoT wireless network that can receive and process the required amount of data for your needs.

To use WiFi as an example: when using it as an IoT network, it works fine for stationary devices that don't require a large coverage range. As you already know through connecting to the regular internet, WiFi IoT connectivity is fairly limited in its parameters and can only connect so far. If you're looking to connect something that requires a more flexible coverage range, you're better off choosing an alternative IoT wireless network.

3.4.1 Alternatives to Wi-Fi for IoT connectivity

3.4.1.1 Cellular connectivity

Cellular connectivity – also referred to as satellite connection – is the best WiFi alternative to connect IoT devices which is typically used when we talk about machine-to-machine (M2M) connectivity. It's the same type of connectivity that we use to connect our smartphones and tablets and uses a broadcast tower to function—typically within a range of around 10 – 15 miles.

- Cellular has the furthest range by far. As long as you are within range of a cellular tower (which is most of the time), you can connect to anyone or any 'thing' on a global scale.
- Cellular is a very reliable IoT connectivity solution. Unlike WiFi, it rarely 'cuts

out' and is available everywhere.

- Ease of use: Cellular is highly compatible—you only need an eSIM or regular SIM card in order to connect.
- Cellular has relatively high-power consumption compared to its alternatives.
- Household-name providers can be expensive, that's why it's crucial to shop around and ensure you're getting a tailored deal that's right for you.

3.4.1.2. LPWAN

Low Power Wide Area Network (LPWAN) is a fairly new contender in the IoT network space, but it offers a lot in terms of breadth of coverage while still maintaining low power consumption. LPWAN does this by using small, cheap batteries to power its connectivity. Various kinds of LPWAN connections have been created for different purposes, such as

- LTE-M (a customized LTE connection designed for small power consumption)
- NB-IoT (Narrowband IoT)
- LoRa

3.4.1.3. Zigbee

Zigbee is another popular alternative to WiFi IoT networks and connectivity. It works using a mesh network structure—connecting a host of sensors or devices so that they work seamlessly together to distribute data to the chosen device. With a mesh network, all IoT devices in the system are able to distribute signals and information around the network.

Designed especially for IoT, Zigbee can connect up to 65,000 devices in its mesh and is already supported by mainstream IoT devices such as Amazon Echo.

- As a mesh IoT networking option, it's one of the best
- Doesn't need a central hub in order to work

- Does have a short coverage range: devices need to be within 30-50 feet of each other
- Low data transfer (around 250 kbps)

3.4.1.4. Bluetooth

Most of us are familiar with the concept of Bluetooth having used it on our phones for the last decade. Bluetooth enables users to send data across short distances using wireless technology.In recent years, Bluetooth has improved drastically in terms of power consumption. Where before it could flatten a battery fairly easily, today's Bluetooth connections run on a fairly low-power model.Bluetooth had a competitive bandwidth of 2Mbps but only has low range capabilities of below 30ft (10m).

3.4.1.5. Z-Wave

Like Zigbee, Z-Wave runs on a radio-frequency (RF) based connection. Unlike Zigbee, however, Z-Wave usually needs to run via a central hub, which can mean the connection is interrupted with latency issues and a limited coverage range. It's worth noting that Z-Wave is slightly slower than Zigbee but does have a more impressive coverage range (of more than 30 feet).Z-Wave uses a 908 MHz band to operate, which enables an increase in coverage range as well as reducing the likelihood of interference. When placed next to each other, Z-Wave is typically more reliable than Zigbee but Z-Wave is supported on far fewer devices.

CHAPTER 4
IoT AND SENSORS

4.1 INTERNET OF THINGS

The Internet of things (IoT) portrays the organization of actual items—"things" or articles—that are inserted with sensors, programming, and different advancements to interface and trading information with different gadgets and frameworks over the Internet. The web of things, or IoT, is an arrangement of interrelated registering gadgets, mechanical and computerized machines, articles, creatures or individuals that are given exceptional identifiers (UIDs) and the capacity to move information over an organization without expecting human-to-human or human-to-PC communication.

A thing in the web of things can be an individual with a heart screen embed, a livestock with a biochip transponder, a car that has implicit sensors to alarm the driver when tire pressure is low or whatever other characteristic or man-made item that can be doled out an Internet Protocol (IP) address and can move information over an organization.

4.2 SENSORS

4.2.1 Introduction

A sensor is a gadget that can distinguish changes in a climate. Without help from anyone else, a sensor is pointless, however when we use it in an electronic framework, it assumes a key part. A sensor can quantify an actual marvel (like temperature, pressure, etc.) and change it into an electric sign. These three highlights ought to be at the foundation of a decent sensor:

- It ought to be delicate to the wonder that it measures
- It ought not be delicate to other actual marvels

- It ought not change the deliberate marvel during the estimation cycle

There is a wide scope of sensors we can adventure to gauge practically every one of the actual properties around us. A couple of normal sensors that are generally embraced in regular day to day existence incorporate thermometers, pressure sensors, light sensors, accelerometers, spinners, movement sensors, gas sensors and some more. A sensor can be depicted utilizing a few properties, the most significant being:

- Range: The most extreme and least upsides of the marvel that the sensor can gauge.
- Sensitivity: The base difference in the deliberate boundary that causes a perceptible change in yield signal.
- Resolution: The base change in the wonder that the sensor can recognize.

4.2.2 Sensor Classification

Sensors can be gathered utilizing a few measures:

- Passive or Active. Detached sensors don't need an outside power source to screen a climate, while Active sensors require such a source to work.
- Another grouping depends on the strategy used to distinguish and gauge the property (mechanical, synthetic, and so forth)
- Analog and Digital**.** Simple sensors produce a simple, or ceaseless, signal while computerized sensors produce a discrete sign.

4.2.3. Step by step instructions to use Sensors in IoT

The improvement of prototyping sheets and the low cost of sensors permit us effectively use them in IoT projects. There are a few prototyping sheets available, appropriate for various ventures relying upon highlights and particulars, the two most well-known sheets being the Arduino Uno and Raspberry Pi 2.

4.2.4 Using Arduino with Sensors:

The first and the most well-known board is the Arduino Uno (Figure 4.1). It is a microcontroller board dependent on an ATmega328P. It is extremely simple to utilize, and a decent beginning stage. This board gives 6 simple and 14 advanced pins. It is wonderful to use with simple and advanced sensors.

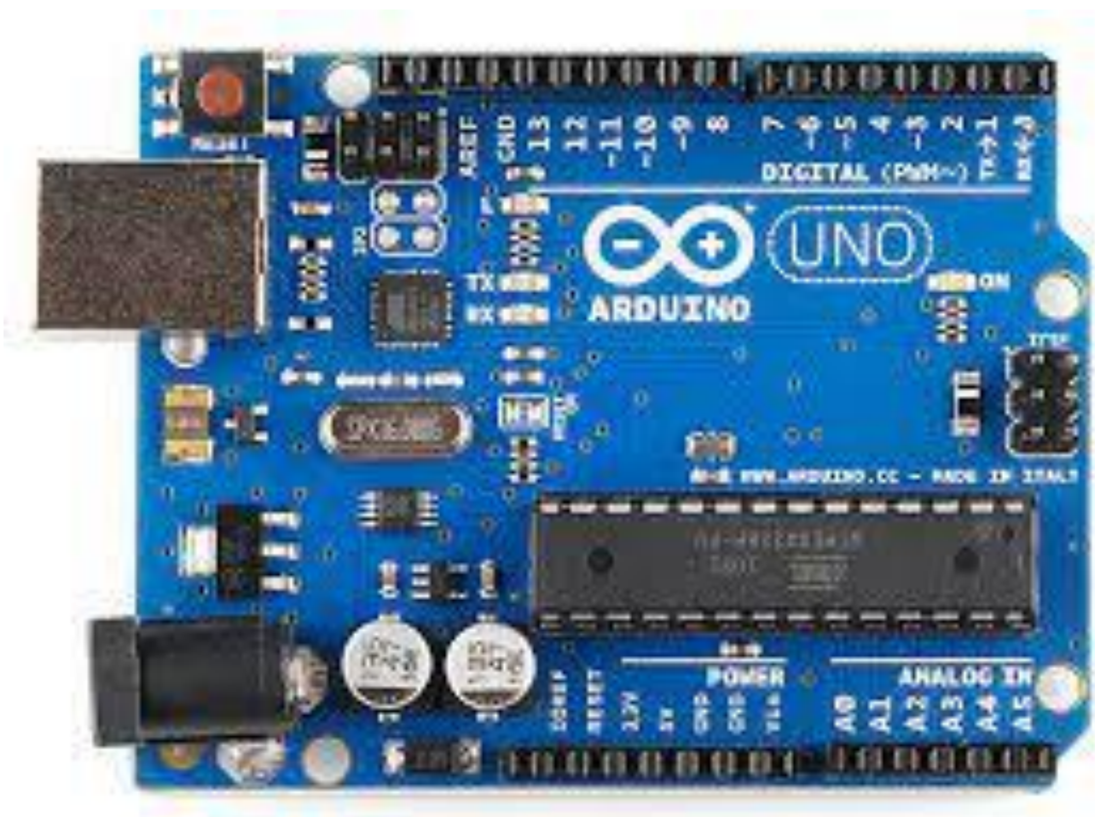

Figure 4.1: Arduino[10]

4.2.5 Using Sensors with a Raspberry Pi:

Raspberry Pi is a single-board computer developed by the Raspberry Pi Foundation. There are several versions of Raspberry Pi one such version is shown in Figure 4.2 with different specifications, but they all have their own operating system based on Linux. It is similar to a PC because it supports video output, USB ports, and keyboards. It is a very powerful board, and the examples below show only a little bit of its power.

Figure 4.2 Raspberry Pi [13]

4.2.6 Various Sensors and their Uses

4.2.6.1 Current Sensor (ACS712)

The ACS712(Figure 4.3) is a fully integrated, hall effect-based linear current sensor with 2.1kVRMS voltage isolation and a integrated low-resistance current conductor. It is simply a current sensor that uses its conductor to calculate and measure the amount of current applied.

Figure 4.3 Current Sensor [12]

4.2.6.2 Temperature & Humidity Sensor (DHT11):

The DHT11(Figure 4.4) is a basic, ultra-low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). Its fairly simple to use, but requires careful timing to grab data. You can get new data from it once every 2 seconds, so when using the library from Adafruit, sensor readings can be up to 2 seconds old. Comes with a 4.7K or 10K resistor, which you will want to use as a pull-up from the data pin to VCC.

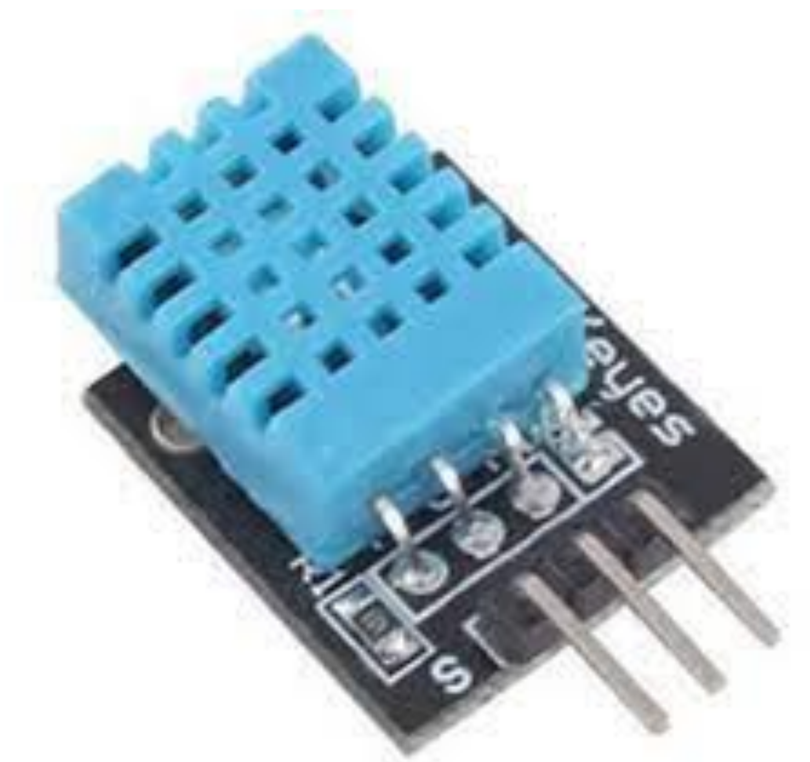

Figure 4.4Temperature Sensor [15]

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4.2.6.3 Ultrasonic sensor (HC-SR04)

The HC-SR04(Figure 4.5) sensor provides 2cm to 400cm of non-contact measurement functionality with a ranging accuracy that can reach up to 3mm. Each HC-SR04 module includes an ultrasonic transmitter, a receiver and a control circuit.There are only four pins that you need to worry about on the HC-SR04: VCC (Power), Trig (Trigger), Echo (Receive), and GND (Ground)

Figure 4.5 Ultrasonic Sensor [11]

4.2.6.4 IR Sensor:

IR sensor(Figure 4.6) is an electronic device, that emits the light in order to sense some object of the surroundings. An IR sensor can measure the heat of an object as well as detects the motion. Usually, in the infrared spectrum, all the objects radiate some form of thermal radiation. These types of radiations are invisible to our eyes, but infrared sensor can detect these radiations.

Figure 4.6 IR Sensor [17]

Current Sensor	Temperature and Humidity Sensor	Ultrasonic sensor	IR Sensor
• 80kHz bandwidth. • 66 to 185 mV/A output sensitivity • Low-noise analog signal path • Device bandwidth is set via the new FILTER pin • 1 mΩ internal conductor resistance • Total output error of 1.5% at TA = 25°C • Stable output offset voltage. • Near zero magnetic hysteresis	• 2.5mA max current use during conversion (while requesting data) • Good for 20-80% humidity readings with 5% accuracy • Good for 0-50 °C temperature readings +-2 °C accuracy • No more than 1 Hz sampling rate (once every second) • Body size 15.5mm x 12mm x 5.5mm • pins with 0.1" spacing • Adafruit Learning Documentation for DHTxx Sensors • RoHS compliant	• Operating voltage: +5V • Theoretical Measuring Distance: 2cm to 450cm • Practical Measuring Distance: 2cm to 80cm • Accuracy: 3mm • Measuring angle covered: <15° • Operating Current: <15mA • Operating Frequency: 40Hz	• 5VDC Operating voltage. • I/O pins are 5V and 3.3V compliant. • Range: Up to 20cm. • Adjustable Sensing range. • Built-in Ambient Light Sensor. • 20mA supply current. • Mounting hole.

Table 4.1 Features of Sensors

Current Sensor	**Temperature and Humidity Sensor**	**Ultrasonic sensor**	**IR Sensor**
• Current flows through the onboard hall sensor circuit in its IC • The hall effect sensor detects the incoming current through its magnetic field generation • Once detected, the hall effect sensor generates a voltage proportional to its magnetic field that's then used to measure the amount of current	• The DHT11 calculates relative humidity by measuring the electrical resistance between two electrodes. • The humidity sensing component of the DHT11 is a moisture holding substrate with the electrodes applied to the surface. • The change in resistance between the two electrodes is proportional to the relative humidity.	• When the ultrasonic wave travels in air and gets objected by any material it gets reflected back toward the sensor this reflected wave is observed by the receiver module • The inbuilt module will calculate the time taken for the US wave to come back and turns on the echo pin high • Now simply calculate the distance using a microcontroller or microprocessor.	• Active infrared sensors both emit and detect infrared radiation. • When an object comes close to the sensor, the infrared light from the LED reflects off of the object and is detected by the receiver.

Table 4.2 Working of Sensors

Current Sensor	Temperature and Humidity Sensor	Ultrasonic sensor	IR Sensor
• Motor speed control in motor control circuits • Electrical load detection and management • Switched-mode power supplies (SMPS)	• Humidity and temperature values in heating, ventilation and air conditioning systems • Weather stations also use these sensors to predict weather conditions	• Used to avoid and detect obstacles with robots like biped robot, obstacle avoider robot, path finding robot etc. • Used to measure the distance within a wide range of 2cm to 400cm • Can be used to map the objects surrounding the sensor by rotating it • Depth of certain places like wells, pits etc can be measured since the waves can penetrate through water	• Climatology • Meteorology • Photo biomodulation • Gas detectors • Water analysis • Anaesthesiology testing • Petroleum exploration Rail safety

Table 4.3Applications of Sensors

CHAPTER 5

SOFTWARE APPLICATION-THINGPSEAK^{TM}

5.1 THINGSPEAK^{TM}

ThingSpeak^{TM}is an IoT analytics platform (Figure 5.1) service that allows you to aggregate, visualize, and analyze live data streams in the cloud. You can send data to ThingSpeak^{TM} from your devices, create instant visualization of live data, and send alerts.According to its developers, ThingSpeak^{TM} is an open-source Internet of Things (IoT) application and API to store and retrieve data from things using the HTTP and MQTT protocol over the Internet or via a Local Area Network. ThingSpeak^{TM} enables the creation of sensor logging applications, location tracking applications, and a social network of things with status updatesThingSpeak^{TM} was originally launched by ioBridge in 2010 as a service in support of IoT applications

ThingSpeak^{TM} has integrated support from the numerical computing software MATLAB from MathWorks, allowing ThingSpeak^{TM} users to analyse and visualize uploaded data using MATLAB without requiring the purchase of a MATLAB license from Mathworks. ThingSpeak^{TM} has a close relationship with Mathworks, Inc. In fact, all of the ThingSpeak^{TM} documentation is incorporated into the Mathworks' MATLAB documentation site and even enabling registered Mathworks user accounts as valid login credentials on the ThingSpeak^{TM} website. The terms of service and privacy policy of ThingSpeak.com are between the agreeing user and Mathworks, Inc.ThingSpeak^{TM} has been the subject of articles in specialized "Maker" websites like Instructible, CodeProject,and Channel 9

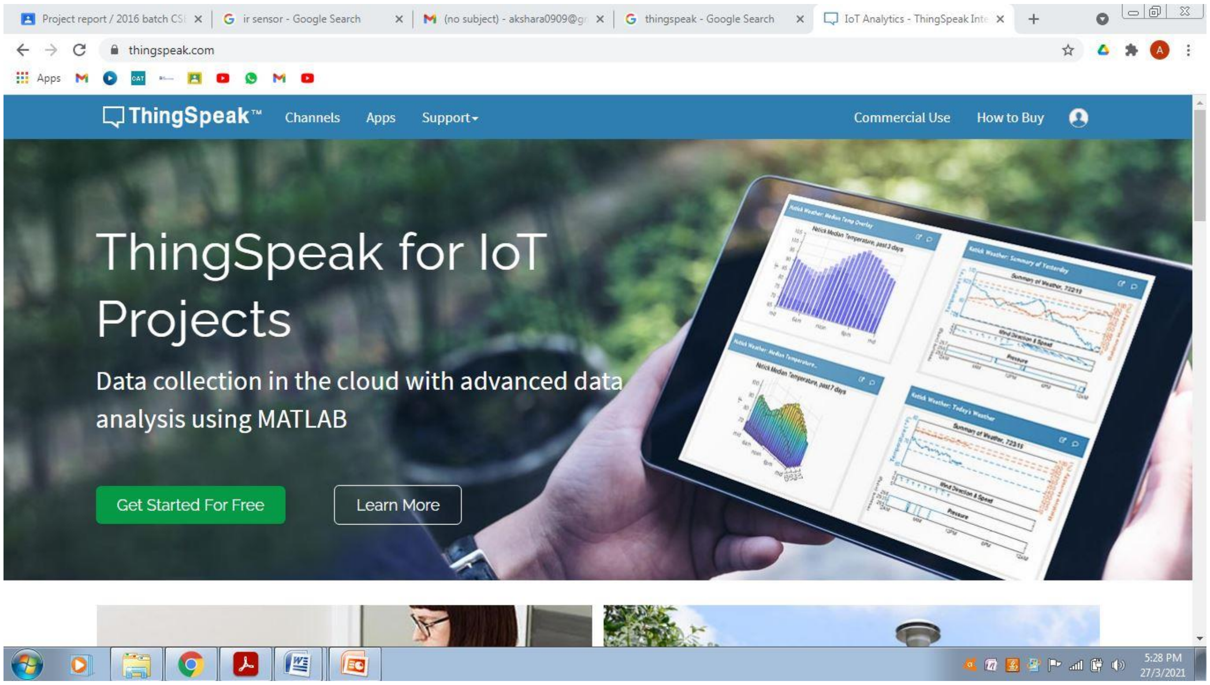

Figure 5.1 Thingspeak™ Platform [14]

Internet of Things (IoT) describes an emerging trend where a large number of embedded devices (things) are connected to the Internet. These connected devices communicate with people and other things and often provide sensor data to cloud storage and cloud computing resources where the data is processed and analyzed to gain important insights. Cheap cloud computing power and increased device connectivity is enabling this trending. IoT solutions are built for many vertical applications such as environmental monitoring and control, health monitoring, vehicle fleet monitoring, industrial monitoring and control, and home automation.

At a high level, many IoT systems can be described using the Figure 5.2

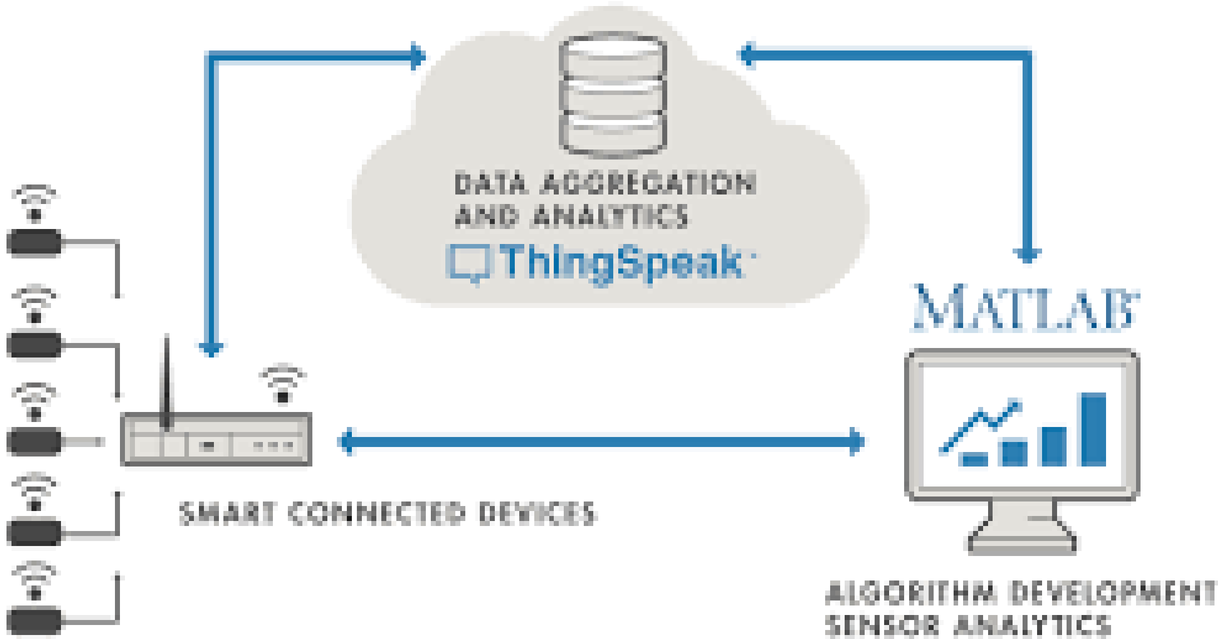

Figure 5.2 Flow diagram-Thingspeak™[14]

From Figure 5.2, on the left, we have the smart devices (the "things" in IoT) that live at the edge of the network. These devices collect data and include things like wearable devices, wireless temperatures sensors, heart rate monitors, and hydraulic pressure sensors, and machines on the factory floor. In the middle, we have the cloud where data from many sources is aggregated and analyzed in real time, often by an IoT analytics platform designed for this purpose. The right side of the diagram depicts the algorithm development associated with the IoT application. Here an engineer or data scientist tries to gain insight into the collected data by performing historical analysis on the data. In this case, the data is pulled from the IoT platform into a desktop software environment to enable the engineer or scientist to prototype algorithms that may eventually execute in the cloud or on the smart device itself.

An IoT system includes all these elements. Thingspeak™ fits in the cloud part of the diagram and provides a platform to quickly collect and analyze data from internet connected sensors.

5.2 FEATURES:

- Collect data in private channels
- Share data with public channels
- RESTful and MQTT APIs
- MATLAB® analytics and visualizations
- Event scheduling
- Alerts
- App integrations

5.3 WORKS WITH:

- MATLAB®
- Arduino®
- Particle Photon and Electron
- ESP8266 Wi-Fi Module
- Raspberry Pi™
- LoRaWAN®
- Things Network
- Senet
- Libelium
- Beckhoff

5.4 THINGSPEAK™ KEY FEATURES:

- ThingSpeak™ allows you to aggregate, visualize and analyse live data streams in the cloud. Some of the key capabilities of ThingSpeak™ include the ability to:
- Easily configure devices to send data to ThingSpeak™ using popular IoT protocols.
- Visualize your sensor data in real-time.
- Aggregate data on-demand from third-party sources.
- Use the power of MATLAB to make sense of your IoT data.
- Run your IoT analytics automatically based on schedules or events.
- Prototype and build IoT systems without setting up servers or developing web software.
- Automatically act on your data and communicate using third-party services like Twilio or Twitter

CHAPTER 6

DESIGNING AND IMPLEMENTATION

6.1 INITIAL CONNECTIONS

The gadget is carried out utilizing the raspberry pi 4 miniature regulators, which fills in as the focal point of information and picture handling and the exchange and the collector focus of the orders from the ThingSpeak™ stage. The information from the sensors is gathered and put away in the stage just as fitting moves are made from the information like AC unit, radiator unit and so forth Every one of these reaction frameworks are controlled with the assistance of the hand-off. The end result is appeared underneath.

6.2 DIFFERENT VIEWS

6.2.1 Top View

Figure 6.1: Final product dimensions

Figure 6.1 is the top view of the final product. It contains the HC-SR04 sensor which is used as a emergency stop button. The hand can be placed in front of it to stop the machine in case of emergencies or when the damaged thread which is detected has to be repaired. The front and the back view of the product are also shown next. The product with its small size can therefore be easily integrated with any machine to monitor its parameters and can be easily used as a data logger.

6.2.2 Front View

Figure 6.2: Front view of the product

Figure 6.2 shows the front view of the product which contains an open slot which is used to connect the microcontroller to the sensors. All the sensors are placed at various parts of the machine and they collect the data and send it to the microcontroller.

6.2.3 Back View

Figure 6.3 Back view of the product

Figure 6.3 shows the back view of the product which contains an open slot which is used to power the microcontroller. All the response systems such as AC unit etc. as well as the machine is connected to the relay for autonomous control of the machine and to improve production efficiency. All the appropriate systems are connected to the device and the program which is written in the micro controller is a CRON Job, thus the program starts running as soon as the device is powered up.

6.2.4 Internal Structure

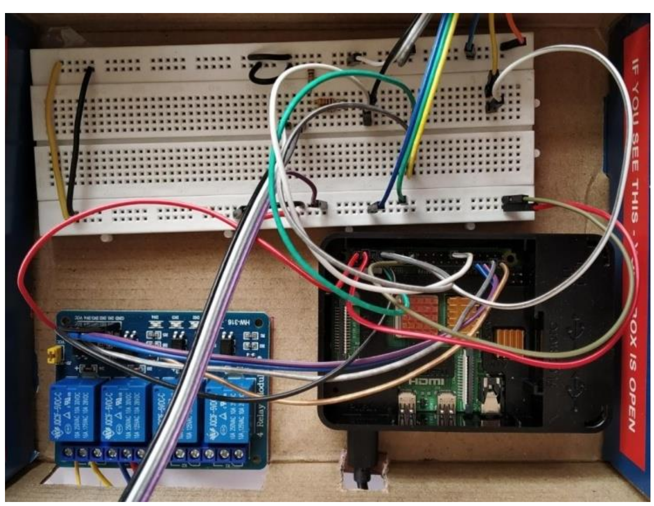

Figure 6.4: Internal structure of the product

Figure 6.4 shows the internal structure of the product which contains the microcontroller, a breadboard and a 4-channel relay. All the appropriate connections are given as shown in the image above. Due to the lack of an actual machine, for simulation one rotating part of the machine and a fan as an AC unit(Figure 6.6) to show the outputs are used whose images are shown below.

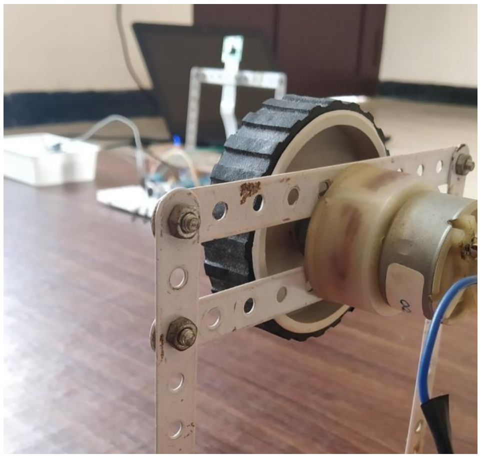

Figure 6.5 Rotating part of the machine

Figure 6.6 AC Unit

Figure 6.7 Oil tank

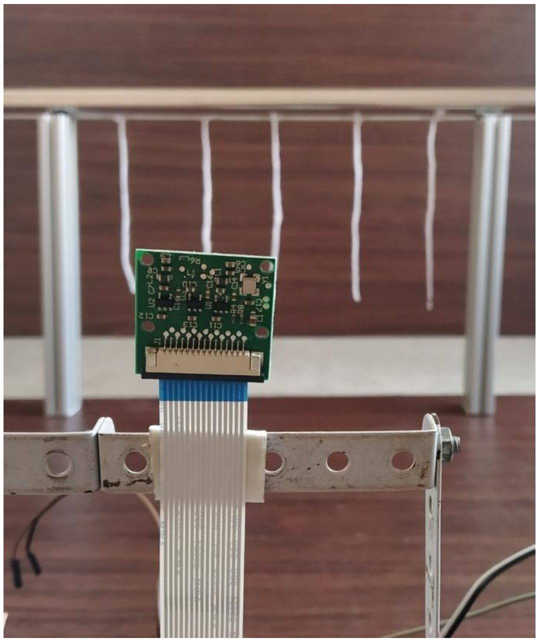

Figure 6.8: Thread in the spinning machine

Here we have the raspberry pi camera connected to the raspberry pi 4 microcontroller which captures the thread in the machine (simulated by the hanging threads) which is used for further processing

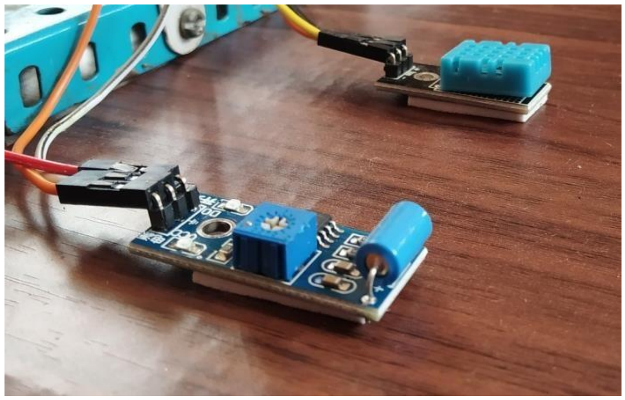

Figure 6.9

Figure 6.9 is the Vibration and the temperature sensor is connected to the device as shown in the figure. Hence the final product construction is shown along with all the sensors and the response systems connected to it. The data from the sensors is collected and transferred to the ThingSpeak™ website as shown below.

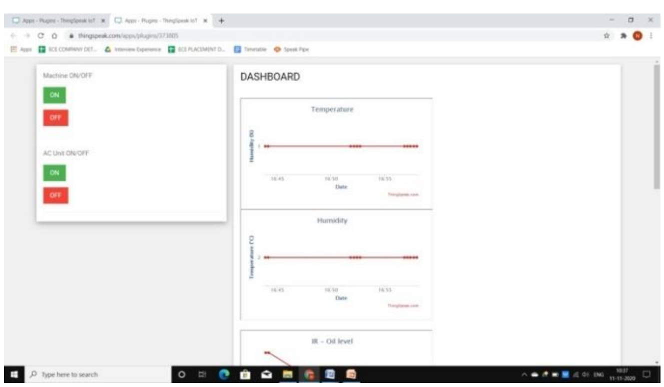

Figure 6.10

Figure 6.10 is the dashboard of the product where the data is displayed in the graphical form. The machine on and off functionalities is also included as shown.

Alerts are also displayed in the website such as when thread breakage is detected by the microcontroller. The ThingSpeak™ platform has been used to construct the website which is an open source IoT platform. The machine can communicate with the website through this platform. Finally, as a special note, mentioned in the introduction there are thousands of threads that are transferred simultaneously. Therefore, we have a rail in which the camera can be placed and it will capture the images as shown in the Figure 6.11. Thus, for prototyping purposes only one section of the threads as shown in Figure 6.8 is used.

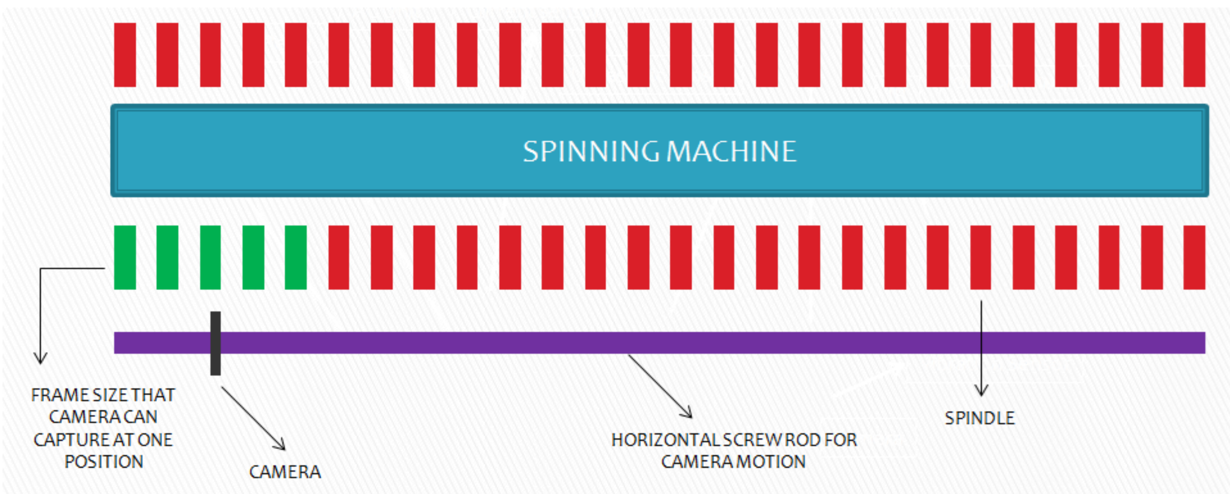

Figure 6.11 Machine illustration

CHAPTER 7
RESULTS AND FUTURE SCOPE

7.1 MONITORING THE DIFFERENT PARAMETERS IN A MACHINE

The most important reason for engine oil is lubrication. It keeps all the moving parts protected, and prevents them from rubbing against one another. Without oil, metal-on-metal wear would destroy your engine in a very short time. Oil creates an atoms-thin layer between moving parts, preventing full contact and prolonging engine life. The second reason is cooling. Most of the cooling needed is supplied by the coolant system (radiator, thermostat, water pump, etc.). However, oil does provide some supplemental cooling for areas of the engine where coolant cannot reach.Oil is also responsible for helping to clean the engine, removing debris like metal finings and other potentially damaging deposits.

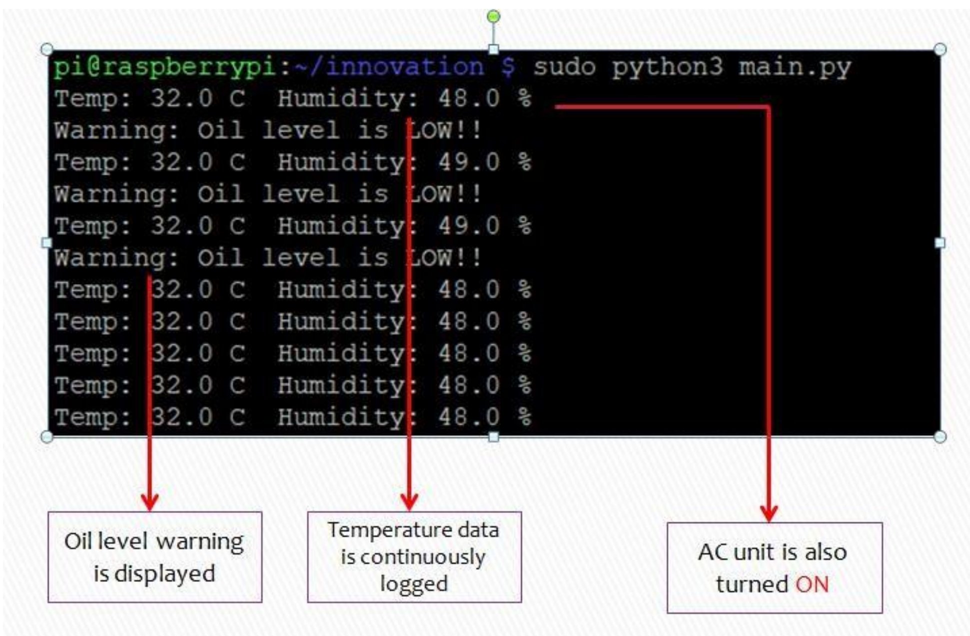

Figure 7.1 Case 1

Figure 7.1 represents a situation when the oil level is low and temperature is low. When the oil level is low, the machine will be turned off and since the temperature is also high, the AC unit is also turned on to regulate the temperature. When the oil level is reached to the desired level, again the machine turns on. By following this method extensive damage to the machine can be reduce and prevented

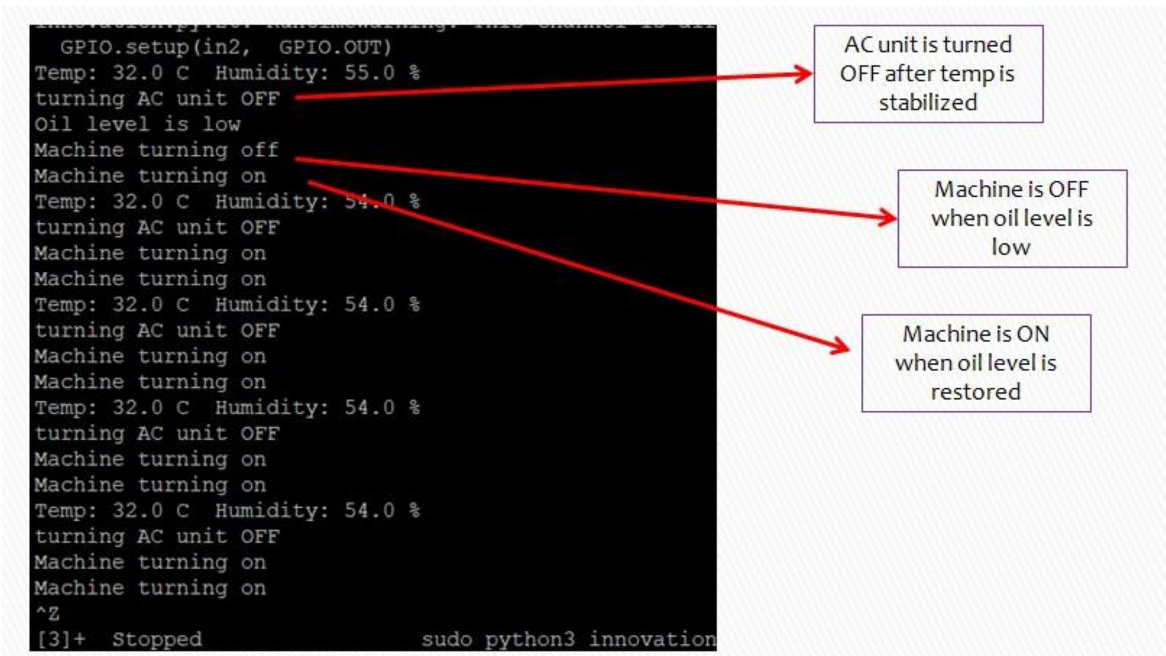

Figure 7.2Case 2

Figure 7.2 represents a situation when the machine turns ON.After the oil level as well as the temperature and humidity of the surroundings are verified, the machine turns on.

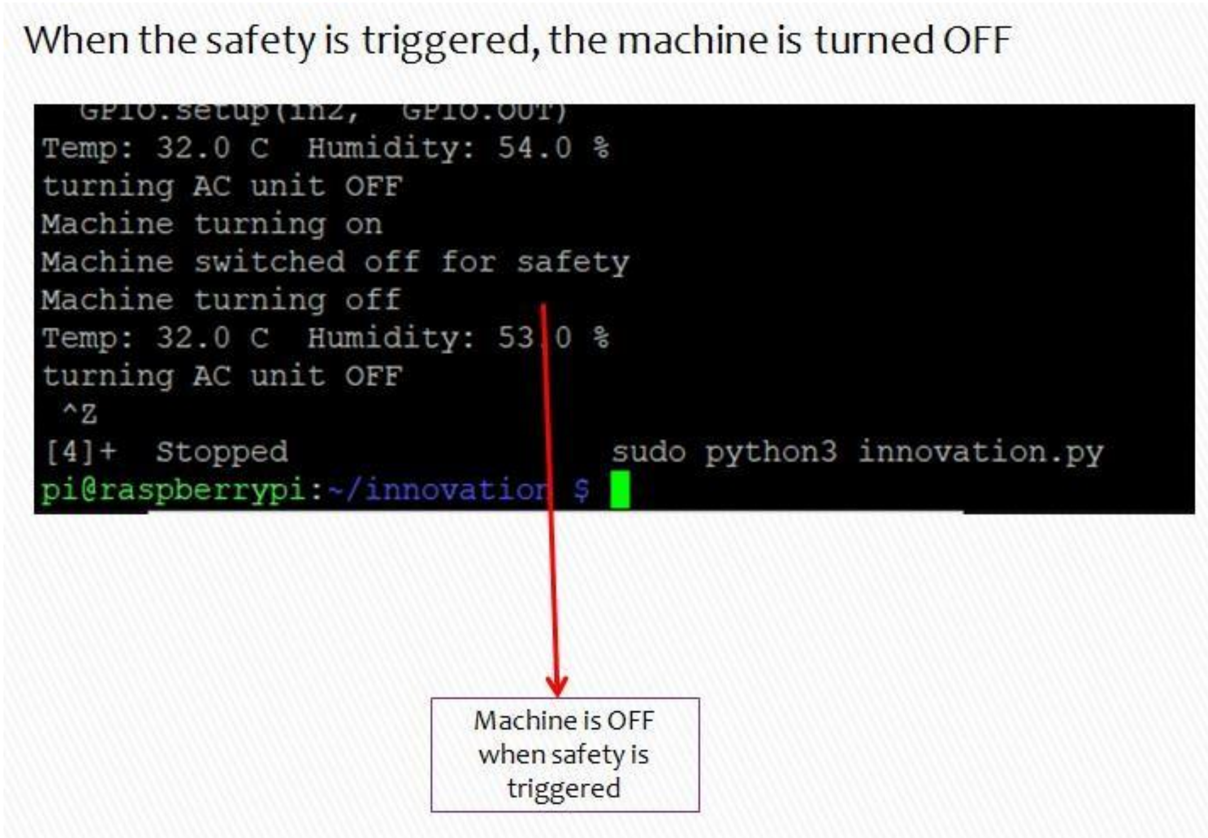

Figure 7.3 Case 3 Safety sensor is triggered

Figure 7.3 represents a scenario when a safety sensor is triggered. Safety sensors are mostly triggered when an external object is detected in a very close proximity to the machine. When this happens safety issues can arise to the third object and also the machine. To prevent this the machine stops working until the object is at a safe distance from the machine. The proximity settings can be determined and it varies from machine to machine. When the safety sensor is triggered, the machine will be turned off. This feature can be used to repair the thread breakage when it is detected by the camera as well as for emergency reasons.

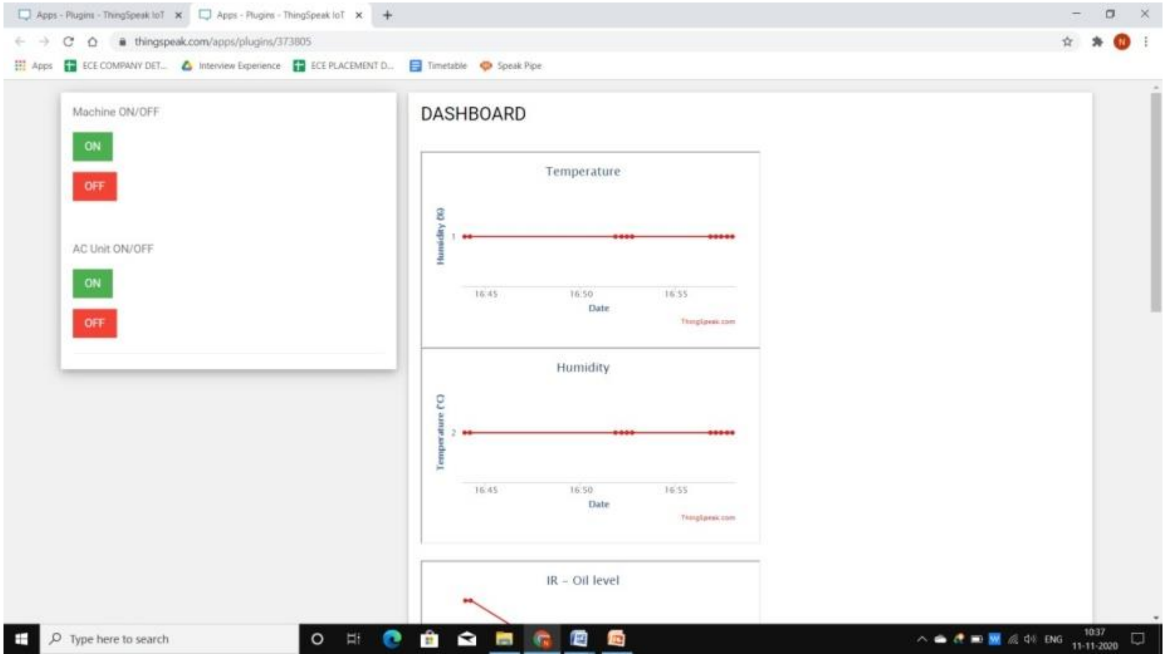

Figure 7.4

All the data is continuously logged into the database and displayed graphically as shown in Figure 7.4. Since numerical data is difficult to make conclusions from, graphical representations are made. This helps in making instant conclusions and also for determining the reason for which the machine has been stopped. So, it serves as both a verification and decision-making tool. The machine ON and OFF control as well as the AC on and off control is provided which can communicate with the microcontroller to take appropriate actions. Here it should be noted that the whenever the oil level is low in the machine, the machine turns off immediately with a warning both in the website as well as in the terminal window. All the data that has been collected in this part can be used for predictive maintenance of the machine by comparing it with the data collected from similar machines.

7.2 THREAD BREAKAGE DETECTION:

The thread detection code will be simultaneously running as soon as the machine turns ON after the initial conditions are satisfied. The camera will move along the rails from one end of the machine to the other, capturing images of 5 threads in one frame, these images are then processed using the image difference algorithm to detect if a thread breakage is there in the frame. If a breakage is detected, the machine alerts the machine supervisor to repair the thread to improve the production efficiency. The machine can then be switched off using the safety sensor or through the website to repair the breakage in the thread.

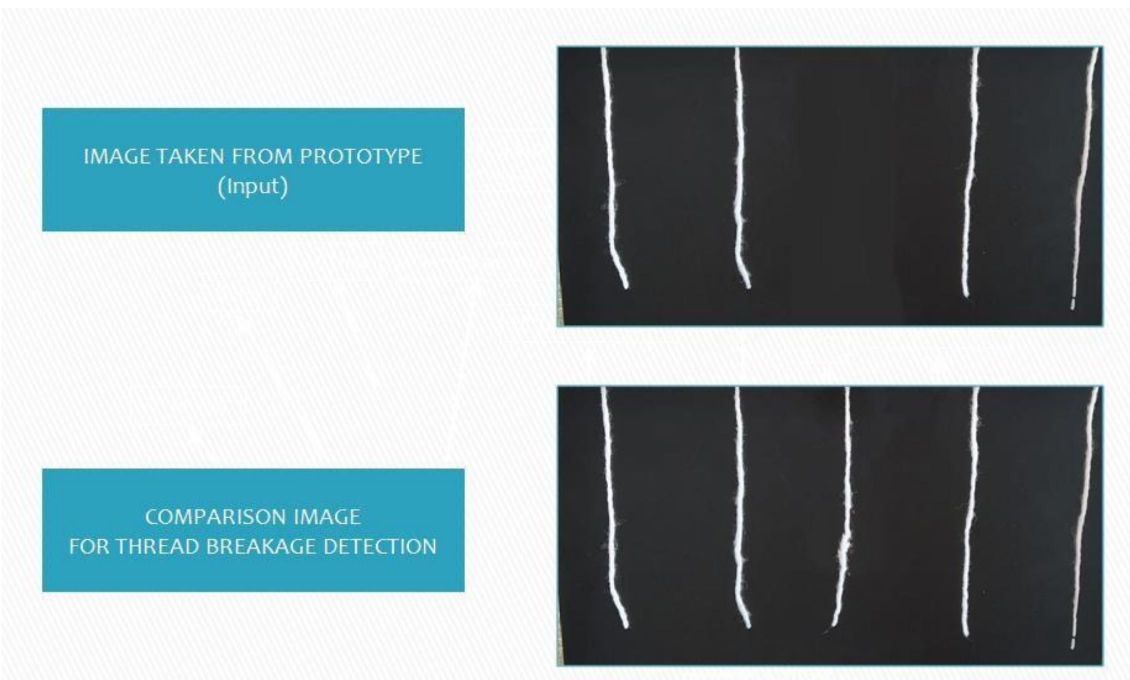

Figure 7.5

The image taken by the camera in one frame includes 5 threads which are then compared with a reference image to detect thread breakage as shown in Figure 7.5

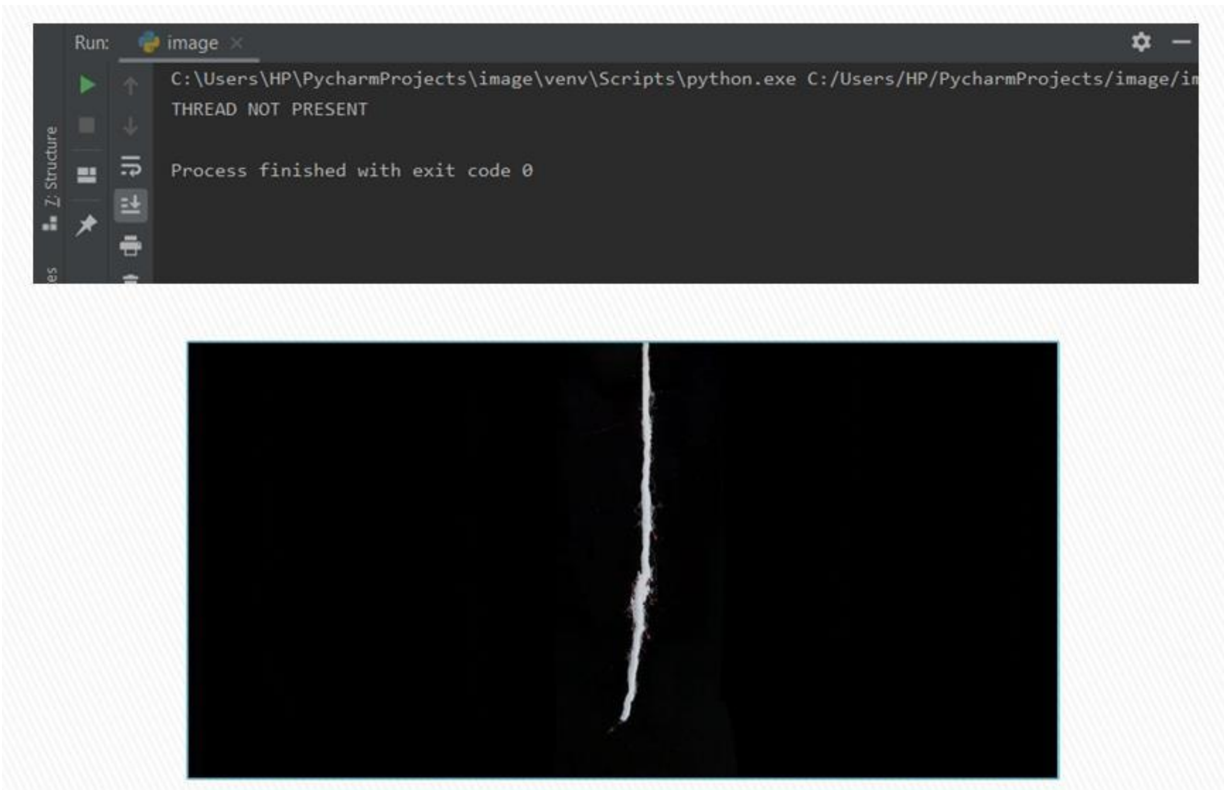

Figure 7.6

Figure 7.6 represents the position of the missing thread and its positioning. As a result easy detection of the broken thread position is known which can save a lot of time and money for machine owner. The image taken by the camera is processed and thread breakage has been detected which is given as an alert to the machine operator

7.3 CONCLUSION

This product will be able to improve the efficiency of the machines by simply monitoring the machine parameters and taking appropriate response actions. This product will be able to measure very precision data which can be used for predictive maintenance of the product. This data can be compared with data from similar machines to take decisions regarding appropriate response systems. In addition to this aspect, the device improves the production, current, manpower efficiency by effectively identifying the thread breakage and hence reducing the time taken to detect such breaks. However, it should be noted that this model of thread breakage identification is applicable only to spinning machines in contrast to the other functionalities which can be easily integrated into any type of machine ranging from heavy duty machines to precision machines. The cost of the device is also nominal making this an affordable solution to improve the efficiency of machines. Currently the thread breakage detection is done with thousands of sensors that are connected with each thread; this decreases the cost efficiency of the machine. However, in this device we use only one camera to detect the thread breakage thus significantly improving the cost efficiency.

7.4 FUTURE ASPECTS

- The data collected from the machines can be used to develop machine learning and artificial intelligence models that can be used to further increase the efficiency of the machine.
- The machine can easily be extended to include a whole lot of other response systems apart from the AC and heater unit that has been mentioned in the demonstration
- The device is capable of adding more sensors to detect other data from the machine such as speed of rotation of the gears etc. from the machine to improve predictive maintenance.
- Messages and emails can be sent from the device to the machine operator for timely response to varying machine parameters.
- The thread breakage system can be extended as thread breakage and repair system to increase the production efficiency of the machine further

APPENDIX

```
import sys
from time import sleep
import urllib.request as ur
myAPI = "PKD2HBBNY24XIDS9"
import RPi.GPIO as GPIO

GPIO.setmode(GPIO.BOARD)
GPIO.setwarnings(False)
GPIO.setup(8,GPIO.IN)

def main():
  print('starting...')
  baseURL = 'https://api.thingspeak.com/update?api_key=%s' % myAPI

  while True:
    try:
      state = GPIO.input(8)
      if state == False:
        sleep(1)
        x=1
      else:
        print("Oil level is low")
        sleep(1)
        x=0

      f = ur.urlopen(baseURL + "&field1=%s&field2=%s&field3=%s" % (1,2,x))
      print(f.read())
      f.close()
      sleep(15)

    except:
      print('exiting.')
      break

# call main
```

```
if __name__ == '__main__':
   main()

import RPi.GPIO as GPIO
import time
import sys
import Adafruit_DHT

ir = 8
TRIG = 16
ECHO = 18
i=0
in1 = 11
in2 = 13
led1 = 15
led2 = 29
led3 = 31
led4 = 37

GPIO.setmode(GPIO.BOARD)
GPIO.setup(TRIG, GPIO.OUT)
GPIO.setup(ECHO, GPIO.IN)
GPIO.setup(ir,GPIO.IN)
GPIO.setup(led1, GPIO.OUT)
GPIO.setup(led2, GPIO.OUT)
GPIO.setup(led3, GPIO.OUT)
GPIO.setup(led4, GPIO.OUT)
GPIO.setup(in1,  GPIO.OUT)
GPIO.setup(in2,  GPIO.OUT)

GPIO.output(in1, False)
GPIO.output(in2, False)
GPIO.output(led1, False)
GPIO.output(led2, False)
GPIO.output(led3, False)
GPIO.output(led4, False)
GPIO.output(TRIG, False)

def led1_off():
        GPIO.output(led1,False)
```

```
def led1_on():
	GPIO.output(led1,True)
	time.sleep(1)

def led2_off():
	GPIO.output(led2,False)

def led2_on():
	GPIO.output(led2,True)
	time.sleep(1)

def led3_off():
	GPIO.output(led3,False)

def led3_on():
	GPIO.output(led3,True)
	time.sleep(1)

def led4_off():
	GPIO.output(led4,False)

def led4_on():
	GPIO.output(led4,True)
	time.sleep(1)

def machine_off():
	GPIO.output(in2,False)
	led3_off()
	time.sleep(1)

def machine_on():
	GPIO.output(in2,True)
	led3_on()
	time.sleep(1)

def ac_off():
	GPIO.output(in1,False)
	time.sleep(1)
```

```
def ac_on():
	GPIO.output(in1,True)
	time.sleep(1)

def temp():
	humidity, temperature = Adafruit_DHT.read_retry(11,4)
	print('Temp: {0:0.1f} C  Humidity: {1:0.1f} %'.format(temperature,
humidity))
	if temperature>=30:
		ac_on()
		led1_on()
	else:
		ac_off()
		led1_off()

def ir():
	if GPIO.input(ir):
		led2_on()
		return 1
	else:
		led2_off()
		return 0

def ultra():
	GPIO.output(TRIG, True)
	time.sleep(0.00001)
	GPIO.output(TRIG, False)
	while GPIO.input(ECHO)==0:
		pulse_start = time.time()
	while GPIO.input(ECHO)==1:
		pulse_end = time.time()
	pulse_duration = pulse_end - pulse_start
	distance = pulse_duration * 17150
	distance = round(distance+1.15, 2)
	if distance<=20 and distance>=5:
		print("Machine switched off for safety")
		i=1
		led4_on()
		machine_off()
	else:
```

```
        i=0
        led4_off()
        machine_on()

try:
    while True:
        temp()
        x=ir()
        if x == 1:
            print("Machine oil level is low")
            machine_off()
        else:
            print("Initial conditions are satisified.....turning machine on")
            machine_on()

        ultra()


except KeyboardInterrupt:
    GPIO.cleanup()
```

```
import RPi.GPIO as GPIO
import time

channel = 17
GPIO.setmode(GPIO.BCM)
GPIO.setup(channel, GPIO.IN)

def callback(channel):
    if GPIO.input(channel):
        print("Abrupt Movement Detected!")
    else:
        print( "Abrupt Movement Detected!")

GPIO.add_event_detect(channel, GPIO.BOTH, bouncetime=300)  # let us know
when the pin goes HIGH or LOW
```

```
GPIO.add_event_callback(channel, callback)  # assign function to GPIO PIN, Run
function on change

# infinite loop
while True:
        time.sleep(1)


from urllib.request import urlopen, Request
import json,time
import RPi.GPIO as GPIO

GPIO.setmode(GPIO.BOARD)
GPIO.setup(37, GPIO.OUT)
GPIO.output(37, True)

def on():
    GPIO.output(37, False)
    time.sleep(1)

def off():
    GPIO.output(37, True)
    time.sleep(1)

while True:
    request =
Request('https://api.thingspeak.com/talkbacks/40529/commands/execute?api_key=
QIJT0UCD8K4JI9KP')
    response = urlopen(request)
    command = response.read()
    command = command.decode()
    command = command
    print(command)
    if command == '1':
        on()
    if command == '0':
        off()


import sys
```

```
import Adafruit_DHT
import time

while True:
	humidity, temperature = Adafruit_DHT.read_retry(11,14)
	print('Temp: {0:0.1f} C  Humidity: {1:0.1f} %'.format(temperature,
humidity))
	time.sleep(1)


import RPi.GPIO as GPIO
import time

GPIO.setwarnings(False)

in1 = 37
in2 = 35
in3 = 33
in4 = 31

GPIO.setmode(GPIO.BOARD)
GPIO.setup(in1, GPIO.OUT)
GPIO.setup(in2, GPIO.OUT)
GPIO.setup(in3, GPIO.OUT)
GPIO.setup(in4, GPIO.OUT)

def relay():
	GPIO.output(in1, True)
	GPIO.output(in2, True)
	GPIO.output(in3, True)
	GPIO.output(in4, True)
	time.sleep(1)

def off():
	GPIO.output(in1, False)
	GPIO.output(in2, False)
	GPIO.output(in3, False)
	GPIO.output(in4, False)
	time.sleep(1)
```

```
while(1):
        relay()
        off()
```

Image Detection:

```
import cv2
import numpy as np

cap = cv2.VideoCapture(0)

while(1):

    _, frame = cap.read()
    hsv = cv2.cvtColor(frame, cv2.COLOR_BGR2HSV)

    # define range of white color in HSV
    # change it according to your need !
    lower_white = np.array([0,0,0], dtype=np.uint8)
    upper_white = np.array([0,0,255], dtype=np.uint8)

    # Threshold the HSV image to get only white colors
    mask = cv2.inRange(hsv, lower_white, upper_white)
    # Bitwise-AND mask and original image
    res = cv2.bitwise_and(frame,frame, mask= mask)

    cv2.imshow('frame',frame)
    cv2.imshow('mask',mask)
    cv2.imshow('res',res)

    k = cv2.waitKey(5) & 0xFF
    if k == 27:
        break

cv2.destroyAllWindows()
```

REFERENCE

[1] Mohammed and S.Djurović, “Stator Winding Internal ThermalMonitoring and Analysis Using In Situ FBG Sensing Technology," inIEEE Transactions on Energy Conversion, vol. 33, no. 3, pp. 1508-1518, Sept. 2018.

[2] Mohammed, J. I. Melecio and S.Djurović “Open-Circuit Fault Detection in Stranded PMSM Windings Using Embedded FBG Thermal Sensors," in IEEE Sensors Journal, vol. 19, no. 9, pp. 3358-3367, May1, 2019.

[3] Mohammed, J. I. Melecio and S. Djurović, "Stator Winding FaultThermal Signature Monitoring and Analysis by In Situ FBG Sensors," inIEEETransactions on Industrial Electronics, vol. 66, no. 10, pp. 8082-8092, Oct. 2019.

[4] Mohammed and S. Djurovic, "In-Situ Thermal and Mechanical Fibre Optic Sensing for In-Service Electric Machinery Bearing Condition Monitoring," 2019 IEEE International Electric Machines & Drives Conference (IEMDC), San Diego, CA, USA, 2019, pp. 37-43

[5] Mohammed and S. Djurović, "FBG Thermal Sensing Features for Hot Spot Monitoring in Random Wound Electric Machine Coils," in IEEE Sensors Journal, vol. 17, no. 10, pp. 3058-3067, 15 May15, 2017.

[6] Alian, Hasib, Shlomi Konforty, Uri Ben-Simon, Renata Klein, and Tur Moshe. "Using optical fiber sensors for health monitoring of rotational systems." In International Conference Surveillance. 2017.

[7] D. S. Vilchis-Rodriguez, S. Djurović, P. Kung, M. I. Comanici and A. C. Smith, "Investigation of induction generator wide band vibration

monitoring using fibre Bragg grating accelerometers," 2014 International Conference on ElectricalMachines (ICEM), Berlin, 2014, pp. 1772-1778.

[8] Fabian, Matthias, J. Borg Bartolo, Morley Ams, Christopher Gerada, Tianfu Sun and K. T. V. Grattan. "Vibration measurement of electrical machines using integrated fibre Bragg gratings."International Conference on Optical Fibre Sensors (2015).

[9] H. Carvalho, A. Rocha, J. L. Monteiro and L. F. Silva, "Parameter monitoring and control in industrial sewing machines - an integrated approach," 2008 IEEE International Conference on Industrial Technology, 2008, pp. 1-6, doi: 10.1109/ICIT.2008.4608388

[10] http://robotechshop.com/shop/arduino/arduino-board/arduino-uno-r3 china/?v=f78a77f631d2

[11] https://components101.com/sensors/ultrasonic-sensor-working-pinout-datasheet

[12] https://en.wikipedia.org/wiki/Current_sensing

[13] https://en.wikipedia.org/wiki/Raspberry_Pi

[14] https://thingspeak.com/

[15] https://www.amazon.in/Robodo-Electronics-DHT11-Temperature/Raspberry/dp/B00BOMEO5U

[16] https://www.elecrow.com/acs712-current-sensor-30a-p-710.html

[17] https://www.fierceelectronics.com/sensors/what-ir-sensor

[18] https://www.indiamart.com/proddetail/ir-sensor-18854322591.html

[19] https://www.sparkfun.com/products/15569

[20] K. M. Sousa, U. J. Dreyer, C. Martelli and J. C. Cardozo da Silva, "Dynamic Eccentricity Induced in Induction Motor Detected by Optical Fiber Bragg Grating Strain Sensors," in IEEE Sensors Journal, vol. 16, no. 12, pp. 4786-4792, June15, 2016

[21] Kevin Jones, Chris Staveley, Jean-Francois Vialla, "Condition monitoring of a subsea pump using fibre optic sensing," Proc. SPIE 9157, 23rd International Conference on Optical Fibre Sensors,2 June, 2014.

[22] Konforty, Shlomi, Michael Khmelnitsky, Iddo Kressel, Renata Klein, Moshe Tur, and Jacob Bortman. "Bearing health monitoring using optical fiber sensors." 4th European Conference of the Prognostics and Health Management Society, 2016.

[23] M. Fabian, D. M. Hind, C. Gerada, T. Sun and K. T. V. Grattan, "Comprehensive Monitoring of Electrical Machine Parameters Using an Integrated Fiber Bragg Grating-Based Sensor System," in Journal of Lightwave Technology, vol. 36, no. 4, pp. 1046-1051, 15 Feb.15, 2018.

[24] M. Fabian, D. M. Hind, C. Gerada, T. Sun and K. T. V. Grattan, "Comprehensive Monitoring of Electrical Machine Parameters Using an Integrated Fiber Bragg Grating-Based Sensor System," Journal of Lightwave Technology, vol. 36, no. 4, pp. 1046-1051, 15 Feb.15, 2018, doi: 10.1109/JLT.2017.2771143.

[25] P. Tavner, "Review of condition monitoring of rotating electrical machines," Electric Power Applications, IET, vol. 2, pp. 215-247, 2008.

[26] P. Zhang, Y. Du, T. G. Habetler and B. Lu, "A Survey of Condition Monitoring and Protection Methods for Medium-Voltage Induction Motors," in IEEE Transactions on Industry Applications, vol. 47, no. 1, pp. 34-46, Jan.-Feb. 2011.

[27] P. P. Kulkarni, M. Patil, S. Shibi, M. Patle and R. Kale, "Review on Online Monitoring of Electrical Machine using IOT," 2019 International

Conference on Nascent Technologies in Engineering (ICNTE), Navi Mumbai, India, 2019, pp. 1-4, doi: 10.1109/ICNTE44896.2019.8945927.

[28] Peng Wei, Zejing Dai, Leilei Zheng, Ming Li, "Fault diagnosis of the rolling bearing with optical fiber Bragg grating vibration sensor," Proc. SPIE 10155, Optical Measurement Technology and Instrumentation,19 October, 2016.

[29] S. Nandi, H. A. Toliyat and X. Li, "Condition Monitoring and Fault Diagnosis of Electrical Motors—A Review," in IEEE Transactions on Energy Conversion, vol. 20, no. 4, pp. 719-729, Dec. 2005.

[30] W. Zhou, T. G. Habetler and R. G. Harley, "Bearing Condition Monitoring Methods for Electric Machines: A General Review," 2007 IEEE International Symposium on Diagnostics for Electric Machines, Power Electronics and Drives, Cracow, 2007, pp. 3-6

[31] Wenyuan Wang, Ping Zhou and Xiangyu Lin "Development of yarn breakage etection software system based on machine vision",(AIP Conference proceedings)

[32] LIU Zhao;ZHANG Ling;WU Zhen-tian;HUO Ming-wu;YAO Jun-hong " Research and Design of Intelligent Yarn Break Tracking Test Car " , School of Electromechanical Engineering,Dezhou University;