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Analysis of Energy Efficient Street Lighting System Using ML

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Abstract: It has become extremely necessary to reduce the consumption of electricity due to the increasing needs and limited resources for its generation. Streetlights place a heavy demand on electricity usage. Conventionally, the streetlights remain lit during their operational hours even when they are not required or when full brightness is not necessary; for example, during periods of low traffic volume or even during summer season. Thus, the focus of this system is to control the intensity and pattern of street lights. This controlling will be done with the help of ML algorithms used for recognizing the need of electricity for a particular area depending on given input parameters like traffic volume of that area, climate in the area, time and day of the week. Use of this system will not just save electricity, but ensure the presence of required light intensity for safety purposes. There is a need to just connect the existing streetlights with the proposed system thus, reducing the cost of investment like building all together new street lights or even installation of sensors. The system will operate on its own without the need of human intervention, though a special access is granted to the administrator.
Keywords: Machine Learning, Energy Conservation, Smart streetlights, Smart city, Energy Efficient

I. INTRODUCTION

Electricity has become an important aspect of modern day life and electricity consumption has increased due to population growth and rapid urbanisation.
The world's population is projected to increase by 72% by the year 2050 [1] and electricity consumption is also expected to rise to meet the increased demands.
A major portion of the city's electricity budget, almost 40% , goes towards powering streetlights [3]. Furthermore streetlights consume 2.3% of global electricity [4] and hence saving energy by smartly modifying the use of streetlights is required.
LEDs can greatly aid in saving electricity consumption. LEDs reduce carbon dioxide emission, have a longer lifetime and consume less electricity.
Around the world, there are 300 million streetlights, out of which only 10% work on LEDs[5]. Using LEDs instead of street lamps can reduce and cut energy cost by 50% [6].
The approach that we used to optimize the use of street lights is presented in this section. The dataset includes different parameters like traffic density, time, temperature, humidity and visibility.
We have used multiple supervised machine learning algorithms. From those, the one which gave most accuracy was finalized. Considering all the data provided, algorithm finds out the intensity requirement and for that requirement it will generates a switching pattern to control the street lights.
Supervised learning algorithms like SVM (Support Vector Machine), Naïve Bayes, Random forest were used. The algorithm first trained the system for different situations.
For example, during periods of low traffic volume, the requirement of light on the streets will be relatively low. So, in this case, the system will suggest different switching patterns (like zig-zag or alternate) that will provide enough light on the streets.
There is an interface provided for the system manager to view the current status of the area he is responsible for, give access to override the system i.e. for exceptions and emergencies. The manager can securely login based on his area and password. The output and representation of this system is simulated on a model built using NodeMCU ESP8266 board and LEDs representing the streetlights.

II. SYSTEM ARCHITECTURE

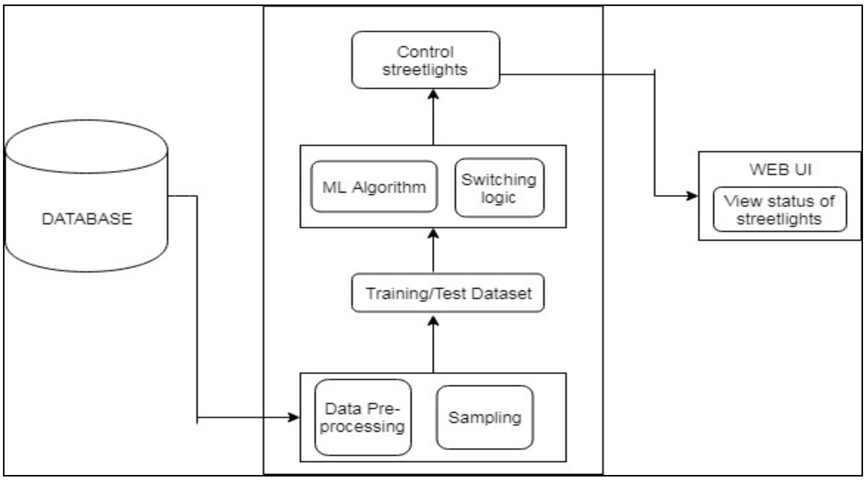

Fig. 1 System Architecture

The database consists of historic records of traffic density, climate, humidity, temperature, day, date, time, etc. In order to improve the quality of the raw collected data, various data preprocessing techniques were applied where the data went through a series of steps during preprocessing such as data cleaning, data integration, data reduction, etc. This dataset was then divided into training and testing datasets which was used by the ML algorithm. The value of light intensity predicted by the algorithm is mapped into a suitable switching pattern which is reflected on the web application.

III. OVERVIEW OF PROJECT MODULES

The project is divided in three major modules:

1) *Web Application:* The web application allows users to sign in and view the current status of the streetlights in the area they govern. The users can also override the ML predicted patterns through this web application.
2) *Hardware:* The hardware system is used to display the output system on the model built. NodeMCU is used control the LEDs on the model. Hardware coding is done in Arduino IDE.
3) *Machine Learning:* Machine learning algorithms are used to learn from the existing data and to predict light intensity for new data. Dataset was preprocessed and used to build an ML model. Preprocessing techniques such as data reduction were applied before using the dataset. The ML algorithm predicted the optimum light intensity required at a particular time. This predicted value of light intensity is mapped to suitable switching patterns of the streetlights.

A. *Web Application*

The web application is intended for 2 types of users:

1) *Area Manager:* Each area will have an assigned area manager who can log into this system to view the status of streetlights or in case of special occasions, manually control the streetlights by overriding the ML module.

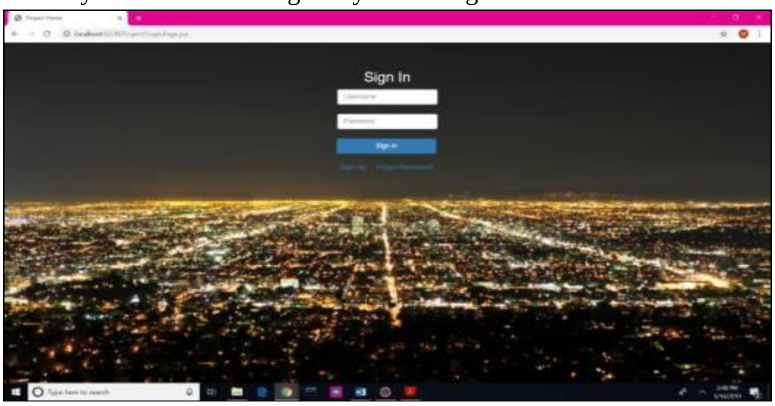

Fig. 2 Home Page

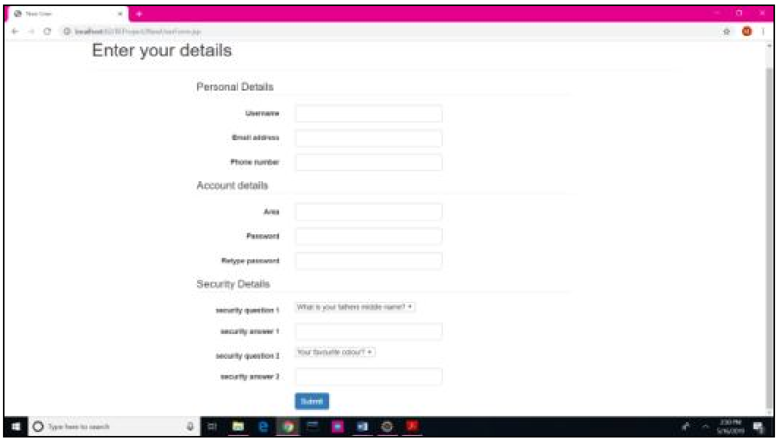

Fig. 3 User Sign Up

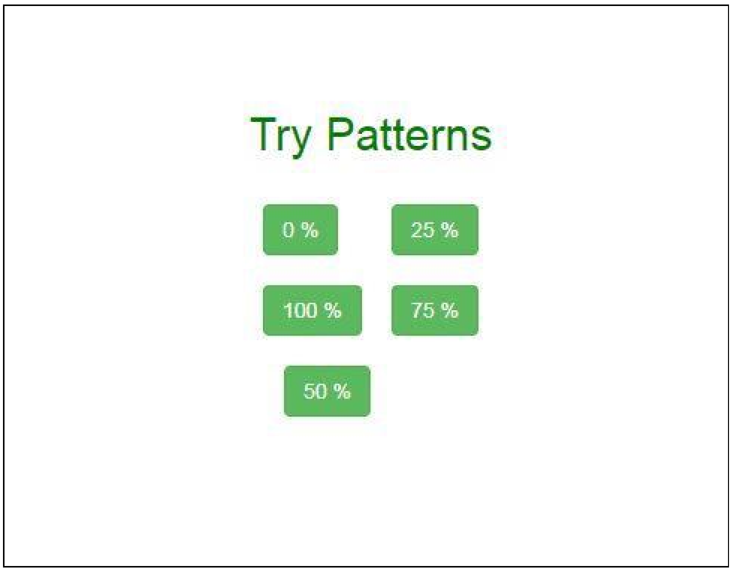

Fig. 4 Manual Control

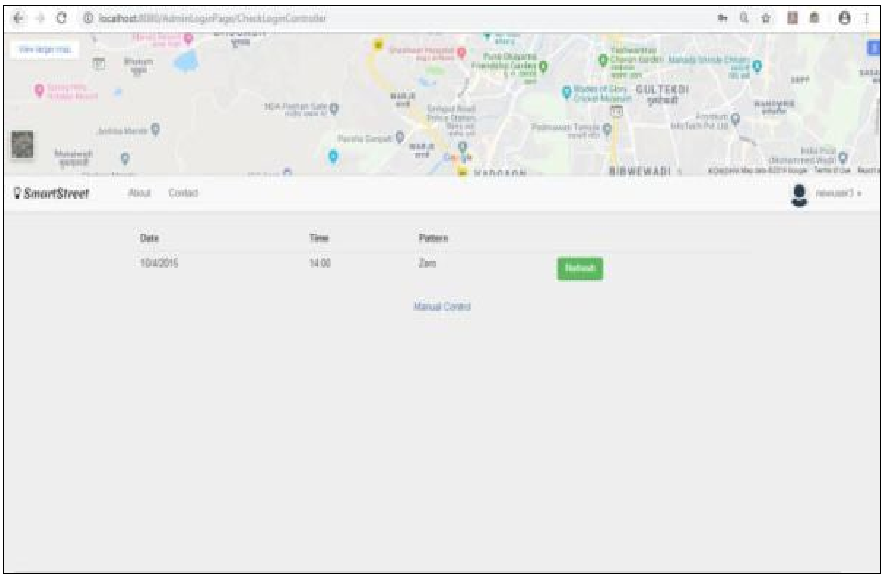

Fig. 5 User Home Page

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2) *Admin:* Admin decides whether or not to grant access rights to an area manager. Only after an admin grants access, will the area manager be able to log into the system.

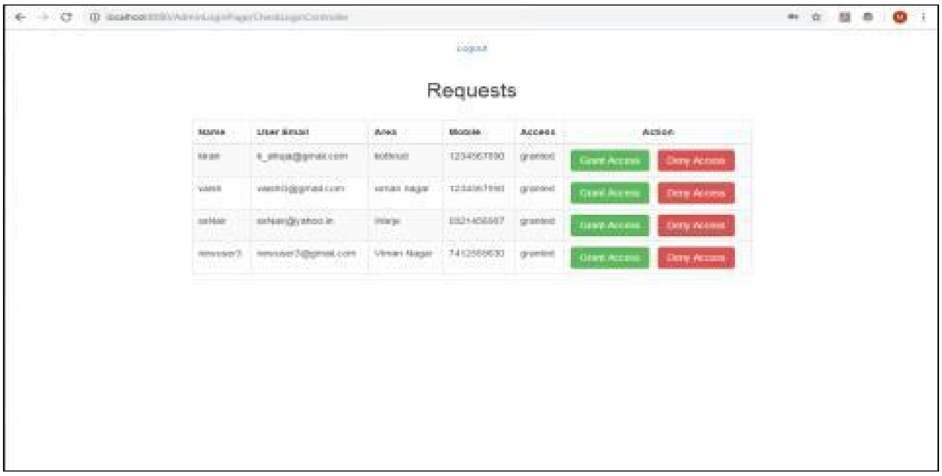

Fig. 6 Admin Home Page

B. *Hardware Setup and Connectivity*

The hardware module of the project is used to display the output. It communicates with the software module to show the results in the form of suitable patterns.

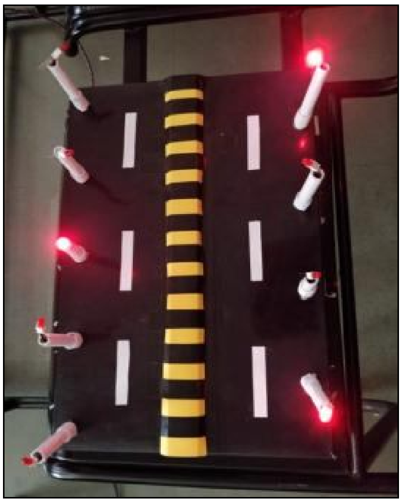

Fig. 7 Model- Pattern 25%

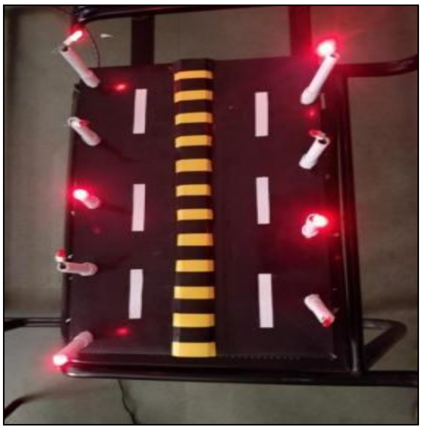

Fig. 8 Model- Pattern 75%

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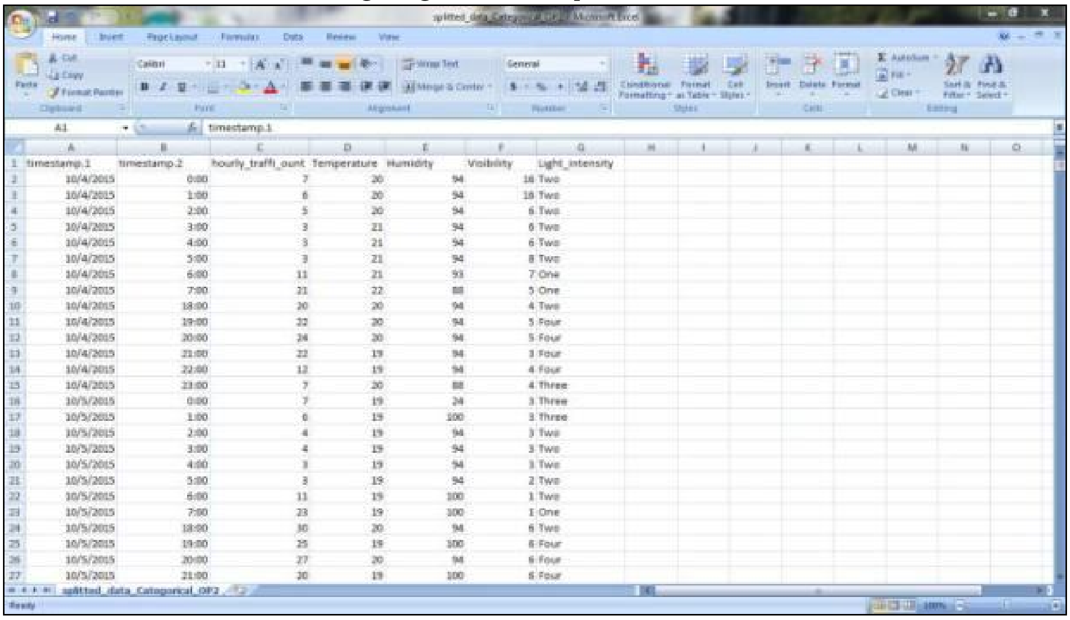
Fig. 9 Model- No lights on

C. Dataset

The traffic dataset used for experimentation is the same data set as used in the following research paper: LSTM-based TrafÞc Flow Prediction with Missing Data, Neurocomputing (2018) [10]. Weather data is then annually combined with the traffic data for the same region based on the date and time. Following image shows a snap of the dataset.



	timestamp.1	timestamp.2	hourly_traffi_ount	Temperature	Humidity	Visibility	Light_intensity
2	10/4/2015	0:00	7	20	94	16	Two
3	10/4/2015	1:00	6	20	94	16	Two
4	10/4/2015	2:00	5	20	94	6	Two
5	10/4/2015	3:00	3	21	94	6	Two
6	10/4/2015	4:00	3	21	94	6	Two
7	10/4/2015	5:00	3	21	94	8	Two
8	10/4/2015	6:00	11	21	93	7	One
9	10/4/2015	7:00	21	22	88	5	One
10	10/4/2015	18:00	20	20	94	4	Two
11	10/4/2015	19:00	22	20	94	5	Four
12	10/4/2015	20:00	24	20	94	5	Four
13	10/4/2015	21:00	22	19	94	3	Four
14	10/4/2015	22:00	12	19	94	4	Four
15	10/4/2015	23:00	7	20	88	4	Three
16	10/5/2015	0:00	7	19	24	3	Three
17	10/5/2015	1:00	6	19	100	3	Three
18	10/5/2015	2:00	4	19	94	3	Two
19	10/5/2015	3:00	4	19	94	3	Two
20	10/5/2015	4:00	3	19	94	3	Two
21	10/5/2015	5:00	3	19	94	2	Two
22	10/5/2015	6:00	11	19	100	1	Two
23	10/5/2015	7:00	23	19	100	1	One
24	10/5/2015	18:00	30	20	94	6	Two
25	10/5/2015	19:00	25	19	100	6	Four
26	10/5/2015	20:00	27	20	94	6	Four
27	10/5/2015	21:00	20	19	100	6	Four

Fig. 10 Overview of Dataset

IV. ALGORITHMS

Three machine learning algorithms were trained with the same dataset and the results were analyzed. Naive Bayes, Decision Tree and SVM were trained and tested with our dataset. The algorithm giving the most accuracy was SVM and this algorithm was then chosen for the final system. Support Vector Machine (SVM) algorithm gives is a supervised learning algorithm which takes labelled training instances and outputs a hyperplane to classify new data. For analyzing machine learning algorithms, Weka libraries and tool was used.

To provide secure login and privacy to users, SHA-1 algorithm is used for password encryption and decryption.

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V. TOOLS AND TECHNOLOGIES USED

NodeMCU ESP 8266 is used to display the output. Its coding is done using Arduino IDE. Communication between NodeMCU and web server takes place by sharing IP addresses. LEDs are connected to NodeMCU using connecting wires. NodeMCU controls the switching of LEDs in order to display various patterns of light intensity as commanded by the user through web server.

MySQL database is used to store user information like name, login ID, password, area under his control, contact details, etc. Eclipse Kepler editor and Tomcat 7.0.92 are used to develop the web server. Since the system is using machine learning to decide the required light intensity, Weka library for Java is used which provides implementation of different machine learning algorithms on the dataset in order to train the system. Technologies like JSP (to create and manage web pages), Servlet (to manage the requests obtained from the web server), JDBC (for connection with the database), etc. are used for system development.

VI. RESULTS

We have applied 3 supervised learning algorithms – Naïve Bayes, SVM, Decision Tree to our system and their performances are discussed below.

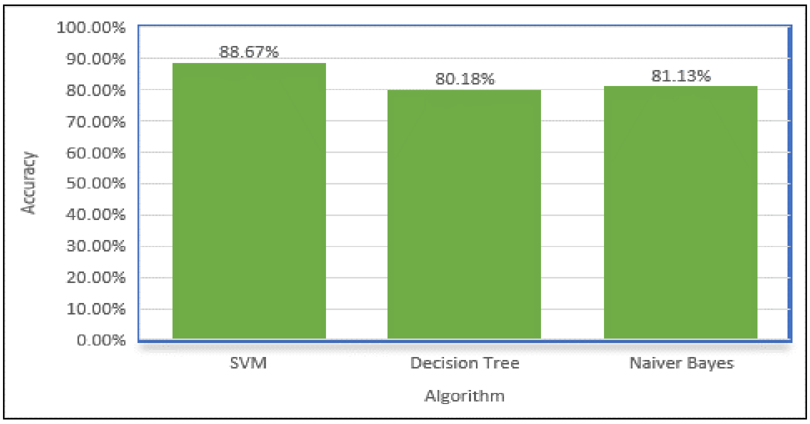

Fig. 11 Accuracy of Algorithms

A. Current System

Let's consider, for a particular street with twelve 60 watts LED light bulbs used for streetlights operating for 14 hours in a day, consume approximately 10.4 kWh of energy.

$12\ LED\ bulbs * 60\ watts * 14\ hrs = 10.4KWh$

Energy consumed by streetlights using current system for a day= 10.4KWh.

B. Our System

For example, consider the data below for a day with hourly required intensity according to our system.

timestamp. 1	timestamp. 2	hourly_traffic_count	Temperature	Humidity	Visibility	Light_intensity	Equivalent percent of lights on	Equivalent number of LED bulbs for a street with 12 lights
10/4/2015	0:00	7	20	94	16	2	50	6
10/4/2015	1:00	6	20	94	16	2	50	6
10/4/2015	2:00	5	20	94	6	2	50	6
10/4/2015	3:00	3	21	94	6	2	50	6
10/4/2015	4:00	3	21	94	6	2	50	6
10/4/2015	5:00	3	21	94	8	2	50	6
10/4/2015	6:00	11	21	93	7	1	25	3
10/4/2015	7:00	21	22	88	5	1	25	3
10/4/2015	18:00	20	20	94	4	2	50	6
10/4/2015	19:00	22	20	94	5	4	100	12
10/4/2015	20:00	24	20	94	5	4	100	12
10/4/2015	21:00	22	19	94	3	4	100	12
10/4/2015	22:00	12	19	94	4	4	100	12
10/4/20:	23:00	7	20	88	4	3	75	9
--	--	--	--	--	--	--	--	Total LEDs=105

Fig. 12 Light requirement of our system

For the above data, total intensity of light required by our system for a day is 35 units.
Total LED bulbs on for a period of 14 hrs = 105 bulb hrs. 105 $bulb\ hrs * 60 watts$= 6.3 KWh
Thus,
Amount of electricity saved =$10.4KWh - 6.3KWh$ = $4.1KWh$
Hence **37%** electricity is saved.
The results show significant energy savings from the approach, without compromising on the safety.

VII. CONCLUSION

Based on the performances of all the 3 algorithms (Naïve Bayes, SVM, Decision Tree) we will be using SVM for final performance evaluation and deployment in future because of its high efficiency compared to others.
Considering that presently all the streetlights are LED street lights, our system saves approximately 37% of energy without compromising on safety. It is a system which follows the principle ‘provide as much as needed’. Because of its simplicity and high savings, our system can be very much helpful is saving energy, money and preserving resources for our future generations.

VIII. ACKNOWLEDGMENT

The project would not have been possible without the kind support and help of many individuals and organizations. We would like to extend my sincere thanks to all of them.
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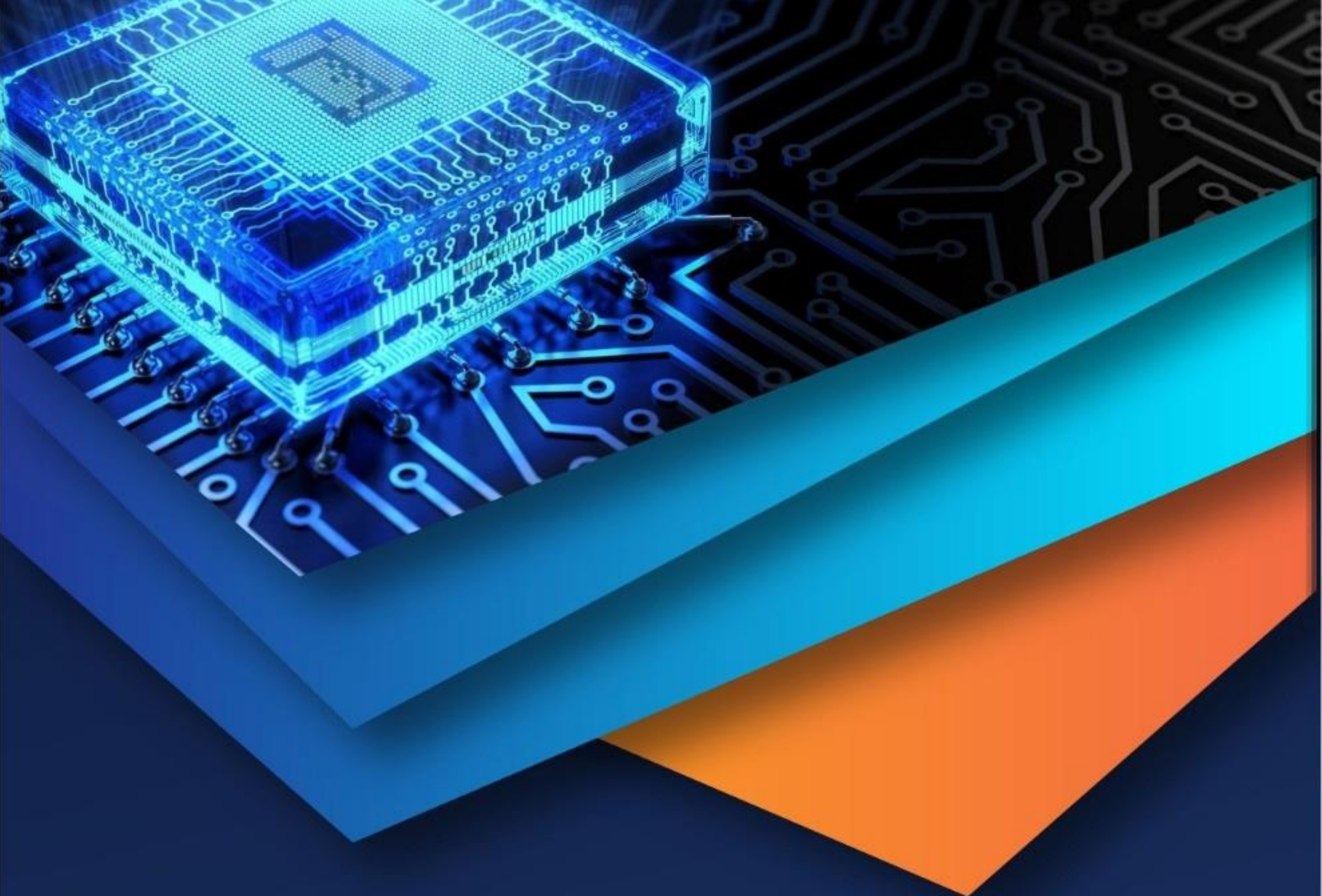

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