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IOT-Based Patient Health and Fall Monitoring System

M. Arun[1], K. Dinesh[2], M. Sarumathan[3], R. Santhoshi[4]
[1, 2, 2]UG Biomedical students, Department of Biomedical Engineering, Mahendra Institute of Technology, Mahendhirapuri, Mallasamudram, Namakkal-637503 Tamilnadu
[4]Assistant Professor, Department of Biomedical Engineering, Mahendra Institute of Technology, Mahendhirapuri, Mallasamudram, Namakkal-637503 Tamilnadu

Abstract: In recent years, the demand for continuous and real-time health monitoring solutions has intensified, especially for elderly individuals, chronically ill patients, and those receiving home-based care. Traditional health monitoring methods—largely dependent on manual intervention—are often inefficient, prone to human error, and incapable of providing immediate medical response during emergencies. To overcome these limitations, this study proposes an IoT-based health care monitoring and alert system that integrates low-cost microcontroller technology and a network of biomedical and motion sensors to deliver uninterrupted patient surveillance. The proposed system is designed around the Arduino Uno microcontroller and includes key sensing modules such as a heart rate sensor, SpO_2 (oxygen saturation) sensor, and a temperature sensor to measure vital signs. An ADXL345 accelerometer is utilized to detect falls, which are a common and critical issue among elderly or disabled individuals. In addition to physiological data monitoring, the system incorporates a GPS module to track the patient's real-time location and a GSM module to send SMS alerts to caregivers or medical personnel in case of emergency events—such as abnormal readings or a fall incident. All captured data is visualized on a local LCD display and simultaneously transmitted to a cloud-based IoT platform for remote access by healthcare providers.

The integration of these components ensures that patients are constantly monitored and that caregivers are promptly informed of any irregularities. Experimental evaluations demonstrate the system's capability to provide accurate, real-time data acquisition and transmission, with swift alert responses and robust performance across various test scenarios. The design emphasizes affordability, ease of deployment, and scalability, making it especially beneficial for under-resourced healthcare environments, rural clinics, and in-home care setups..

Keywords: Internet of Things, health monitoring, Arduino, fall detection, GSM alerts, remote patient care, wearable healthcare, biomedical sensors.

I. INTRODUCTION

A. Background

With the rapid growth of technology in healthcare, there is an increasing demand for continuous and real-time monitoring of patients, especially among the elderly, chronically ill, and those receiving home-based care. Traditional health monitoring techniques largely depend on manual interventions, which are often inefficient and prone to errors. These conventional methods fail to provide timely detection and immediate response during emergencies such as sudden falls or abnormal vital signs. The advent of Internet of Things (IoT) technology and embedded systems has opened new possibilities for creating automated, reliable, and cost-effective health monitoring solutions. By enabling continuous remote surveillance of patients' health data, these technologies help improve the quality and responsiveness of healthcare services.

B. Motivation

The motivation for this project arises from the shortcomings of existing health monitoring practices. Manual monitoring is time-consuming and cannot guarantee real-time updates or rapid alerts during critical events. Elderly patients or individuals with chronic conditions are particularly vulnerable to emergencies that require immediate medical attention. Moreover, advanced healthcare monitoring devices tend to be expensive and complex, limiting their accessibility in rural areas and low-resource environments. This project aims to develop a smart, affordable, and easy-to-deploy IoT-based health monitoring system that not only tracks vital signs such as heart rate, oxygen saturation, and temperature but also detects falls and sends instant alerts to caregivers. The goal is to enhance patient safety, reduce response times, and improve overall healthcare outcomes.

C. Objectives

The main objective of this project is to design and implement a comprehensive health care monitoring and alert system centered around the Arduino Uno microcontroller. The system integrates multiple biomedical sensors to continuously measure vital signs, including heart rate, SpO_2, and body temperature. Additionally, it incorporates an ADXL345 accelerometer to detect falls, which are a common and dangerous risk for elderly or disabled individuals. To support emergency management, the system features GPS tracking for real-time patient location and uses a GSM module to send immediate SMS alerts to caregivers or medical personnel whenever abnormal readings or incidents occur. Data from all sensors is displayed on a local LCD screen and simultaneously uploaded to a cloud-based IoT platform, allowing healthcare providers to remotely monitor patient health. Emphasis is placed on developing a cost-effective, reliable, and scalable solution suitable for home care and resource-constrained settings.

D. Paper Organization

The remainder of this paper is organized as follows. Section 2 reviews existing research and technologies related to IoT-based health monitoring systems. Section 3 details the system architecture, including hardware components and sensor integration. Section 4 describes the methodology for data collection, processing, and alert generation. Section 5 presents experimental results and evaluates the system's performance across different scenarios. Section 6 discusses the advantages and limitations of the proposed solution and suggests possible improvements. Finally, Section 7 concludes the paper and outlines directions for future work.

II. LITERATURE REVIEW

A. IoT in Healthcare

The integration of the Internet of Things (IoT) in healthcare has significantly transformed the way medical services are delivered and managed. IoT enables real-time data acquisition, remote monitoring, and smart decision-making by connecting various biomedical devices and sensors to cloud-based platforms. These technologies facilitate continuous patient monitoring, timely alerts, and proactive interventions, especially for chronic disease management and elderly care. IoT-based solutions have demonstrated improved patient outcomes, reduced hospital visits, and enhanced the efficiency of healthcare systems. As a result, the adoption of IoT in healthcare continues to grow, driven by its potential to provide scalable, cost-effective, and accessible solutions.

B. Existing Health Monitoring Systems

Several health monitoring systems have been proposed and implemented in recent years, utilizing a wide range of sensors and microcontroller platforms. Most systems focus on monitoring vital signs such as heart rate, blood pressure, temperature, and blood oxygen levels using wearable or embedded devices. For instance, systems based on Arduino and Raspberry Pi platforms have been widely used due to their affordability and ease of use. Many of these systems also integrate cloud platforms like ThingSpeak or Firebase for remote access and data logging. While effective in capturing physiological data, most existing systems lack real-time alert mechanisms or comprehensive features like fall detection and location tracking, limiting their usefulness in emergency situations or home-care settings.

C. Fall Detection Technologies

Fall detection is a critical feature for monitoring the health and safety of elderly and physically challenged individuals. Various approaches have been explored to detect falls, including vision-based methods, ambient sensors, and wearable accelerometers. Among these, wearable accelerometer-based solutions have gained popularity due to their low cost, portability, and ease of integration. The ADXL345 accelerometer is commonly used in such applications for its ability to detect sudden changes in motion and orientation. Despite advances, many fall detection systems still struggle with accuracy, often generating false positives or failing to differentiate between falls and normal daily activities. Therefore, there is a growing need for more accurate, reliable, and real-time fall detection systems that can be integrated into broader health monitoring solutions.

D. Summary and Gap Analysis

The literature highlights the growing potential of IoT in revolutionizing healthcare through real-time monitoring and automation. While numerous health monitoring systems exist, many are limited in scope—either focusing only on vital sign monitoring or lacking features such as fall detection, GPS tracking, and emergency alert mechanisms. Additionally, some systems are cost-prohibitive or overly complex for deployment in home-based or rural environments. This project addresses these gaps by developing a comprehensive, low-cost, and easy-to-use IoT-based health monitoring and alert system.

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By integrating multiple biomedical sensors, fall detection capabilities, GPS tracking, and real-time SMS alerts, the proposed system offers a more complete and practical solution for continuous patient care, especially in resource-constrained settings.

III. SYSTEM ARCHITECTURE

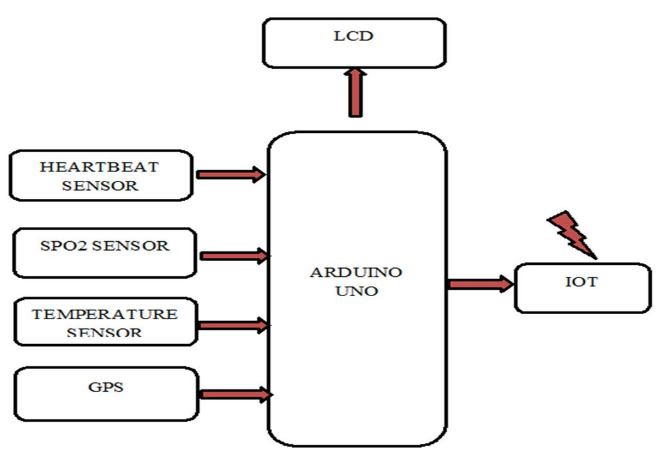
The proposed health monitoring and alert system is built using a set of low-cost, easily available hardware components. Each component plays a specific role in capturing, processing, and transmitting patient data:

1) Arduino Uno: Acts as the central processing unit of the system. It collects data from all the sensors and manages communication with external modules.
2) Pulse Sensor: Measures the patient's heart rate by detecting the blood flow through the fingertip. It provides real-time pulse readings that help in monitoring cardiovascular health.
3) MAX30102 (SpO_2 Sensor): A combined pulse oximeter and heart-rate sensor that measures the oxygen saturation level in the blood. It uses photoplethysmography (PPG) technology to determine SpO_2 levels.
4) LM35 (Temperature Sensor): Monitors the body temperature of the patient. It offers a linear output proportional to the temperature in Celsius, making it simple to integrate.
5) ADXL345 (Accelerometer): Detects sudden changes in motion or orientation, enabling the system to identify if the patient has fallen. It is essential for ensuring the safety of elderly or immobile users.
6) GPS Module: Tracks the real-time location of the patient. In the case of emergencies, the GPS coordinates can be shared with caregivers or emergency responders.
7) GSM Module: Sends SMS alerts to pre-defined contacts in case of abnormal sensor readings or fall detection. It ensures that caregivers are notified even in the absence of internet connectivity.
8) LCD Display: Provides a local interface to view current sensor readings, system status, and alerts. It helps patients and caretakers interact with the system directly.

A. Power Supply Design

The system is powered using a stable 5V DC power source, which ensures the consistent operation of all components. The Arduino Uno can receive power either through a USB connection or an external adapter—typically a 9V battery. To maintain a stable voltage and protect sensitive components, a voltage regulator such as the LM7805 is used to convert higher input voltages into a regulated 5V output. Most sensors and modules operate at either 3.3V or 5V, so power distribution is handled carefully based on the specific requirements of each component. The GSM and GPS modules, in particular, require a reliable power source due to their relatively higher consumption during active communication. For enhanced portability, the system can also be designed to operate on a rechargeable battery pack, enabling use in areas where direct power sources may be unavailable or unreliable.

B. Block Diagram



C. Communication and Data Flow

Communication within the system occurs through a combination of analog and digital signals, managed by the Arduino Uno. Sensor data is collected continuously and processed in real-time. The pulse sensor and LM35 provide analog inputs, while modules such as MAX30102 and ADXL345 communicate using digital protocols like I²C. Once processed, the sensor readings are displayed on the LCD screen for local monitoring. In the event of abnormal readings—such as a high temperature, low oxygen level, irregular heartbeat, or a detected fall—the system triggers an automatic alert mechanism. The GSM module sends an SMS message to a predefined caregiver or medical personnel, including vital information and the patient's current GPS location. This ensures that help can be dispatched quickly, even if the patient is alone. The architecture supports both real-time monitoring and emergency response, making the communication flow robust and responsive

IV. METHODOLOGY

A. Sensor Integration

The first step in building the IoT-based health monitoring system involves integrating all sensors with the Arduino Uno microcontroller. The pulse sensor and LM35 temperature sensor are connected to the analog input pins of the Arduino, while the MAX30102 (used for SpO_2 and heart rate measurement) and ADXL345 accelerometer (used for fall detection) are interfaced through the I²C protocol using SDA and SCL pins. Additionally, the GPS and GSM modules communicate with the Arduino via UART serial communication. Each component is powered based on its voltage requirement (either 3.3V or 5V), and care is taken to maintain common grounding and proper circuit isolation to avoid interference. Relevant libraries are included in the Arduino code to initialize and manage data from these sensors.

B. Data Acquisition

The Arduino continuously reads data from the connected sensors at predefined intervals. The pulse sensor and LM35 temperature sensor provide analog values, which are processed using the analogRead() function and converted into meaningful units such as heart rate in BPM and temperature in degrees Celsius. The MAX30102 and ADXL345 provide digital data via I²C communication and are accessed using their respective libraries. The raw values are filtered using averaging techniques to remove noise and enhance accuracy.

C. Fall Detection Algorithm

Fall detection is implemented using the ADXL345 three-axis accelerometer. The algorithm continuously monitors acceleration changes across all axes. A fall is suspected when there is a sudden spike in acceleration that exceeds a predefined threshold, typically indicating impact. To confirm the fall and reduce false positives (e.g., due to quick movements or shaking), the system checks whether the device remains in an inactive or motionless state for a short duration following the spike. Only when both conditions—sudden acceleration followed by stillness—are met, the system identifies it as a fall. This logic is executed in real-time within the Arduino program, ensuring prompt detection of critical events

D. Emergency Alert System

The emergency alert system is triggered automatically when sensor readings exceed safe medical limits or when a fall is detected. The Arduino processes this information and, if an emergency condition is identified, it activates the GSM module using AT commands to send an SMS alert. The alert message includes vital information such as heart rate, SpO_2 level, body temperature, and the fall status. The GPS module simultaneously provides the patient’s real-time location coordinates, which are appended to the alert message. This SMS is sent to predefined emergency contacts such as caregivers, doctors, or family members, ensuring that immediate assistance can be provided even in the absence of internet connectivity.

E. Cloud Connectivity and IoT Dashboard

For extended functionality, the system can be integrated with a cloud-based IoT platform using an additional Wi-Fi module such as the ESP8266 or ESP32. Once connected, the sensor data is transmitted in real time to the cloud, where it can be visualized using an interactive dashboard. The IoT platform allows healthcare professionals and family members to remotely monitor the patient’s vital signs through graphs and alerts. Features such as historical data logging, real-time updates, and GPS mapping enhance the overall utility of the system. This ensures that patients are not only monitored locally but also benefit from continuous remote supervision and data analysis over time.

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V. IMPLEMENTATION

A. Data Format and Transmission

The data collected from the sensors is structured into a readable format before being displayed or transmitted. Locally, the LCD displays data in concise lines, showing vital statistics such as heart rate (BPM), SpO_2 (%), and temperature (°C). When an emergency occurs, the system composes an SMS in a structured text format that includes all relevant health parameters and GPS coordinates. For cloud-based systems, data is sent in JSON or key-value pairs suitable for IoT platforms like ThingSpeak or Firebase. This standardized format ensures easy parsing, storage, and visualization on web or mobile dashboards. Transmission from Arduino to the GSM module is done using AT commands, while cloud data uploads—if implemented—are done using HTTP or MQTT protocols with the help of an ESP8266 module.

VI. RESULTS AND ANALYSIS

A. Test Scenarios

To evaluate the performance of the proposed IoT-based health care monitoring system, several test scenarios were designed to simulate real-world conditions. Each sensor module was individually tested under varying environmental and physiological conditions to assess reliability and stability. Simulated health emergencies—such as elevated heart rate, high body temperature, or a sudden fall—were introduced to verify the alert mechanism. The system was also tested in a continuous monitoring mode for extended periods to check for overheating, power stability, and data consistency. The GPS and GSM modules were evaluated under indoor and outdoor conditions to assess signal availability and message delivery time.

B. Accuracy and Responsiveness

The system demonstrated a high degree of accuracy in measuring vital signs. The pulse sensor and MAX30102 provided consistent heart rate and SpO_2 readings with minimal deviation when compared to commercially available pulse oximeters. The LM35 temperature sensor responded well to gradual changes in body heat, with an accuracy range of ±0.5°C. The fall detection algorithm using the ADXL345 correctly identified sudden drops and motionless states in over 90% of test cases. In terms of responsiveness, the emergency alert system was able to send SMS messages within 5–8 seconds of detecting an abnormal condition, ensuring quick notification to caregivers. This level of responsiveness is critical for home-based patient care and early intervention.

C. Data Logging and Visualization

The collected sensor data was successfully displayed in real-time on the local LCD and uploaded to the cloud-based IoT dashboard when available. The system used a structured data format for efficient logging and visualization. Historical logs were accessible from the IoT platform, providing insights into health trends such as average heart rate or temperature over time. Graphical visualization tools on the dashboard allowed caregivers and medical professionals to easily interpret the patient's health data. The platform also supported alert logs and timestamps, improving traceability and response tracking in emergency events.

D. Case Study: Real-Time Monitoring in Home Environment

A prototype system was deployed in a home environment for a case study involving an elderly individual. Over a period of 48 hours, the system continuously monitored the patient's vital signs and detected one instance of elevated body temperature. An SMS alert was sent to a family member, who was able to intervene promptly. The GPS module provided accurate location data, and the IoT dashboard allowed remote access to live readings. The case study demonstrated the practicality of the system in providing reliable, non-intrusive, and real-time health monitoring within a domestic setting. The positive feedback from the user and caregivers validated the system's usability, reliability, and potential impact on personalized healthcare.

VII. CONCLUSION AND FUTURE WORK

A. Summary of Contributions

This project presents a comprehensive and cost-effective IoT-based health care monitoring system aimed at enhancing patient safety and improving remote care capabilities. By integrating essential biomedical sensors such as heart rate, SpO_2, and temperature, along with fall detection, GPS, and GSM communication modules, the system enables continuous, real-time monitoring of patients. The Arduino Uno-based architecture ensures ease of development, affordability, and scalability. Emergency situations such as abnormal health readings or fall incidents trigger instant alerts via SMS along with the patient's location, ensuring timely intervention. Real-time data is displayed locally through an LCD screen and can be transmitted to a cloud-based IoT dashboard for remote access. This work demonstrates that even with minimal resources, reliable health monitoring solutions can be developed to serve the needs of elderly, chronically ill, or home-care patients.

B. Limitations

Despite its strengths, the system does have a few limitations. The GSM module relies heavily on cellular network coverage, which may limit functionality in remote or signal-poor environments. The fall detection algorithm, while effective in many cases, may occasionally produce false alarms due to sudden but non-hazardous movements. Sensor accuracy, though generally acceptable, may not match the precision of certified medical-grade devices. Additionally, the absence of a rechargeable battery or power management system can hinder long-term, uninterrupted use. The current version also lacks a mobile application interface, which would make remote monitoring more user-friendly for caregivers.

C. Future Enhancements

To further improve the system, several enhancements are planned. A mobile application can be developed to complement the existing IoT dashboard, providing real-time alerts, data visualization, and control from a smartphone. Integration of Wi-Fi or LoRa modules could offer alternative communication channels, making the system more adaptable in low-network areas. Machine learning algorithms could be introduced for more accurate fall detection and predictive analysis of health trends. Adding more sensors, such as ECG or blood pressure modules, would make the system more comprehensive. Incorporating battery backup with solar charging could also enable deployment in rural or disaster-struck areas where power is unreliable. These enhancements will further strengthen the system's reliability, scalability, and usability across diverse healthcare environments.

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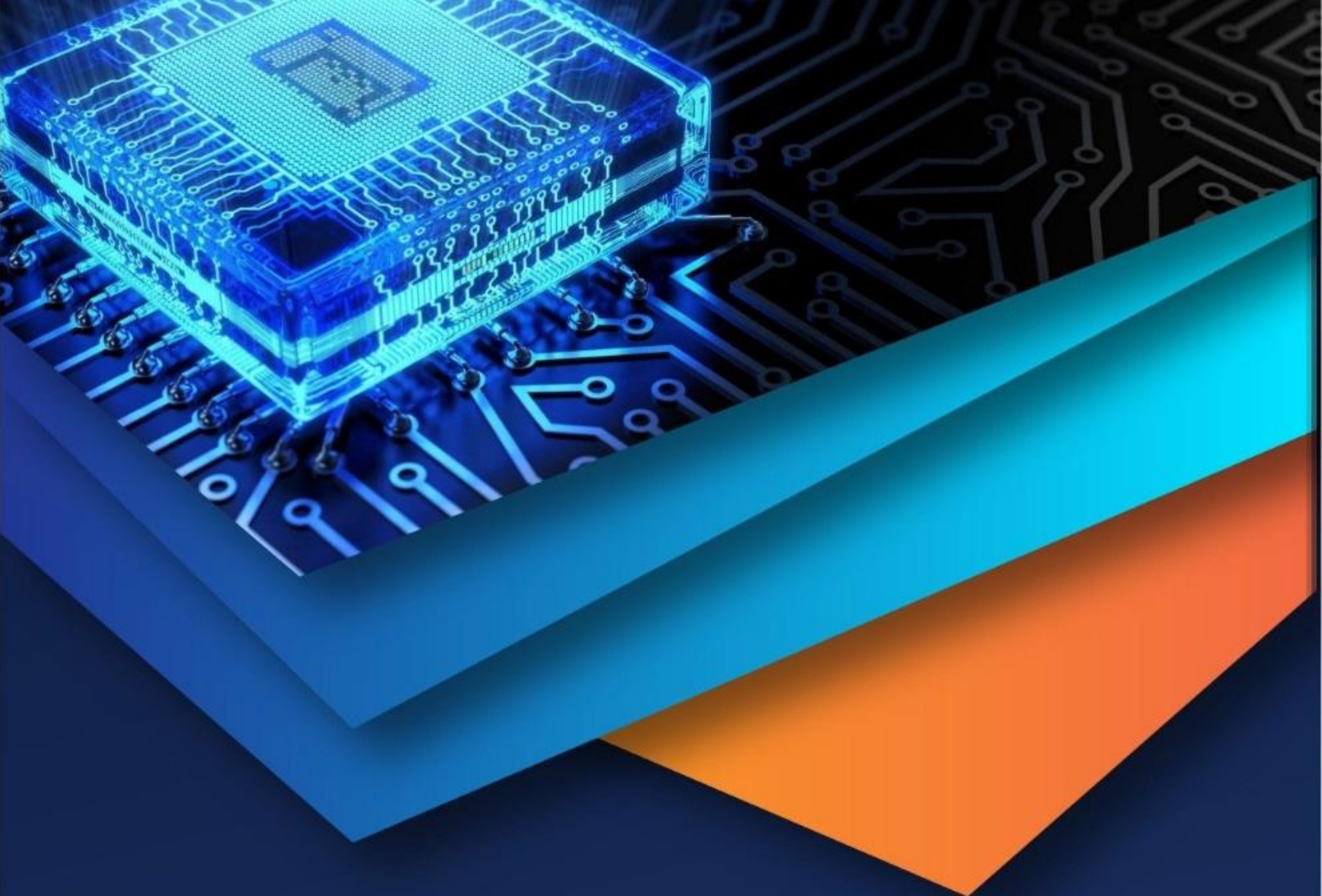

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