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Enhancement of Road Safety using Accelerometer and Gyroscope

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Abstract: In recent years, monitoring a road condition becomes an utmost important. This paper introduces a framework to monitor road condition, based on sensors (accelerometer, gyroscope and GPS) built in a smartphone. Using machine learning system, quality of different road sections is obtained and it is possible to visualize a road quality map of a selected region. Further, this system generates a personal warning system for road condition along with development of a historical record of road conditions. This provides a constructive feedback to drivers and local authorities. The system reduces the cost of external hardware, development and maintenance cost involved.
Keywords: Accelerometer, Gyroscope, GPS, Machine Learning

I. INTRODUCTION

According to statistics provided by World Health Organization (WHO) report [1] (2018), the number of road traffic deaths continues to rise steadily, reaching 1.35 million in 2016. It shows that most of the road accidents are caused by the poor condition of road. India has a road network of over 5,903,293 kilometers (3,668,136 mi) as of 31 January 2019, the largest road network in the world. According to the statistics of Government of India data [2] the number of road accidents in 2017 was 4,64,910. Over the span of recent two decades, there has been a colossal increment in the vehicle populace. This increment in the number of vehicles has provoked issues like clog in rush hour and various accidents on street and the primary factor for this, is the inadequate condition of the streets. Intelligent transportation system is working in the region of traffic congestion control, which is of extraordinary significance. Potholes formed because of substantial downpours, ill-conceived drainage framework in urban areas and transportation of heavy vehicles, turn into a major purpose behind high-chance of mishaps and loss of human lives.

One of the significant issues in developing nations are maintenance of streets and potholes on the road which is the reason for serious harm in driver’s safety. Therefore, drivers' safety might improve with the establishment of pothole recognition methods. Consolidated approaches for monitoring road surface conditions involve the adoption of the costly and sophisticated hardware equipment’s such as ultrasonic [2] sensor or specific accelerometers with a data acquisition system [3]. Both approaches incur a high cost of installation, maintenance and require more human effort, which can induce error while deploying or collecting the data. There are other ways to collect data from the sensing technologies to solve the problem of road surface condition monitoring. Nowadays smartphone is equipped with various sensors such as accelerometer, gyroscope, GPS, microphones, etc. Thus, Smartphone based road condition monitoring is one of the such helpful application.

The paper is structured as follows: related work done is presented in Sect. 2. Data description is presented in Sect 3. Proposed methodology is presented in Sect. 4. Comparison of Sensors & external hardware is presented in Sect. 5. Performance analysis of algorithm is presented in Sect. 6 and Sect. 7 concluded the work carried out.

II. RELATED WORK

In this section, work done of road monitoring condition is described. Researchers find automatic detection and notification of potholes and humps on roads to aid drivers [3]. It is observed that, microcontroller module is used to gather the information about the potholes and humps with the help of a PIC 16F877A microcontroller which consists of an ultrasonic sensor which are used to measure the distance between the car body and the road surface. Researchers proposed Nericell, a system that performs rich sensing by piggybacking on smartphones that users carry with them in normal course [4]. They focus specifically on the sensing component, which uses the accelerometer, microphone, GSM radio, and/or GPS sensors in these phones to detect potholes, bumps, braking and honking. Researchers investigate an application of mobile sensing which is a detecting and reporting of the surface conditions of roads [5]. It describe a system and use associated algorithms to monitor civil infrastructure using a collection of sensor-equipped vehicles. Further, this system uses the inherent mobility of the participating vehicles, opportunistically gathering data from vibration and GPS sensors, and processing the data to assess road surface conditions.

Researchers proposes a pothole detection model in real time making use of Android phones with accelerometers [6]. The data from the accelerometer is used to identify potholes. Researchers used a low-cost imaging kinetic sensor which shows the visualization and meteorological analysis of potholes [7]. In this, images are taken with the help of the kinetic sensor. Further, the images are imported to the MATLAB environment for the further processing. Researchers proposes a stereo vision-based pothole detection system which uses the disparity map generated from an efficient disparity calculation algorithm [8]. Researchers uses camera to classify several road conditions [9].

It is evident from the literature that an adequate research was carried out to monitor road condition based on external hardware used which incur a high cost of development and maintenance. However, very few studies focused on accelerometer and gyroscope. Therefore, this paper introduces a framework to monitor road condition, based on built in sensors (accelerometer, gyroscope and GPS) in a smartphone. Using machine learning system, quality of different road sections is obtained and it is possible to visualize a road quality map of a selected region. This methodology also provides a feedback to drivers and local authorities about road condition based on historical data of road condition. The system reduces the cost of external hardware, development and maintenance cost involved. Table 1 summarize the literature survey.

Table. 1. Summary of literature survey

Author	Smartphone Sensor	External Hardware	Detection Methods
R. Madli et al. [3]	Not Used	Ultrasonic Sensors, GPS	Threshold
P. Mohan et al. [4]	Accelerometer, Microphone, GPS	Not Used	Threshold
J. Eriksson et al. [5]	Not Used	Accelerometer, GPS	Threshold / Machine Learning Algorithm
Artis Mednis et al. [6]	Accelerometer	Not Used	Threshold
Moazzam et al. [7]	Not Used	Kinetic Sensor	Three-dimensional (3D) reconstruction
Zhang et al.[8]	Not Used	Stereo Camera images	Image Processing Algorithm
D Rajamohan et al.[9]	Not Used	Camera Images	Three-dimensional (3D) reconstruction

III. DATA DESCRIPTION

This section describes a data set used for experiment. In this methodology, the data set that have created contains unlabeled data related with accelerometer, gyroscope, GPS readings. This data has been extracted from mobile sensors using a smartphone application.

A. Data set Format

Dataset created using Mobile application with 11 attributes like Time, Mills, Ax, Ay, Az, Gx, Gy, Gz, Lat, Lon and Speed. It contains data from 3-axis accelerometer, 3-axis gyroscope, GPS, speed and Timestamp with 24936 tuples in 70:30 ratio for training and testing purpose.

B. Features and Label Description

Accelerometer data readings usually contains irrelevant data (noises). Therefore, a pre-processing phase should be applied in order to reduce noise and improve the road quality recognition. Due to several factors such as braking, jerks or vibrations, veering, turning, and as well as subtle changes in sensor orientation, a considerable amount of noise is added to these signals. A Low-Pass Filter can be helpful to remove high frequencies signals (noise) in the input signal by applying a suitable threshold to the filter output reading. Further, dataset will be labelled into 3 classes of (+1, 0, -1). Majority of dataset being of 0 class which signify normal road/plain road. The +1 class will signify roads with a hump/ speed brakers and -1 class will signify roads with potholes. Separate tables for potholes & speed breakers will be used to plot points on maps based on Lat & Lon positions. Figure 1. Shows our sample dataset.

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TIME	Mills	Ax	Ay	Az	Gx	Gy	Gz	Lat	Lon	Speed	Class
19-02-2019 6.29	1550000000000.0	8.052307	26.270752	-8.163956000000000	0.37294006	-0.56599426	0.20121765	10.60214027	76.13445451	11.12	0
19-02-2019 6.29	1550000000000.0	-5.7814026	-5.998291	12.038315000000000	-2.3552094000000000	0.38316345	-0.12155151	10.60214027	76.13445451	11.12	-1
19-02-2019 6.29	1550000000000.0	4.966171300000000	23.59404	-8.111282000000000	1.6608429	-0.5670624	0.31413270000000000	10.60214027	76.13445451	11.12	0
19-02-2019 6.29	1550000000000.0	-2.3816223000000000	-5.5888824	22.232819	-1.5764923	0.02949524	0.021194458	10.60214027	76.13445451	11.12	0
19-02-2019 6.29	1550000000000.0	-4.1222076	24.005844	-24.940125	1.4541779	1.319519	-0.3665619	10.60049944	76.1345304	13.23	0
19-02-2019 6.29	1550000000000.0	11.665146	-5.428482	28.129745	-2.4809113	-0.10899353	-0.13966370000000000	10.60049944	76.1345304	13.23	-1
19-02-2019 6.29	1550000000000.0	5.0691223	19.258133000000000	-7.440918000000000	1.8312836	0.90834045	-0.27494812	10.59991616	76.13461878	12.65	0
19-02-2019 6.29	1550000000000.0	2.3277588	-6.3957367	20.611954	-0.950119	0.98184204	-0.33674622	10.59991616	76.13461878	12.65	0

Figure 1. Sample Dataset

IV. PROPOSED WORK

This section gives detail description of proposed methodology. Description of proposed methodology is divided into sections viz system design, machine learning algorithm and working of system.

A. System Design

The proposed methodology develops a road condition monitoring framework that detects, analyses and predicts the state of road sections using smartphone sensors. The proposed system does not depend on any external hardware. In this system, road conditions could be detected and analyzed by smartphones according to readings from accelerometer and gyroscope sensors. Proposed system architecture is given in figure 2.

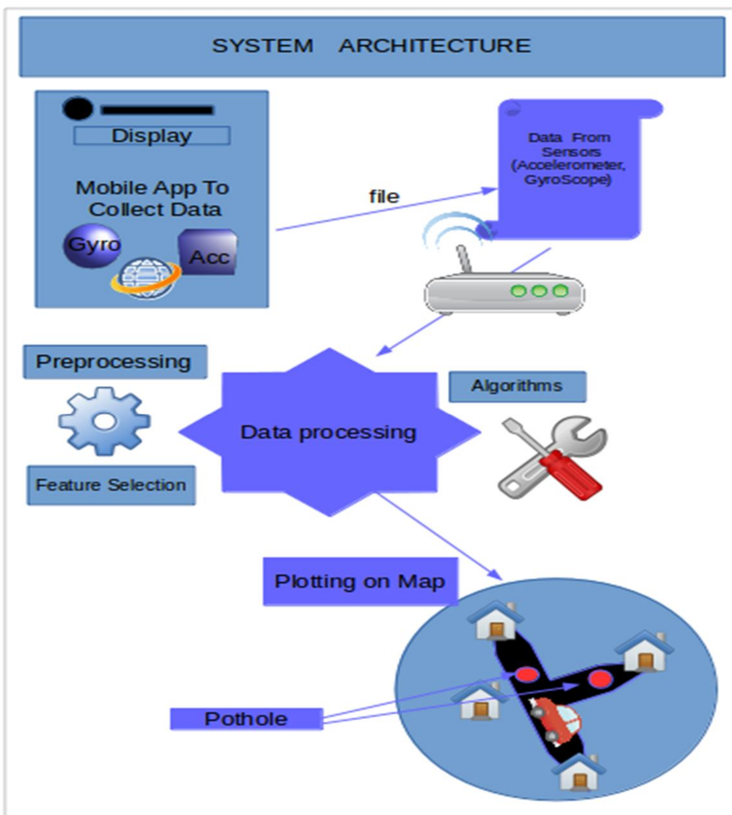

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Figure 2. System Architecture Diagram

B. Machine Learning Algorithms

In the proposed methodology, C4.5 decision tree classifier is used to model dataset. The C4.5 algorithm is used in Data Mining as a Decision Tree Classifier which can be used to generate a decision based on a certain sample of data. It creates a binary tree to model the classification process. Once the tree is built, it is applied to each tuple in the dataset and assign a class for that tuple. The algorithm inherently employs Single Pass pruning process to mitigate over fitting. It can work with both discrete and continuous Data. C4.5 can handle the issue of incomplete data very well.

C. Working of System

The proposed methodology worked in two phases viz training phase and deployment phase which is explain below,

1) Phase 1: Training Phase

In this phase, data preprocessing, feature extraction and training a classifier model is explained.

a) Data Pre-processing: Data are generally incomplete, noisy and inconsistent. Therefore, a data preprocessing phase should be applied to reduce noise and improve the quality of data. Due to several factors such as jerks or vibrations, turning, braking, and as well as subtle changes in sensor orientation, a considerable amount of noise is added to these signals. So, to remove noise from data a low-pass filter can be helpful to remove noise in the input signal by applying a suitable threshold to the filter output reading.

b) Feature Extraction: In the Feature Extraction stage, effective features will be extracted from specific types of road patterns on acceleration and rotation around gravity. The features are selected in the training phase and a classifier model would be generated which can identify the road condition based on fine data. It will be labeled into (+1,0, -1) and these labels will classify road in speed-brakes, normal road and potholes respectively. This step of feature extraction serves as inputs into the classification algorithms for recognizing roads quality.

c) Training a Classifier Model: After extracting features and selecting tuples, system obtain features for each road condition. After that, a classifier model is trained based on road conditions through machine learning technique to identify road types. For each road condition, the input into the machine learning algorithm is in the form of (11-dimensional features, label), where the 11-dimensional features are the tuples obtained from the Feature Extraction and the label is the type of the road.

2) Phase 2: Deployment Phase

The proposed system installed on smartphone will sense real-time motion of vehicle to detect and identify road conditions. The proposed system first takes the readings of accelerometer and gyroscope embedded on smartphone. After that, predicts the road quality based on the classifier model trained in the training stage and integrates proposed system with maps to improve the user experience. Sensors like accelerometer and gyroscope provides accurate data and proposed system can easily determine potholes on rainy day, foggy day and even when potholes are filled with water. Finally, a history of all reported road condition is saved.

V. COMPARISON OF SENSOR & EXTERNAL HARDWARE

This section depicts the comparison between various sensors and external hardware's based on sensor based and algorithm based.

A. Sensor Based Comparison

The table 2 depicts the comparison between various sensors and external hardware's used to detect potholes on roads, each of them have unique accuracies according to the methodology adopted to detect the cause. In discussion above, it is observed that sensors used in the proposed methodology outperformed in terms of accuracy and gives precise results.

Table. 2. Sensor Based Comparison

References	Smartphone Sensors			External Hardware				
	Accelerometer	Gyroscope	GPS	Accelerometer	GPS	Kinetic Sensor	Stereo Camera Images	Ultrasonic Sensors
[3]	N	N	N	N	Y	N	N	Y
[4]	Y	N	Y	N	N	N	N	N
[5]	N	N	N	Y	Y	N	N	N
[6]	Y	N	N	N	N	N	N	N
[7]	N	N	N	N	N	Y	N	N
[8]	N	N	N	N	N	N	Y	N
[9]	N	N	N	N	N	N	Y	N

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B. Algorithm Based Comparison

The table 3 depicts the machine learning algorithm/ detection method used to arrive at precise results using internal sensors and external hardware's. Labelling of data done in various methods varies according to the size of dataset.

Table. 3. Algorithm Based Comparison

Reference No.	Data Labelling	Detection Methods
[3]	Not Mentioned	Threshold
[4]	Not Mentioned	Threshold
[5]	Manually	Threshold/Machine Learning
[6]	Not Mentioned	Threshold
[7]	Not Mentioned	3D Reconstruction
[8]	Not Mentioned	Image Processing
[9]	Manually	3D Reconstruction

VI. PERFORMANCE ANALYSIS

In this section, results of a simulations performed using the proposed methodology are presented.

A. Time vs Shift Graph

This is time vs shift graph which tells the direction of acceleration with respect to time, when the vehicle was in motion. In this methodology, shift function is created which is combination of Y axis and Z axis of accelerometer because Z axis tells us the vertical shift and Y axis gives us information about lateral shift of the vehicle in motion. Further, shift function is taken on Y axis with respect to time function on X axis in milliseconds. Graphs values definitely gives us clear indications of potholes and speed brakes detected on road and road conditions. Figure 3 gives clear picture of time vs shift graph.

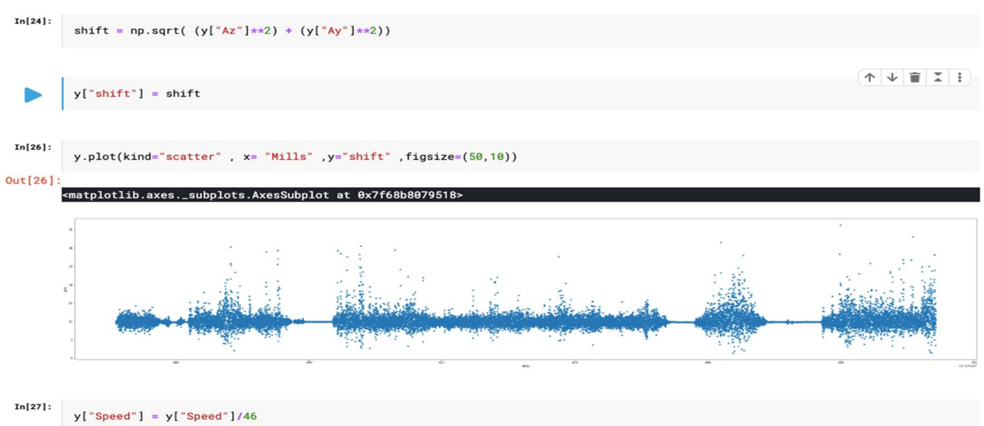

Figure 3. Time vs Shift Graph

B. Time vs Speed graph

This is time vs speed graph which tells the acceleration with respect to time, when the vehicle was in motion and also gives us information about brakes and pauses taken during the trip. This is useful in calculations and gives us better accuracy and edge in calculation. Figure 4 gives clear picture of time vs speed graph.

```
In[27]: y["Speed"] = y["Speed"]/46

In[28]: y.plot(kind="scatter" , x= "Mills" ,y="Speed" ,figsize=(50,10))
Out[28]: <matplotlib.axes._subplots.AxesSubplot at 0x7facbda46940>
```

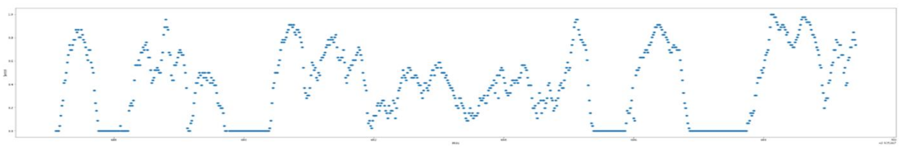

Figure 4. Time vs Speed Graph

C. *Time vs Gyroscope graph*

A gyroscope is a device designed to have a wheel mounted or spinning disc on a base such that its axis can turn freely in one or more directions in order to maintain its orientation regardless of any movement of the base. However, the orientation changes because of an external torque and in a different direction. This Graph tells us the movement of gyroscope with respect to time, which gives us information of external torque applied and movement caused due to it. Figure 5 gives clear picture of time vs gyroscope graph.

```
In[20]: y.plot(kind="scatter" , x= "Mills" ,y="Gz" ,figsize=(50,10))
Out[20]: <matplotlib.axes._subplots.AxesSubplot at 0x7f68b812ab38>
```

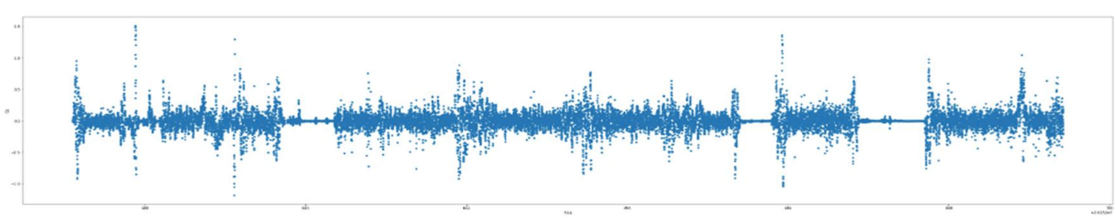

Figure 5. Time vs Gyroscope Graph

VII. CONCLUSION

The Road Safety application is an attempt to provide its users with better knowledge about the routes of their transportation. With further work in this field, it is possible for this project to play a proactive part in improving road conditions in developing countries. This paper introduces a framework to monitor road condition, based on sensors (accelerometer, gyroscope and GPS) built in a smartphone. Using machine learning system, quality of different road sections is obtained and it is possible to visualize a road quality map of a selected region. The system reduces the cost of external hardware, development and maintenance cost involved. As a future work, improve the road condition detection algorithm through detecting other road anomalies and trying other machine learning classifiers.

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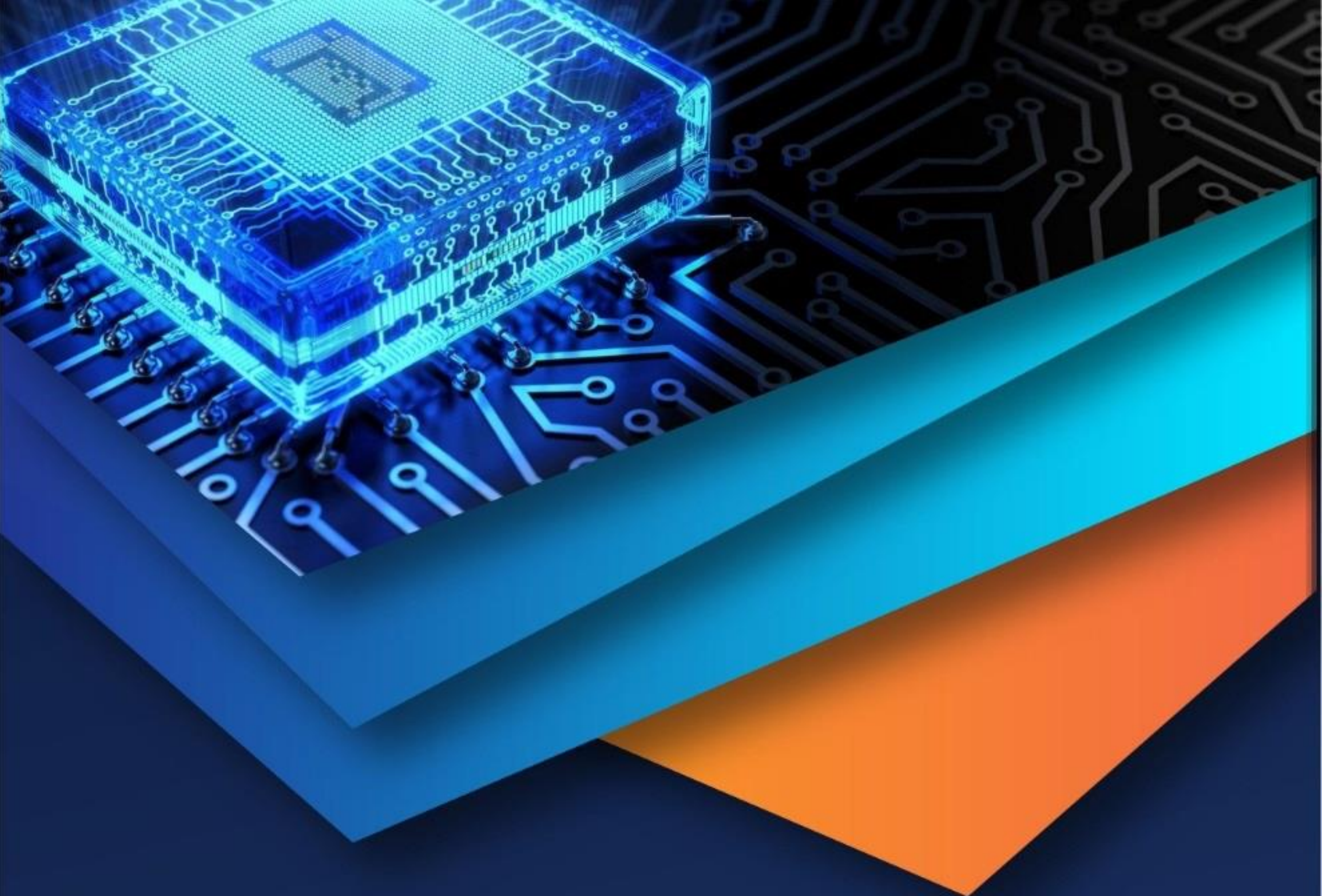

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