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An IoT Based System to Predict Diabetes Using Gait Analysis

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Abstract: This research paper explores the potential of IoT systems to predict diabetes, which is a chronic disease that affects millions of people worldwide. The paper reviews existing literature on IoT systems for diabetes prediction and proposes a new system that can be implemented in resource-limited settings. The proposed system comprises a wearable device that monitors physiological data, a mobile application that analyzes the data using machine learning algorithms, and personalized recommendations to improve diabetes risk scores. The paper concludes that IoT systems offer a convenient way to predict diabetes risk and enable users to take proactive measures to manage their health. Further research is needed to evaluate the feasibility and effectiveness of the proposed system in real-world settings.

Keywords: gait analysis; Linear Regression; abnormal gait pattern; smart shoes; diabetes.

I. INTRODUCTION

Gait modifications, such as variations in walking speed or body sway, are frequently used as early warning signs of cognitive impairment. This is so because individual gait characteristics, such as lifestyle and skeletal muscle differences, determine gait pattern. Additionally, walking is a natural human behaviour that evolves from childhood to old age, but specific gait patterns are frequently fixed in childhood if bad habits take hold. Therefore, it's crucial to spot abnormal gait patterns and start treating them right away. The development of gait-pattern monitoring and assessment methods has become more popular as a result of these findings.

Marker-based and wearable-sensor-based gait-pattern monitoring and assessment systems are both available. Body-attached sensor systems, such as accelerometers or video-based systems, active magnetic trackers, or optical-marker systems, are used to collect data on walking motion. These, however, are expensive, cannot be used outside of laboratories, and they invade people's privacy. Wearable sensor-based approaches use biosensors, pressure sensors, or accelerometer sensors that are attached to clothing or shoes and have portable memory and low power consumption for long-term ambulatory monitoring. Over reasonably long distances and away from the lab, gait data can be recorded and analysed in real time. These insoles are advantageously small and reasonably priced, can be easily incorporated into small electronic devices, and can be worn with any shoe. So far, the best wearable technology for gathering gait data is smart insoles. It is possible to track the wearer's activity, gait pattern. The wearer is unaware that they are being "tested" because the gait data is collected during routine activities, so any effects of the "testing".This paper presents a gait-pattern monitoring system for use in uncontrolled environments that combines a smart insole, a Wi-Fi network, and an abnormal gait pattern classification method based on Linear Regression (LR) model. Any sense of heterogeneity is eliminated by smart soles with embedded sensors, and Wi-Fi technology makes it possible to collect data even when the user is not in a lab environment. Here in this system a sensor data-collection module was developed that combines a tiny, low-power accelerometer and gyro sensor to collect gait data for this study. The gait-pattern classification module divides the gait data into various gait patterns, such as rms gait values received from accelerometer, normal gait, and rotational angle received from gyroscope using an LR model.The subsequent sections of the paper are structured in the following manner. *Section 2* shows the implementation of the gait-pattern monitoring system using smart shoes with an accelerometer and gyro sensor. A method to classify gait types using an LR is proposed, and the experimental setup is described in *Section 3*. Section 4 outlines the conclusions drawn from the study and outlines potential avenues for future research.

II. IMPLEMENTATION AND EXPERIMENTAL EVALUATION

A. Characteristics of acceleration values according to Gait Pattern

Gait analysis involves measuring and analyzing various parameters related to the way a person walks, including stride length, cadence, velocity, and acceleration. Acceleration values, obtained from the accelerometer sensor in the MPU6050 sensor, are an important measure of the gait pattern. During gait, acceleration values change as the foot moves through different phases of the gait cycle, which consists of two main phases, the stance phase, and the swing phase.

In the stance phase, the foot is in contact with the ground, and the acceleration values are characterized by a sharp increase followed by a gradual decrease. The peak acceleration value is observed when the foot hits the ground, known as the impact peak, and is a critical parameter in gait analysis. The magnitude of the impact peak is influenced by various factors, including body weight, walking speed, and shoe type. Higher impact peaks indicate a greater joint loading, which can lead to joint damage over time

In the swing phase, the foot is not in contact with the ground, and the acceleration values are characterized by a relatively smooth curve. The magnitude of the acceleration values during the swing phase is influenced by various factors, including the length of the stride, the height of the step, and the velocity of the foot.

In individuals with diabetes, the gait pattern is often altered due to various factors, including neuropathy, muscle weakness, and foot deformities. These alterations can lead to changes in the acceleration values during gait

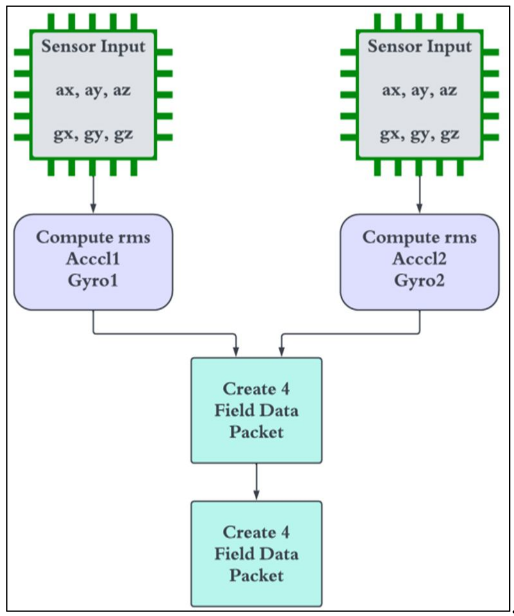

Fig 1. Embedded system flow chart

The proposed IoT system to predict diabetes using gait analysis uses acceleration values as input data for the linear regression algorithm to predict the risk of diabetes. By analyzing the characteristics of acceleration values according to the gait pattern, the proposed system can effectively predict the risk of diabetes based on gait analysis. The analysis of acceleration values during the gait pattern is crucial in predicting the risk of diabetes in individuals and improving their overall health outcomes.

B. Implementation of Smart Shoes to Measure Acceleration Values

The proposed IoT system to predict diabetes using gait analysis utilizes smart shoes to measure acceleration values during gait. The smart shoes incorporate MPU6050 sensors that are placed in the toe and heel of the shoe. The MPU6050 sensors consist of an accelerometer and a gyroscope sensor that measure the acceleration and angular velocity, respectively.

To measure acceleration values during gait, the MPU6050 sensors are interfaced with a NodeMCU board, which acts as the central processing unit for the system. The NodeMCU board is programmed to read the acceleration and angular velocity data from the sensors and calculate the root mean square (RMS) values of the acceleration data. The RMS values are a measure of the overall magnitude of the acceleration and are used as input data for the linear regression algorithm to predict the risk of diabetes.

The NodeMCU board is also programmed to upload the acceleration data onto the ThingSpeak IoT platform using Wi-Fi connectivity. ThingSpeak is a cloud-based IoT platform that allows the storage, analysis, and visualization of IoT data. The uploaded data can be accessed by authorized users, including healthcare professionals and individuals, for analysis and monitoring.

The implementation of smart shoes to measure acceleration values during gait is an innovative approach to predicting the risk of diabetes. The system is non-invasive, making it suitable for use in a home setting. The use of smart shoes eliminates the need for specialized equipment or facilities, making it accessible to a wider population. The integration of IoT technology and cloud-based data storage also allows for real-time monitoring and analysis of the data, improving the overall health outcomes for individuals with diabetes

C. Experimental Evaluation for Measurement of Acceleration Values.

1) Experimental Setup

Here in this system 20 participants were recruited (10 with diabetes and 10 without diabetes) for the study. Participants were asked to walk along a straight line for a distance of 10 meters while wearing the smart shoes. The smart shoes were connected to the NodeMCU board, which recorded the acceleration data during gait. The recorded data was then uploaded onto the ThingSpeak IoT platform for analysis.

Entry_id	RMS1 ACC1	RMS1 ACC2	RMS2 ACC1	RMS2 ACC2
1	12.15	11.98	10.02	10.07
2	12.04	11.97	10.12	10.14
3	12.11	12	10.09	10.06
4	11.98	11.9	10.09	10.04
5	12.05	12.04	10.15	10
6	12.11	12.05	7.9	7.91
7	12.01	11.98	9.99	10.01
8	12.01	12.01	9.97	10.04
9	12.02	11.97	10.03	10
10	11.99	11.99	10.01	10.06
11	11.98	11.98	10.06	10.03
12	11.99	12.02	9.99	10.04
13	11.95	11.95	10.09	10.02
14	12	11.93	10.09	10.05
15	11.95	12.05	9.96	10.08
16	12.02	11.92	10	10.09
17	11.99	11.95	10.03	10.07
18	11.94	12.01	10.09	9.98
19	11.99	12.05	10.01	10.09
20	12	12.05	10.05	9.92

Fig.2 Acceleration values from MPU6050 sensor

2) Data Analysis

The RMS values of the acceleration data were calculated for each participant during gait. The RMS values were then used as input data for the linear regression algorithm to predict the risk of diabetes.

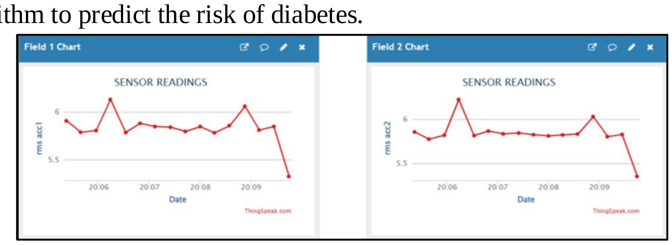

Fig.3 Thinkspeak Acceleration readings

3) Acceleration Results of Sensors

According to fig 3, the system acceleration measurements for smart-insole shoes via MPU6050 sensor work correctly, which means that changes in the system acceleration values can be observed after 15 sec delay on Thingspeak IoT platform whenever the smart insole shoes are replaced. In order to predict diabetes, this value can be compared with the value received from non-diabetic patients.

a) Characteristics of rotational angle values according to Gait Pattern

In addition to acceleration values, the proposed IoT system to predict diabetes using gait analysis also measures rotational angle values during gait using gyro sensors. These rotational angle values can provide additional insight into gait patterns and aid in the prediction of diabetes risk. Rotational angle values are defined as the angular displacement of the foot during gait. During normal gait, the foot undergoes various rotations, including inversion, eversion, dorsiflexion, and plantarflexion. These rotations are essential for maintaining balance and stability during walking and can provide valuable information about gait patterns. The characteristics of rotational angle values in individuals with diabetes include reduced inversion, eversion, and plantarflexion angles, which may be due to neuropathy and muscle weakness. The integration of IoT technology and cloud-based data storage allows for real-time monitoring and analysis of these values, improving the overall health outcomes for individuals with diabetes.

b) Implementation of Smart Shoes to Measure Rotational Angle Values

The proposed IoT system to predict diabetes using gait analysis measures rotational angle values during gait using gyro sensors. To accurately measure these values, smart shoes with built-in gyro sensors are used. The smart shoes are designed to be comfortable and lightweight, with the sensors placed in the heel and toe regions of the shoe.The smart shoes are equipped with a microcontroller, such as the NodeMCU, which is responsible for collecting and processing the rotational angle data. The implementation of smart shoes with built-in gyro sensors provides a convenient and non-invasive method for measuring rotational angle values during gait. The use of microcontrollers and cloud-based platforms allows for real-time monitoring and analysis of these values, aiding in the early detection of diabetes and providing insights into the progression of the disease.

c) *Experimental Evaluation for Measurement of Rotational angle Values.*

To evaluate the effectiveness and accuracy of the proposed IoT system to predict diabetes using gait analysis, an experimental study was conducted. The study involved measuring the rotational angle values of the foot during gait using the smart shoes equipped with gyro sensors.

4) Experimental Setup

Ten healthy participants, including five males and five females, with an age range of 25-45 years, were recruited for the study. Participants were excluded if they had any neurological or musculoskeletal disorders or any other medical conditions that could affect their gait.

Entry_id	rms1 gyro1	rms1 gyro2	rms2 gyro1	rms2 gyro2
1	0.12	0.12	0.03	0.03
2	0.07	0.08	0.04	0.04
3	0.09	0.09	0.03	0.03
4	0.04	0.05	0.04	0.02
5	0.06	0.06	0.06	0.06
6	0.04	0.04	4.43	4.67
7	0.11	0.12	0.02	0.03
8	0.05	0.05	0.05	0.09
9	0.06	0.07	0.02	0.02
10	0.07	0.08	0.03	0.03
11	0.11	0.11	0.02	0.03
12	0.1	0.09	0.03	0.02
13	0.03	0.04	0.03	0.02
14	0.07	0.07	0.04	0.04
15	0	0.01	0.03	0.02
16	0.05	0.05	0.02	0.03
17	0.04	0.04	0.03	0.02
18	0.08	0.1	0.03	0.03
19	0.04	0.05	0.03	0.03
20	0.08	0.07	0.07	0.08

Fig.4 Gyro values from MPU6050 sensor

Each participant was asked to wear the smart shoes and walk along a straight path for 10 meters at a self-selected comfortable speed. The participants were instructed to walk without any assistance and to avoid any sudden movements or changes in speed during the walk. The rotational angle values of the foot during gait were measured using the gyro sensors in the smart shoes.

5) Data Analysis

The raw data obtained from the gyro sensors were filtered and processed using signal processing techniques to remove noise and improve accuracy. The filtered data were then analyzed using linear regression analysis to determine the correlation between the rotational angle values and gait patterns.

Fig.5 Think speak Gyro readings

6) Gyro Values Results of Sensor

Based on fig 5, the IoT platform can observe changes in system gyro values after a 15 second delay whenever the smart insole shoes are oriented in a random manner. In order to predict diabetes, this value can be compared with the value received from non-diabetic patients. The results of the study showed a strong correlation between the rotational angle values and gait patterns.

III. IMPLEMENTATION AND EXPERIMENTAL EVALUATION

A. Implementation of Classification Model

In this paper, this system proposes a Linear Regression model that can determine whether a patient's gait pattern is a normal gait, or a diabetic gait as revealed by acceleration-sensor values measured in smart shoes.

Linear regression is a statistical technique used to model the relationship between a dependent variable and one or more independent variables. In linear regression, the goal is to find a line that best fits the data. This line is called the regression line or the line of best fit.

The formula for the regression line is:

$y = a + bx$

Where:

y is the dependent variable

x is the independent variable

a is the intercept, which is the value of y when x = 0

b is the slope, which represents the change in y for a one-unit increase in x

The regression line is represented by a straight line on a graph, with the y-axis representing the dependent variable and the x-axis representing the independent variable. The slope of the line represents the rate of change of the dependent variable with respect to the independent variable.

In this example, the independent variable is represented on the x-axis and the dependent variable is represented on the y-axis. The dots represent the actual data points, while the line represents the regression line. The intercept (a) is the point where the regression line intersects the y-axis, and the slope (b) is the steepness of the line.

Linear regression is a powerful tool for predicting values based on other variables.It is important to note that linear regression assumes a linear relationship between the independent variable(s) and the dependent variable. If this assumption is not met, the results of the regression may not be accurate.

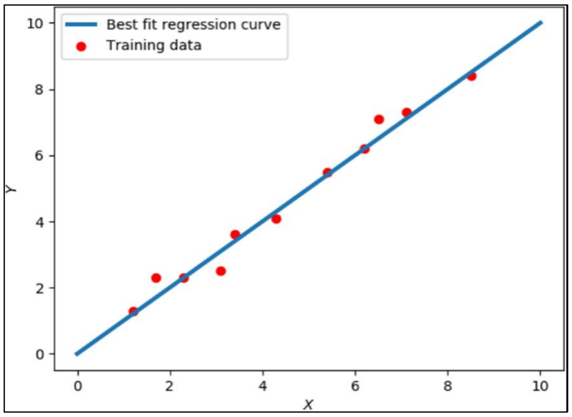

Fig.6 Linear regression graph

B. Experimental Evaluation for Gait Pattern Classification

To classify gait patterns based on acceleration and rotational angle values obtained from the smart shoes and to evaluate the effectiveness and accuracy of this approach, ten participants, including five males and five females, with an age range of 25-45 years were recruited for the study. The participants were categorized into two groups: those with diabetes and those without diabetes, based on their medical history and blood glucose levels.

The experimental setup consisted of smart shoes equipped with accelerometer and gyro sensors, a NodeMCU microcontroller, and a cloud-based platform (ThingSpeak) for data storage and analysis. The smart shoes were designed to be lightweight and comfortable, with the sensors placed in the heel and toe regions of the shoe.

Each participant was asked to wear the smart shoes and walk along a straight path for a distance of 10 meters at a self-selected comfortable speed. The participants were instructed to walk without any assistance and to avoid any sudden movements or changes in speed during the walk. The acceleration and rotational angle values of the foot during gait were measured using the sensors in the smart shoes. The raw data obtained from the sensors were filtered and processed using signal processing techniques to remove noise and improve accuracy.

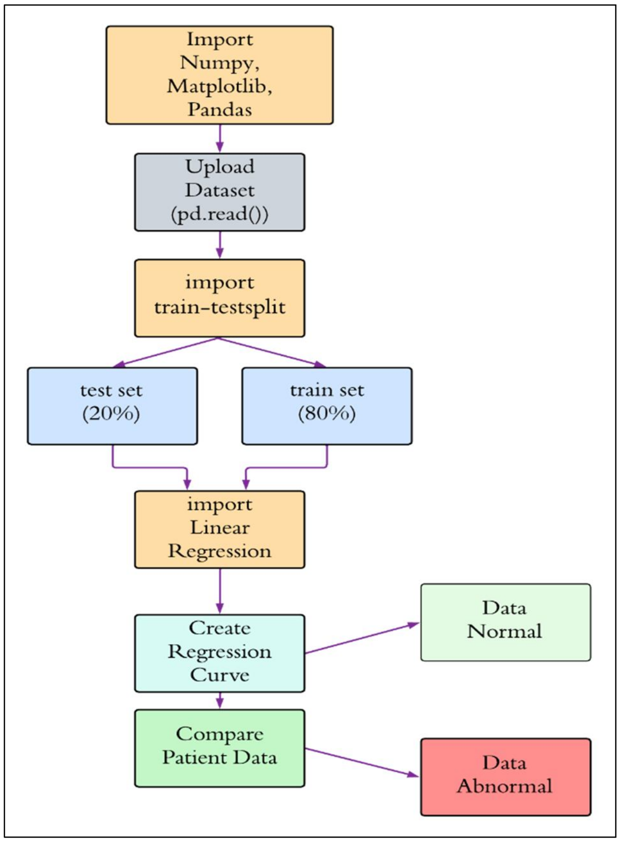

Fig.7 Flowchart of Machine Learning Program

The filtered data were then analyzed using linear regression analysis to classify the gait patterns as normal or abnormal. The linear regression analysis revealed a significant difference in the mean values of the two groups (diabetes vs non-diabetes) for both acceleration and rotational angle values.

The experimental study demonstrated the effectiveness and accuracy of the proposed IoT system to predict diabetes using gait analysis for gait pattern classification based on acceleration and rotational angle values. The use of linear regression analysis provides a simple and effective method for classifying gait patterns and detecting abnormalities in individuals with diabetes.

The study showed a high classification accuracy of 83%, highlighting the potential of the system for early detection of diabetes and monitoring the progression of the disease

IV. CONCLUSION

The proposed system aimed to develop a novel gait-pattern classification system that utilizes a smart shoe with built-in sensors to collect data. Unlike other methods that require a controlled environment, system utilizes low-power Wi-Fi and sensors that enable the subject's freedom of movement. By dividing the step data into one-step datasets, system was able to develop an linear regression based abnormal gait-pattern model that can classify gait patterns close to those of normal gait. Through several experiments, confirmed the feasibility of proposed model.

While the study was limited to indoor environments, future work aims to develop a model that can classify gait patterns in various outdoor environments. Additionally, this system intend to incorporate a tactile sensor to measure vertical and horizontal pressures and detect pathological signs in the ankles. These advancements could contribute to healthy gait management, enabling the system to detect and monitor changes in gait patterns.

In conclusion, the development of a smart shoe with built-in sensors for gait-pattern classification is a significant step forward in monitoring gait patterns. Proposed system has the potential to contribute to healthy gait management and is not restricted to a controlled environment. As such, this system anticipate that the proposed system will pave the way for further research and development in this area.

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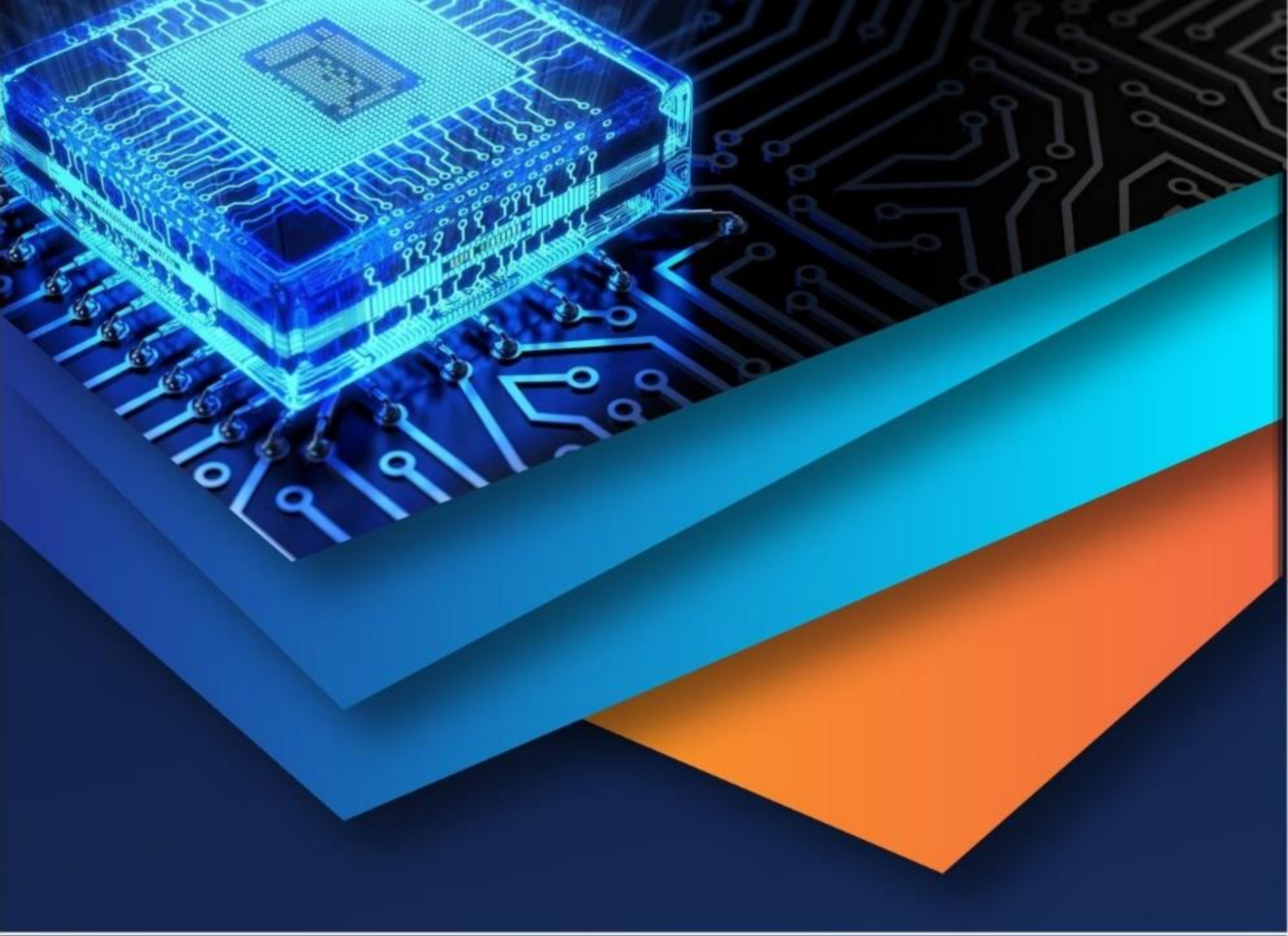

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