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Advanced Mining Safety: Real-Time Gas Monitoring and Emergency Response System

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Abstract: ***As we know coal mine are hazardous as it contain harmful gasses like carbon monoxide methane etc. Also we need to take care of the surrounding temperature and humidity of the mine. Along with, it is necessary to also continuous monitor the health of workers of the mine like pulse rate, rate of oxygen in blood for which we have used various type of sensors to make this system work more efficient along with that we also have integrated the buzzer which will give signal to the main control room via Wi-Fi as we have used ESP8266 microcontroller to communicate through the mines.***
Keywords: (Nord MCU ESP8266 Wi-Fi module, MQ7, MQ4, MAX30102, DHT11, Buzzer, LCD)

I. INTRODUCTION

One of the most important industry, which provide energy for production and various industrial applications is Coal Mine . However, coal mines are also dangerous because of the surrounding atmosphere where workers work because it contains toxic and flammable gasses like carbon monoxide (CO) and methane (CH_4), also fluctuating weather inside the mine like temperature and humidity. Many incidents have occurred due to explosions, asphyxiation, and poor environmental conditions in mines. Therefore, the need for an effective and real-time monitoring system is critical to ensure the safety of miners and to mitigate these risks.
In addition to gas detection, it is also important to continuously monitor the workers' health because of the environmental conditions which can lead to stress, fatigue, emergencies. To make a complete system that can detect hazardous gasses, monitor environmental conditions, as well as to monitor the health in real-time which would alert and communicate with the main control room would greatly improve safety measures of the workers and provide early warnings to prevent accidents caused by it. This paper presents a gas detection monitoring using sensors such as the MQ7 sensor for carbon monoxide (CO) detection, the MQ4 sensor for methane (CH_4) detection and for monitoring the environmental conditions such as humidity and temperature we are using DHT11 sensor and temperature sensor respectively .Also to monitor workers health like to monitor the pulse rate , oxygen level in the blood we are using MAX30102 sensor which will detect and also give alert if it is low than a certain level to reduce the risk of life. The data from these sensors is processed by a microcontroller, which compares the values against predefined safety thresholds and triggers alerts in case of dangerous conditions. The objective of this system is to provide a comprehensive, real-time monitoring solution for coal mines that monitor the presence of different hazardous gases enhances worker safety by continuously tracking the environment and workers health, providing early warnings to prevent accidents, and quick responses in case of emergencies.

II. METHODOLOGY

A. System Architecture

System contain three main type of function first one is gas detection second one is health monitoring and third one is environmental monitoring all this thing are interconnected and managed by esp8266 microcontroller this microcontroller act as CPU and gives alert when hazardous conditions are detected we also receive the real time alarm

B. Hardware Components

1) *MQ7 Sensor:* this sensor is used to detect carbon monoxide gas which is commonly found in mining environment the mq7 sensor operates by heating 18 dioxide that is sno2 layer which changes resistance and presence of Co2 this change in resistance is converted to a digital signal that the microcontroller can process it.



Fig. 1 MQ7 sensor

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2) *MQ4 Sensor:* The MQ4 sensor detects methane, a highly flammable gas present in mines. It uses similar principles to the MQ7 sensor, making it sensitive to methane concentrations. This sensor is crucial for preventing explosions and ensuring safe air quality.



Fig. 2 MQ4 sensor

3) *DHT11 Sensor:* The DHT11 sensor monitors temperature and humidity levels within the mine. It uses a thermistor for temperature detection and a capacitive

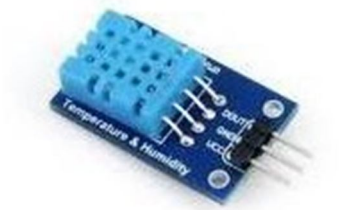


Fig. 3 DHT11 Sensor

4) *Additional Temperature Sensor:* To ensure accuracy and reliability, an extra temperature sensor is included. This sensor serves as a backup, allowing for redundancy in temperature monitoring, which is crucial in scenarios where there are sharp temperature shifts across various sections of the mine.



Fig. 4 DS18B20 Temperature Sensor

5) *MAX30100 Sensor:* The MAX30100 sensor gathers essential health information from workers, such as pulse rate and blood oxygen levels (SpO_2). This data is critical for evaluating each worker's physical condition in real time, which helps identify and mitigate potential health risks



Fig. 5 MAX30100 Sensor

6) *Microcontroller ES8266:* We chose the esp8266 microcontroller because it's small, efficient, and has built-in wi-fi, which makes it ideal for use in remote mining areas. it collects data from the sensors and checks it against set safety limits. if any reading goes over its threshold, the system triggers an alert and sends it to the control room via wi-fi. the esp8266 make sure that fast data processing and keeps everything connected for real-time monitoring.



Fig. 6 Nodemcu ESP8266

C. Data Processing and alert method

The data collected by the sensors is quickly processed by the esp8266 microcontroller. Each sensor has set safety limits.
Gas sensors: the limits are based on safety standards for carbon monoxide and methane levels.
Temperature and humidity: limits are defined to prevent risks, especially in high-risk areas of the mine.

D. Worker Health

Pulse rate and oxygen levels have set thresholds to prevent health issues.
The microcontroller checks the sensor readings against these limits, and if any value goes too high or low, it triggers an alert. this includes sounding a loud buzzer to warn workers nearby

E. Communication Setup

The communication system leverages the Wi-Fi capabilities of the ESP8266 module, facilitating the transmission of data from the mines to a control room, even over considerable distances. Wi-Fi is the preferred choice due to its low latency and support for multiple simultaneous connections. This enables regular data transmission, ensuring the control room receives timely updates with real-time information.
The ThingSpeak dashboard is set up to provide the following functionalities:
Real-time Data: Continuous monitoring of sensor readings, updated in real-time.

F. Circuit Design

The connections between the sensors and the ESP8266 microcontroller are optimized for smooth data transfer. Each sensor interfaces with the microcontroller using GPIO (General Purpose Input Output) pins:
The MQ7 and MQ4 sensors are connected to the analog input pins, and their outputs are processed through an analog-to-digital conversion.
The DHT11 and additional temperature sensors are connected through digital input pins, with data conversion handled within the sensor module.
The MAX30102 sensor uses the I²C (Inter-Integrated Circuit) interface, which ensures accurate data reading with minimal delay.

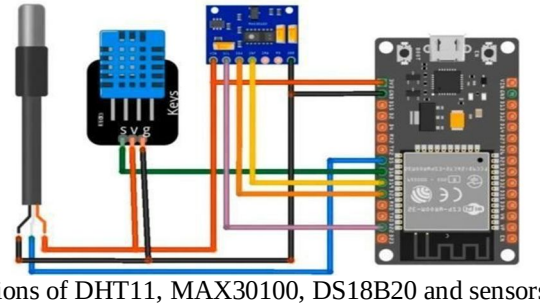


Fig. 7 Connections of DHT11, MAX30100, DS18B20 and sensors with Node mcu

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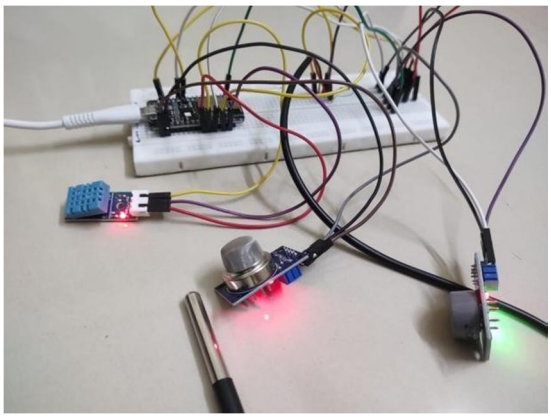


Fig. 8 Connections between MQ7, MQ4, DHT11 sensor with node mcu

G. Testing Protocols

Extensive testing was conducted in controlled environments that simulate hazardous conditions found in mines. The tests focused on:

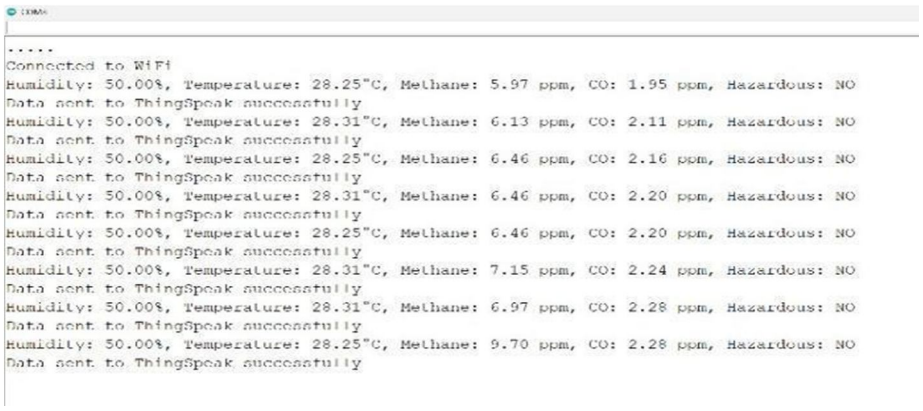
Sensor Accuracy and Sensitivity: Each sensor's performance was evaluated under various gas concentrations and environmental conditions.

Threshold Calibration: Safety thresholds were calibrated according to OSHA standards to ensure reliable activation points.

Alert Response Time: The interval between a threshold breach and the triggering of an alert was measured to ensure rapid response times.

Wi-Fi Stability and Range: The ESP8266's Wi-Fi connectivity was assessed across different ranges and environmental factors typical of mining conditions to ensure stable communication with the control room.

Infrastructure Development: Investing in infrastructure upgrades is crucial for improving the overall appeal of real estate, particularly in underserved or high-potential areas.



```
.....
Connected to WiFi
Humidity: 50.00%, Temperature: 28.25°C, Methane: 5.97 ppm, CO: 1.95 ppm, Hazardous: NO
Data sent to ThingSpeak successfully
Humidity: 50.00%, Temperature: 28.31°C, Methane: 6.13 ppm, CO: 2.11 ppm, Hazardous: NO
Data sent to ThingSpeak successfully
Humidity: 50.00%, Temperature: 28.25°C, Methane: 6.46 ppm, CO: 2.16 ppm, Hazardous: NO
Data sent to ThingSpeak successfully
Humidity: 50.00%, Temperature: 28.31°C, Methane: 6.46 ppm, CO: 2.20 ppm, Hazardous: NO
Data sent to ThingSpeak successfully
Humidity: 50.00%, Temperature: 28.25°C, Methane: 6.46 ppm, CO: 2.20 ppm, Hazardous: NO
Data sent to ThingSpeak successfully
Humidity: 50.00%, Temperature: 28.31°C, Methane: 7.15 ppm, CO: 2.24 ppm, Hazardous: NO
Data sent to ThingSpeak successfully
Humidity: 50.00%, Temperature: 28.31°C, Methane: 6.97 ppm, CO: 2.28 ppm, Hazardous: NO
Data sent to ThingSpeak successfully
Humidity: 50.00%, Temperature: 28.25°C, Methane: 9.70 ppm, CO: 2.28 ppm, Hazardous: NO
Data sent to ThingSpeak successfully
```

Fig. 9 Data Displayed on Serial Monitor of Arduino IDE

III.RESULTS

Our system is designed to detect a dangerous gases, environmental conditions, and worker health in real time. During testing in a controlled environment, we noted several Things:

A. Gas Detection

The MQ7 sensor is used for detection of carbon monoxide (CO), the safe level is below 10ppm if this gas exceed above 35ppm an alert is shown in form of buzzer

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Fig. 11 CO Gas Data displayed on ThingSpeak

B. Methane Monitoring

Similarly, the MQ4 sensor is used for detecting methane (CH4), and in case of methane safe level is from 100ppm and alert is shown above 500ppm This result show trust toward the machine and ability to provide correct warning so that workers can work peacefully



Fig. 10 Methane Gas Data displayed on ThingSpeak

C. Environmental Monitoring

The DHT11 sensor is used to track both temprature and humidity, it records temperature between 18 to 30 degree celcius and humidity between 30% and 85%. This reading are useful to identify different risks



Fig. 12 Humidity Data displayed on ThingSpeak



Fig. 13 Temperature Data displayed on ThingSpeak

D. Health Monitoring:

The MAX30102 sensor is use to calculate accurate pulse rate and oxygen level. The system alert the worker via buzzer if worker's pulse rate dropped below 50 bpm or exceeded 100 bpm.

Alerting and Communication System Data communication between the sensors and the control room ran smoothly due to the ESP8266 microcontroller. In our prototype the data is being transmitted wirelessly over Wi-Fi so that it enable continuous monitoring from the control room. Immediate buzzers are sent if the system detects dangerous gas levels, unsafe environmental changes, or checking health parameters. This technique of alerting proved dependable for notifying both workers and control room staff of any dangers.

IV. LIMITATIONS AND CHALLENGES

Our project worked well but faced some unique challenges in coal mines, tackling these is important to ensure reliable performance and make the system practical in tough conditions.

A. Sensor drift and calibration

MQ sensors are used to detect gases showed tiny differences in their readings and this is known as sensor drift. this is common in chemical sensors and can affect accuracy. periodic calibration and regular maintenance can fix this. adding automated alerts for calibration can help avoid mistakes and keep things running smoothly. signal strength was also weak in some areas, causing delays in alerts.

B. Health monitoring in tough conditions

Tracking worker health was tricky due to dust and moisture in the mines. the max30102 sensor often gave errors when dust collected on its lens. to fix this, stronger sensors or protective covers could be used to block dust and water. testing the sensors regularly can also keep them working well.

C. Better than previous systems

Most old mine safety systems only work on gas detection and use wired setups, which are slow. our system tracks gas, monitors the environment, and checks worker health all at once. It check health issues in time so action can be taken before things get worse. our wi-fi alert buzzer system is fast and works even in short distance of the mine. this makes our system more advanced and successful than previous setups

REFERENCES

The “Surveillance and Safety System for Underground Coal Mines Predicted on Low Power WSN” by [1] which presents a system which is based on (WSN) wireless sensor networks with focus on low power consumption. The major objective is to monitor hazardous conditions underground coal mines ensuring real-time data collection and analysis to enhance safety.

The "Coal Mine Safety Monitoring and Alert System" studied by [2] proposed an IoT-based solution for safety monitoring. This system provided real-time alerts for hazardous conditions like gas leaks and temperature changes, reducing risks associated with underground mining operations. The "IoT-Based Coal Mine Safety Monitoring and Alerting System" by [3] utilized IoT technologies to enhance safety monitoring in coal mines. It's integration with different sensors with the help of communication networks to detect the gas leaks, change in temperature providing timely alerts to operators.

The "Performance Assessment of MAX30100 SpO2/Heart Rate Sensor" by [4] evaluated the accuracy and efficiency of this sensor for physiological monitoring. Although primarily designed for health monitoring, the findings have implications for monitoring mine workers' well-being in hazardous conditions.

The "Internet of Things-Based Coal Mine Safety Monitoring System" by [5] developed an IoT-enabled framework for realtime monitoring and hazard detection in coal mines. The system is embedded with different sensors, cloud-based storage, and analytics tools so that we can reduce risks and improve safety.

The "Real-Time Safety Monitoring System in Coal Mines Using IoT" by [6] highlighted the use of IoT technologies to be effective for the safety monitoring in mines. This study tells the integration of wireless communication and data analysis to provide real-time alerts.

The "Automatic Monitoring System for Coal Mine Safety Based on Wireless Sensor Network" by [7] proposed solution for real-time coal mine safety monitoring. The system is aim to to detect the hazardous gas leaks in the environment also the temperature fluctuations and the changes of the humidity this ensure that there is continuous monitoring underground and integrating the sensors and wireless communication the system provides the correct decisions and reduce risk.

The "Design and Construction of a System for Measuring Carbon Monoxide, Hydrogen, and Methane Concentrations in a Co-Current Downdraft Biomass Gasifier" by [8] focused on developing a system for precise measurement of hazardous gas concentrations in biomass gasifiers.The system is designed to detect the harmful gasses like Hydrogen Methane and carbon dioxide which are critical for safety this work contributes to enhance safety protocols in the environment.

The "Mining Safety System" by [9] provides real time monitoring of toxic gasses and environmental conditions with help of IOT and Wireless Sensor Networks(WSNs) which helps to focus on improving mining safety. Advanced technologies like RFID, ZigBee, fiber optic sensors, and neural networks are used for accurate hazard detection and fire prevention.

The "Coal Mine Safety Monitoring and Alerting System Using IoT" by [10] provides real time data and alerts to timely interfere, showing the efficiency and reliability of IOT in increasing miner safety based on sensors that help to monitor toxic gasses, temperature, and humidity.

The "Coal Mine Safety System" by [11] propose a coal mine safety system using sensors to monitor gasses, temperature, and humidity. The system provides real-time alerts via wireless communication, increasing safety by enabling timely responses and reducing risks associated with manual monitoring.

The paper "Evolutionary Model of Coal Mine Safety System Based on Multi-Agent Modeling," by [12] uses multi-agent modeling with a combination of evolutionary algorithms that provides a pathway for reducing accidents and improving safety outcomes that advances the field of coal mine safety systems.

The "Wireless Surveillance and Safety System for Mine Workers Using ZigBee" by [13] provides ZigBee technology to develop an efficient, reliable, and cost-effective wireless safety system for mines. The paper "IoT-Based Smart Mine Safety System Using Arduino" by [14] integrates Arduino with various sensors and with help of IOT communication technologies, the system can monitor hazardous conditions in real time and send alerts whenever necessary.

The paper "IoT-Based Coal Mine Safety Monitoring and Alerting System" by [15] The proposed system of combination of gasses, temperature, humidity, and vibration sensors allows continuous monitoring of hazardous conditions, real-time alerts, and quick emergency response.

The paper "Coal Mine Safety Intelligent Monitoring Based on Wireless Sensor Network" by [16] provides a Wireless Sensor Networks (WSNs) based coal mine safety monitoring system which helps in real time continuous monitoring of gas levels, temperature, and humidity in coal mines. The system aims to detect hazardous conditions and alert both workers and the control room.

The paper "Smart Helmet for Coal Mines Safety Monitoring and Alerting" by [17] Proposes a wearable smart helmet that integrates sensors like gas sensors, temperature and humidity sensors, vibration sensors, and a GPS tracker, all connected to a wireless communication system. With the help of a helmet, continuous monitoring of environmental conditions and alerts to both the wearer and the central monitoring system happens if any parameters exceed the safety limits, such as gas leaks, extreme temperature or hazardous vibrations.

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The paper "Safety of Coal Miners Using IoT" by [18] Proposes an IOT-based safety system which uses sensors to track environmental parameters like gas levels, temperature, humidity and vibrations to detect hazardous conditions. Data transmission happens through a wireless central monitoring system, which enables real time alerts for miners and supervisors.

The paper "IoT-Based Smart System for Mine Workers Safety" by [19] uses a system which uses sensors to monitor key parameters such as gas levels, temperature, and humidity, along with GPS tracking for real-time location monitoring. When unsafe conditions are detected, alerts are generated.

The paper "Design of IoT Based Coal Mine Safety System Using NodeMCU" by [20] integrates sensors (gas, temperature, humidity, and vibration) with the NodeMCU microcontroller to monitor environmental conditions in real time. Hazardous conditions like gas leaks or abnormal temperatures are reported with the help of wireless communication to the central system and alerts the workers.

The paper "Design and Development of Coal Mine Safety System Using IoT" by [21] Uses sensors to track parameters like gas concentration, temperature, and humidity, and transmits data with help of wireless communication to a central server and alerts are generated automatically whenever unsafe conditions are detected.

V. CONCLUSIONS

This project presents a real-time monitoring system for coal mines that combines gas detection, environmental monitoring, and worker health tracking to improve mine safety. Using sensors like the MQ7 for carbon monoxide, MQ4 for methane, DHT11 for temperature and humidity, and MAX30102 for pulse and oxygen levels, the system continuously checks for hazardous conditions and health risks. When dangerous levels are detected, alerts are sent to both miners on-site and a control room via the ESP8266 Wi-Fi module, ensuring quick responses. Although testing showed high accuracy, challenges like sensor drift, Wi-Fi signal issues, and environmental effects on health monitoring sensors suggest that periodic maintenance and improvements are needed. Future enhancements include predictive analysis and better sensors for better measurements

VI. ACKNOWLEDGMENT

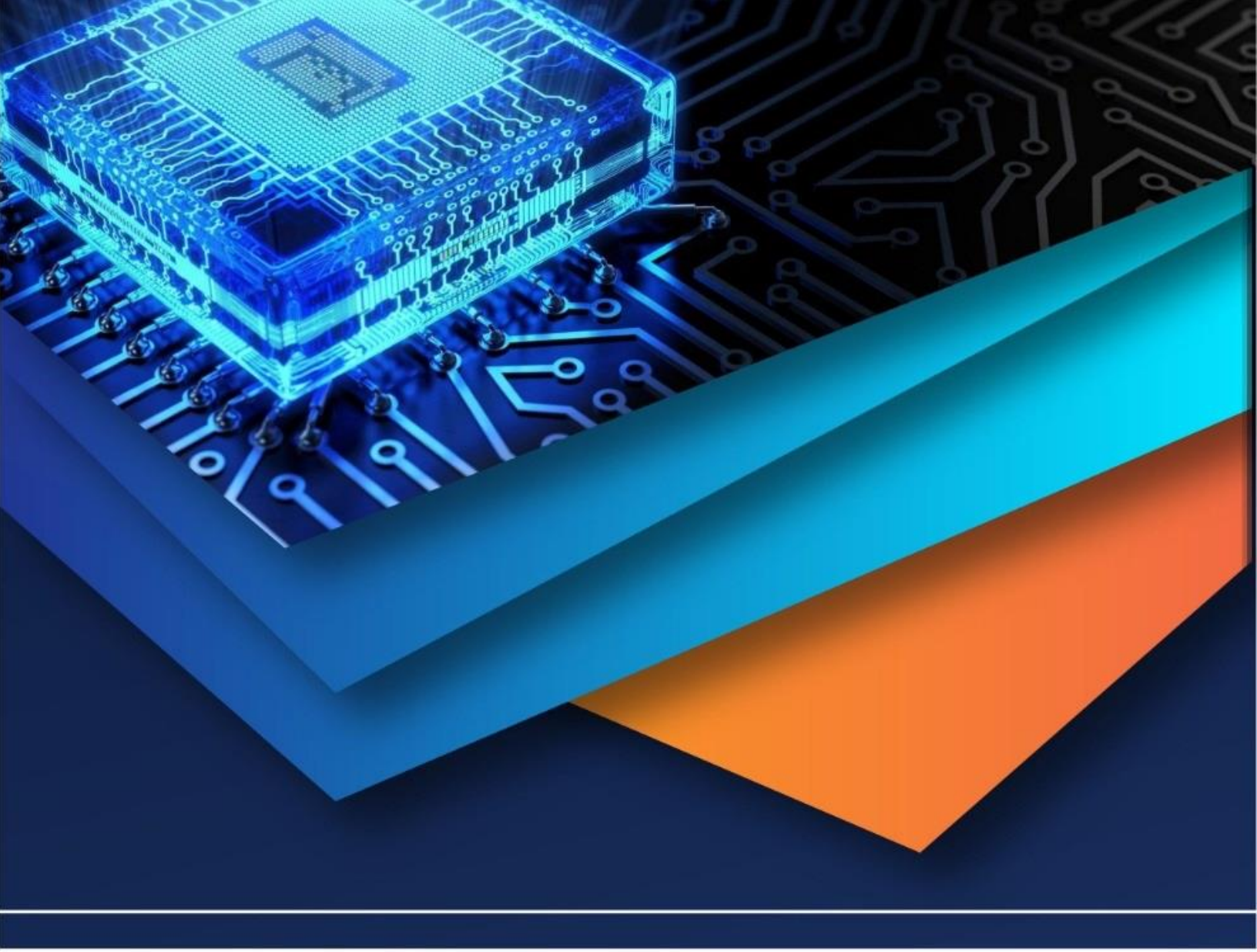
I Firstly, we would express our gratitude to Prof. (Dr.) Kiran Ingale our EDAI guide for their valuable guidance and support. I would like to acknowledge the Department of Multidisciplinary Engineering (DOME), Vishwakarma Institute of Technology, Pune for providing the resources and Environment necessary for conducting this research.

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