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Bolt-on Autonomous E-Vehicle System

Mohit Borkar[1], Pratiksha Patil[2], Pratyaksh Pandey[3], Prerana Kolipaka[4], Prof. Rajkumar Komati[5], Prof. Alka Barhatte[6]
[1, 2, 3, 4, 5, 6]*School of Electronics and Communication Engineering,MIT-WPU, Pune,India*

***Abstract:** In this research we have undertaken the task to design and develop a Level - 3 bolt-on autonomous electric vehicle system, which includes lateral and longitudinal controls which means speed and steering. The paper includes the sensors used for obstacle detection and planning in the autonomous vehicle system, and how using stereo cameras reduces the number of sensors needed to be used in the sensor suite. The Autonomous system will be retro-fitted on any existing electric vehicle to make it autonomous and thus increasing its product life cycle.*
***Keywords:** YOLOv3, steering angle, virtual lane, Jetson nano*

I. INTRODUCTION

Autonomous driving is considered as one of the big challenges in the automotive industry. Reliable and affordable autonomous vehicles would create a large social impact. In particular, a reduction in road fatalities, a more steady flow of traffic, a reduction of fuel consumption and noxious emissions, as well as an improvement in driver comfort and enhancement of mobility for elderly and handicapped persons is expected. Accordingly, autonomous mobility systems have been targeted by governments and industry for the first part of next decade. Autonomous vehicles are the thing of the future we all were eager to see. It is one of the major challenges posed to us. The main problem arises in terms of safety and reliability. Autonomous vehicles consist of a large number of sensors to accurately perceive the environment and make decisions so as to reach the desired destination safely. They rely on sensors, actuators and complex algorithms to do this task. The inputs from various sensors are analysed and a decision is made considering the current scenario through the algorithm implemented. Autonomy is classified into 5 levels by SAE, depending on the independence from the human interface- the driver- with level 1 being not autonomous and level 5 meaning fully autonomous.

This project is an autonomous driving system for Electric Vehicles (EV). This system is of a bolt-on type, which can be implemented on any EV to achieve level 3 autonomy, i.e. Latitude and Longitudinal controls. There are various sensors which collect the short range data for obstacle avoidance, and a few Global Positioning Systems to obtain long range data, that being the route planning from source to destination. Since the system is bolt-on, the autonomous parts can be removed to provide entirely manual operation. The project that is being presented here is restricted to a specific domain (environment), and the domain considered here is MIT, Pune college campus.

II. PROPOSED ALGORITHM

Perception: By using a LiDAR camera, the environment around the vehicle is perceived.

1) *Obstacle Avoidance:* By using the data gathered by the LiDar camera sensors, we can decide what the position of an object is; and by observing its subsequent frames we can also determine the heading of the obstacle according to which we can then manoeuvre the vehicle.
2) *Path Planning:* Calculating the trajectory/ path of the vehicle based on the given Source and Destinations. This method uses a search tree pruning based on the relative polar coordinates of the source and the destination.

A. Perception

The environment around the vehicle is perceived using a LiDAR camera. A LiDAR camera uses a rgb camera and a LiDAR to compute the distance of the object from the camera. The rgb camera frame is used to understand the type of object and the LiDAR gives a depth frame which helps us obtain the distance of the object. For this project, we have used the Intel Realsense L515 LiDAR camera. For object detection, the YOLOv3 (you only look once) algorithm is used. The algorithm consists of 53 layers of convolutional network and as the whole frame is taken as a blob at a time the operational time is faster in yolo as compared to other CNN modules. Since in the Yolo model, the whole network is in a single pipeline it can be easily optimized end to end directly on detection performance. The approach used is, it splits the frame into grids and each grid directly predicts a bounding box and object classified . These give a large candidate of bounding boxes and are concluded into final prediction by post processing step. Using YOLOv3 provides as good accuracy as that provided by Regional-Based Neural Networks(R-CNNs).

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B. Obstacle Avoidance

For the obstacle avoidance algorithm, a virtual lane is created on the image frame. When an object is detected, the position of the object with reference to the virtual lane is analysed. Depending on the position and distance of the object, a decision is made to continue moving, stop, swerve from left or swerve from right. The steering angle is then calculated using the position coordinates of the object with reference to the ego vehicle.

The steering angle is calculated using triangle's rule (pythagoras rule) where the distance between the car and obstacle is known, which is height and the width of the area which the obstacle is taking in front of the vehicle is known. These will help us calculate the hypotenuse and using the sine angle we can calculate the theta (steering angle) required. Once we get the angle we can add a certain error angle in order to cross the threshold angle for safety concerns.

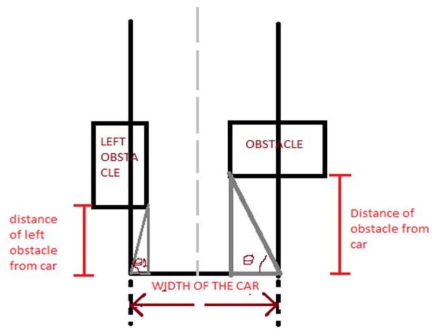

Fig 2.2.1: Steering angle measurement

C. Path Planning

To know exactly how to traverse the area, there was a need to come up with an algorithm to find the best route from source to destination. Since the area in question is like a simple maze, a maze solver algorithm would be useful and will provide the necessary data. It was decided to settle on A* (A- star) algorithm. To make the algorithm run properly, there was a need to convert the map into a maze.

The roadmap of the selected area was taken, and then converted into a monochromatic picture, with roads colored in black and everything else being in white. Since the original map was 500 x 500 pixels to begin with, the time required for processing the route was too long. To get around this problem, we then reduced the number of pixels by decreasing the resolution : essentially, the average color of a 5 x 5 area (cell) was taken and the dominant was applied to the selected area (Fig. no. 4.3.3).

Now, running this image through the algorithm by providing the necessary inputs, it was found the time to be in acceptable margins. The resulting path is highlighted in red (Fig no. 4.3.4). This data is obtained in the form of cell numbers, which when plotted give the resulting path to take.

To correlate this path with the real world path, a coordinate map was projected onto Fig. no. 4.3.4, which gave us the mapped coordinates of the cell, i.e. converting image X,Y coordinates to real world latitude and longitude values. An Android application called "Bluetooth GPS Output" was used to obtain the coordinates. With this data, a live position of the vehicle was obtained and from that the rough path was decided, with the finer details like swerving, accelerating and braking handled by the data obtained from obstacle avoidance algorithm.

D. Bolt-on System Design

The objective of the project is to make a system that can be retro-fitted onto any existing e-vehicle to make it autonomous. For the bolt-on system, there needs to be a mechanism that can actuate the brake, accelerator pedal and steering wheel. A mechanism was designed using pulleys and stepper motors to actuate the accelerator and brake pedal. For actuating the steering, a mechanism was developed using sprockets and chain drive, driven by stepper motors.

III. SYSTEM SPECIFICATIONS

A. Jetson Nano Single board computer for processing the camera inputs and path planning algorithm.
B. Intel Realsense L515 LiDAR Camera.
C. Android application to get the real-time gps coordinates.
D. SPYDER python IDE for implementation of the algorithms.

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IV. RESULTS

A. Perception

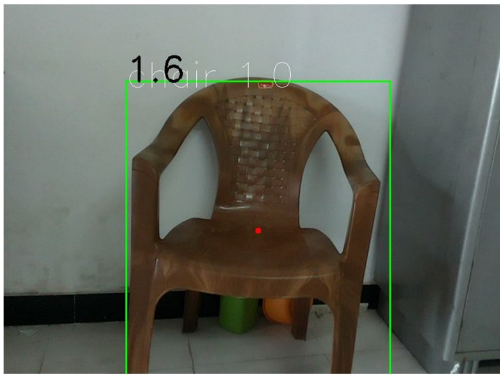

Fig 4.1.1 Object detection with distance

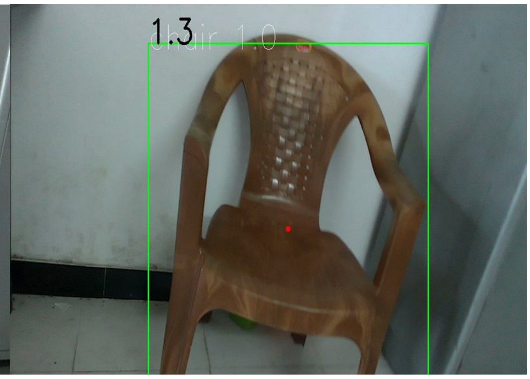

Fig 4.1.2 Object detection with distance

B. Obstacle Avoidance

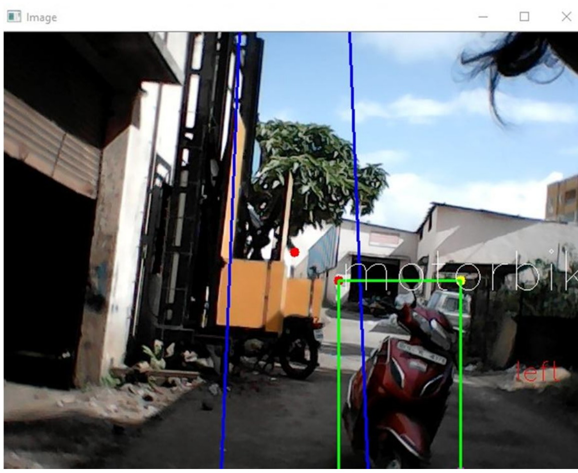

Fig 4.2.1 Obstacle Avoidance decision (swerve left)

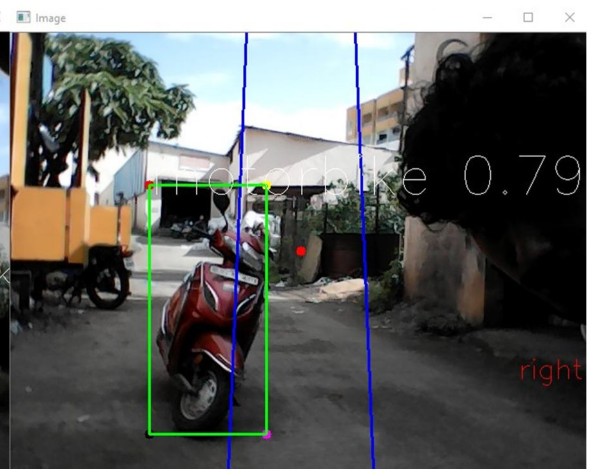

Fig 4.2.2 Obstacle Avoidance decision(swerve right)

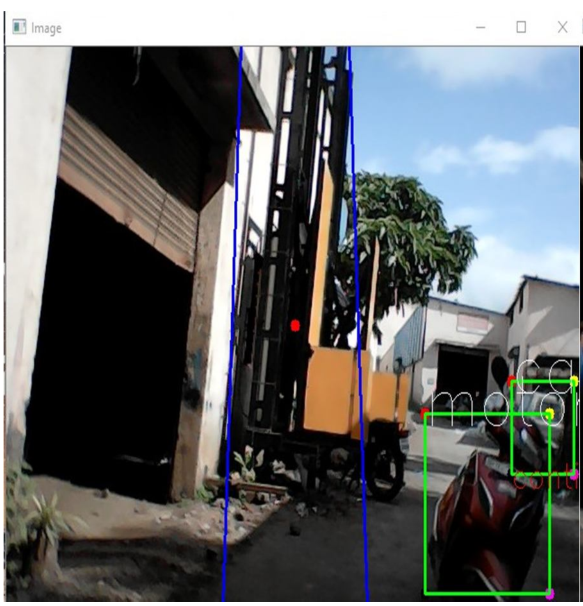

Fig 4.2.3 Obstacle avoidance decision (continue forward)

Fig 4.2.4 Obstacle Avoidance decision (stop)

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C. Path Planning

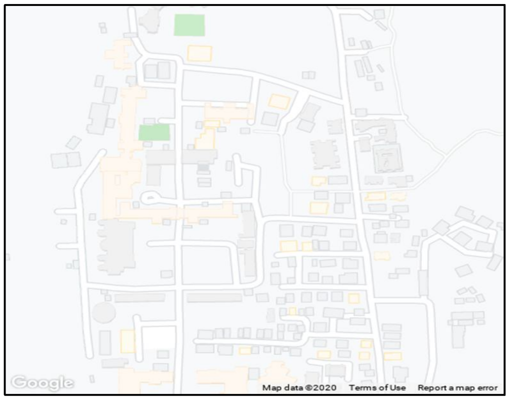

Fig 4.3.1: MIT Campus Map

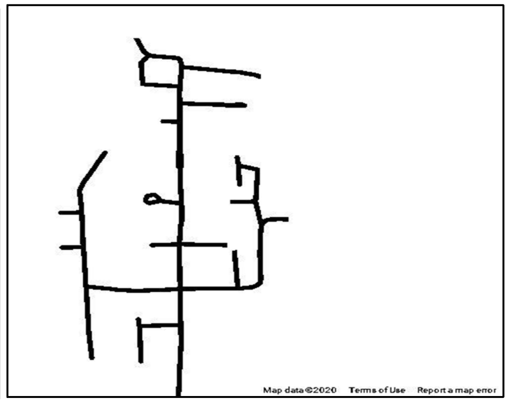

Fig 4.3.2: Roads in MIT,Pune Campus

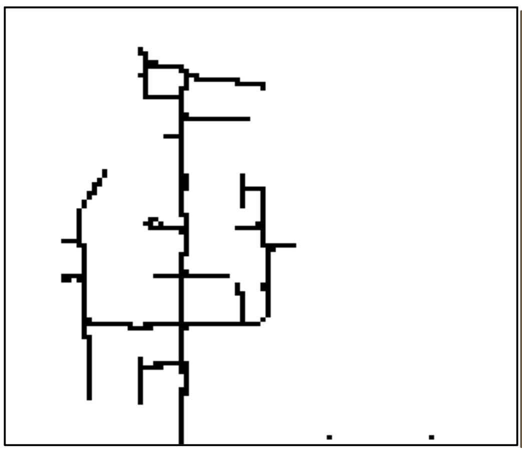

Fig 4.3.3: Prepped image for A* algorithm

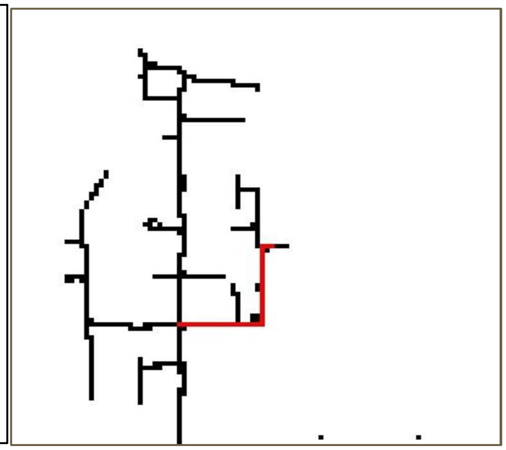

Fig 4.3.4: Resulting Image with Highlighted Path

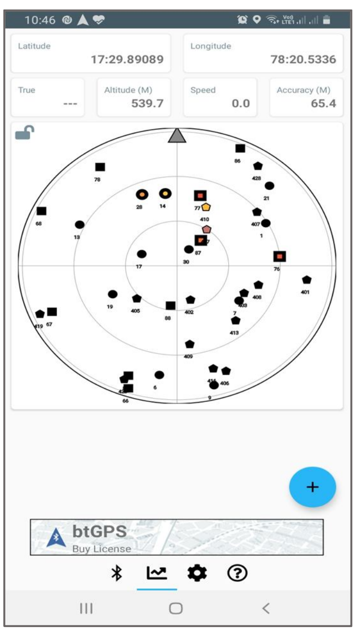

Fig.4.3.5: GPS application on phone

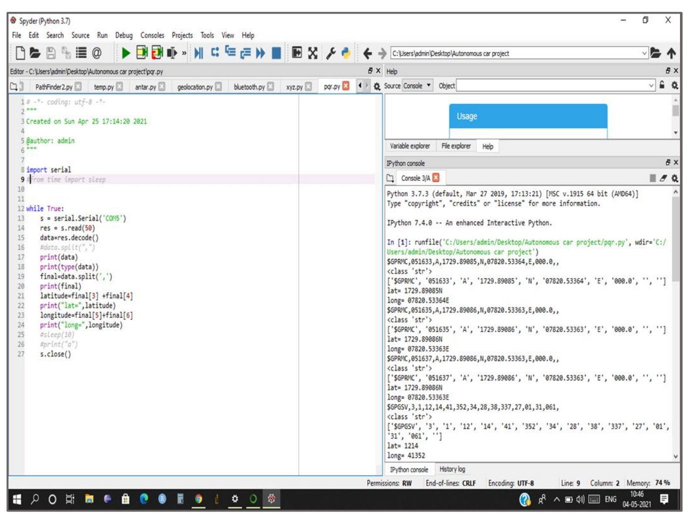

Fig 4.3.6 : GPS coordinates sent to laptop through bluetooth

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D. Bolt-on System Design

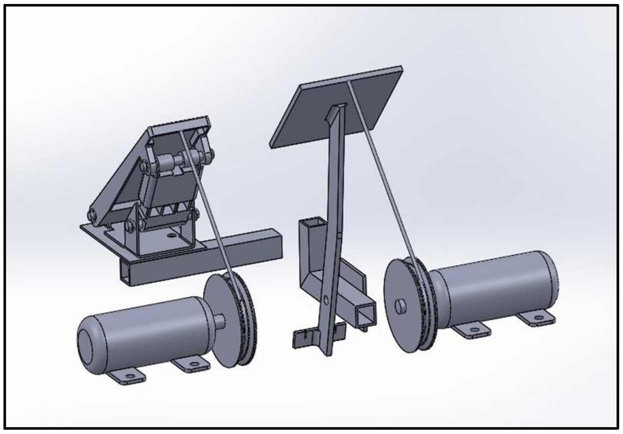

Fig 4.4.1 Bolt-on System Design for brake and accelerator pedal

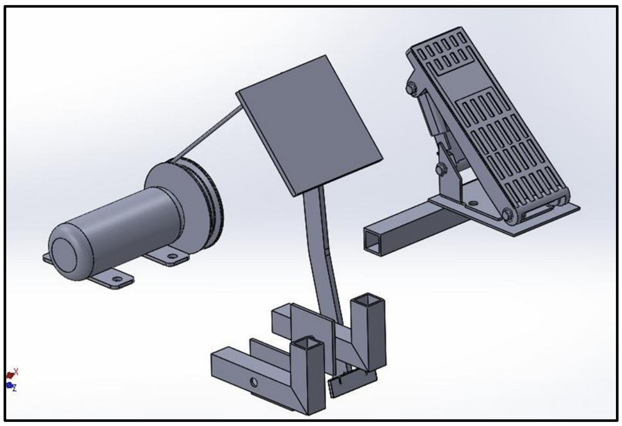

Fig 4.4.2 Bolt-On-system design for brake pedal

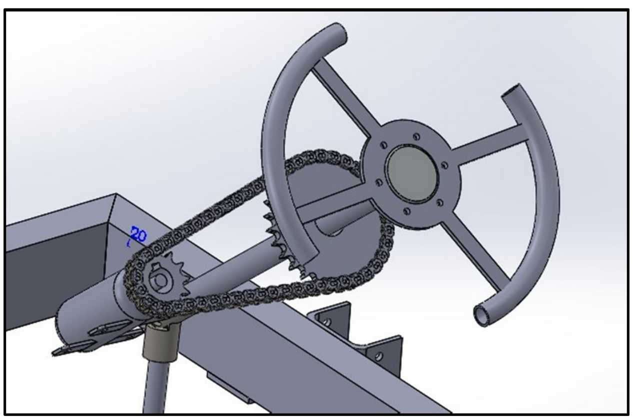

Fig 4.4.3 Bolt-on System Design for Steering wheel

V. CONCLUSION

Bolt-on driven mechanism helps to convert an existing E-vehicle into a partial Autonomous Vehicle using multiple systems like perception of environment and obstacle avoidance. Path planning using GPS and Maze Solver algorithms will help to locate and track paths. Using all the sub-systems, control and actuation of brake and throttle pedal along with swerving of steering wheel is done with information of the surroundings around the vehicle.

VI. FUTURE SCOPE

Autonomous E-Vehicle will be useful to increase safety,avoid traffic problems and also prevent injuries. The self driving mode has many benefits such as reducing the energy cost, maximum driving efficiency. This project can be implemented on a greater scale and increase the product life cycle of existing e-vehicles. The project can be implemented on a greater level, increasing the domain environment. Along with gps data, image data can also be added to accurately localize the vehicle in real-time.

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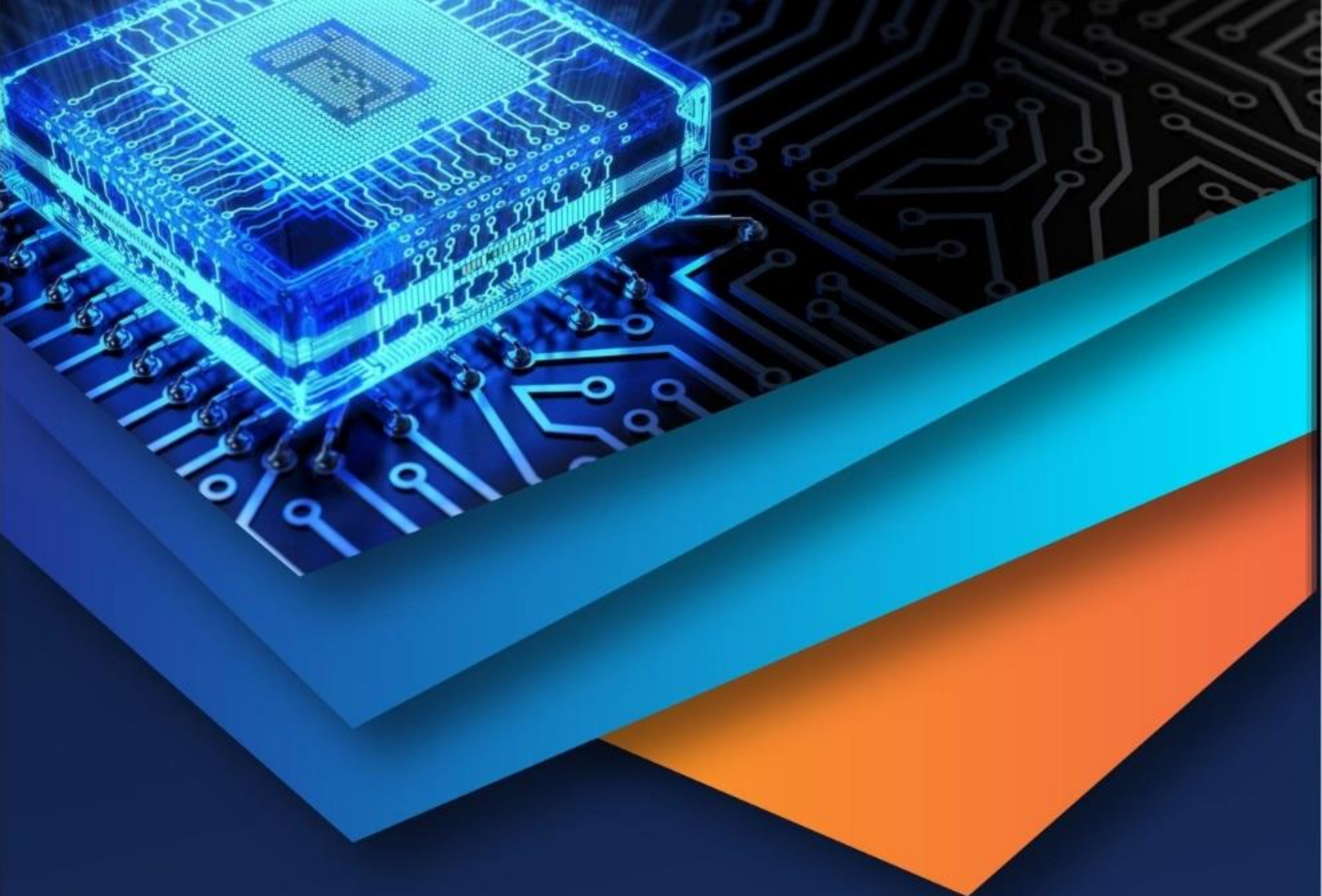

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