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Generalized Avoidance Model for Polygon Shaped Obstacles in Indoor Environment

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Abstract: Obstacle avoidance in robotics is a very vital and important aspect. Many techniques developed to perform obstacle avoidance. With the advent of cutting-edge technologies, it has become more prominent in robotics. While there exist algorithms and models that perform obstacle avoidance, this project is to implement obstacle avoidance with minimal deviation from the original path. The intention is to do this task by applying a concept called sensor-fusion. Sensor fusion techniques have been making rounds among the scientific community over the years. Many scholars and researchers have incorporated many algorithms associated with sensor fusion in their respective works. There are algorithms with HMI and fuzzy logic systems involved. The type of obstacles in these works are uncertain in most of the cases except for curvature obstacles that uses bug algorithm to travel along the curvature obstacle. The paper on the other hand, defines the nature of the obstacle viz. Polygonal obstacles that are considered in this work. The proposed work is keen about algorithm developed on the platform of FPGA (Zybo Z7-10).
Keywords: Obstacle avoidance, FPGA, Verilog, Polygon

I. INTRODUCTION

Obstacle avoidance is one of the most basic problems in mobile robotics. In those systems where there are no other moving objects other than the robot itself, static obstacle avoidance is sufficient. The obstacle avoidance robotics used for detecting obstacles and avoiding the collision. The design of obstacle avoidance robot requires the integration of many sensors according to their task. The obstacle detection is primary requirement of this mobile robot. The robot gets the information from surrounding area through mounted sensors on the robot. Some sensing devices used for obstacle detection like bump sensor, infrared sensor, ultrasonic sensor etc. Ultrasonic sensor is most suitable for obstacle detection and it is of low cost and has high ranging capacity. There exist models that perform obstacle avoidance of both defined and undefined obstacle. The differentiator that makes the work in this is the fact that the deviation from the original path of the obstacle minimized and henceforth the path of propagation remains intact. This project intends to use a Zybo Z7-10 FPGA board. It has approximately 35,000 logic cells. It has a system clock of 125MHz and around 90 DSP slices. As mentioned in [2], local navigation technique involves a technique called the adaptive navigation. It keeps track of distance from the obstacle and robot in three directions. A maximum distance defined as a boundary value beyond which the robot does not detect the objects. The obstacles are convex polygons in this case and the avoidance mechanism evaluated mathematically. The trajectory of the mobile robot decided based on the nature of the polygon. Hence, this makes the design more feasible and compact. For the path-planning model that make use of various algorithms based on the requirement [2] categorized as off-line path planning and online path planning. Depending on the nature of the environment, either local or global environment, the robot collects the surrounding information and orients accordingly. The first aspect for path planning is the DDA algorithm for straight path tracing and DDA arc drawing for arc tracing. It introduces a new algorithm called the Virtual Circle Tangents algorithm, which computes the shortest path from source to target. In this, the polygon shaped obstacles generalized by representing them as circles encircling the edges of the polygon. The mobile robot navigates through the path by an algorithm called randomized incremental algorithm. In the case of sensor fusion model [3], for collision free mobile robot navigation, method defines various models for obstacle avoidance viz. Fuzzy logic, Kalman Filtering and ANN. In Fuzzy systems, raw inputs from the sensors taken into consideration and are processed with respect to the membership function. These inputs fuzzified to give the probabilities of collision. Based on the collision probability, the robot decides the motor action. The implementation done using simulators such as Webot Pro. Alternatively, the Kalman Filtering is a technique used to estimate the position and orientation of the obstacle. ANNs have proven to be more powerful and more adaptable method, compared to traditional linear or non-linear analyses. The layers of processing neurons connected in different ways. The neurons trained to learn behaviour of any system, using sets of training data and learning algorithms to tune the individual weight of the links. Weights altered to improve the robustness of the system. Once the errors for the training data minimized, the ANNs can remember the functions, and be engaged in further estimations. The data closely linked with the processing. One major problem currently is determining the best topology for any given problem. Recent research in such robot navigation have successfully used neural networks in sensor fusion. Quadratic Bezier curves algorithm [4] functions in terms of conditional probability. The quadratic Bezier curve can be improved through a division and conquer technique whose basic operation is the generation of multiple midpoints on a specific curve. The platform of the mobile robot constructed with three ultrasonic sensors placed around the front of the platform with 45° between them. These sensors utilized to sense the locations of obstacles in any environment surrounding the mobile robot. Based on sensor(s) detection for obstacles in the environment of the mobile robot, five different scenarios introduced and studied. To navigate the robot in the unknown environment, two main points taken into consideration: Firstly, the smooth rotation of the mobile robot around the obstacles performed to avoid a collision; and secondly, the robot should follow the shortest path to reach a target with minimum time. In the sense, this algorithm works as follows. Given that the distance from the obstacle is X and given that the collision probability is Y, the best path to avoid the obstacle is Z. This solves many complex cases for a polygon with any number of sides and works fine even in an indoor environment. The implementation in [1] deals with concepts of Human-Computer Interaction. This is also a cutting- edge technology that is making rounds in the scientific communities all across the globe. Robots equipped with HMI models are a novel approach in navigation robots in indoor environment.

II. OBSTACLE AVOIDANCE MODEL

Obstacles except curvatures can be characterized by vertices and edges. The project intends to make use of sensor data to perform obstacle avoidance. The sensors in this scenario are ultrasonic sensor (HC SR04) operating at frequency of 40 KHz, framed as fused elements to trace the object. The tracing of the object at every iteration with respect to the system clock, in our case FPGA board results the distance of separation from obstacle. The mentioned ultrasonic sensor possesses a beam angle of 30 degrees and a range of 2cm to 350 cm. Such fused ultrasonic sensor array measures distance from an encountered obstacle at each iteration.

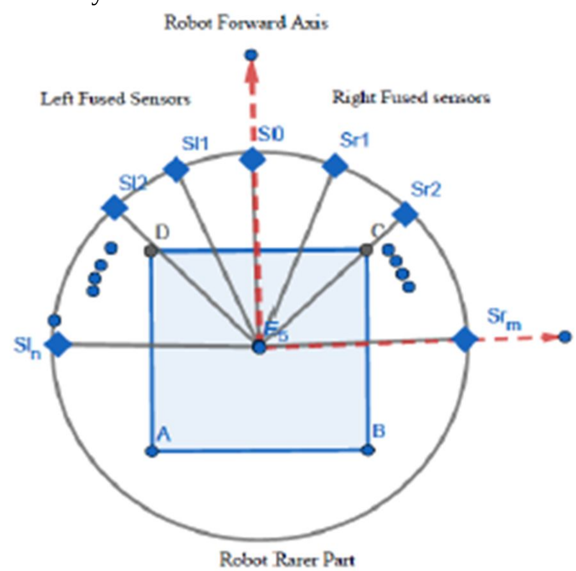

Fig 1. Sensor placement

With respect to the angle of object from the individual sensor elements in the array and distance of separation, the mobile robot executes obstacle avoidance procedure. This array of sensors positioned such that it covers maximum area in the front part of the mobile robot. These sensors keep track of the obstacle distance and their position. Hence, based on the distance from the obstacle and the orientation of the robot, the motor action decided. The environment considered in this scenario is a static environment i.e. a fixed and defined obstacle. In General, real world objects characterized by edges and vertices barring curvature type objects. Hence, polygons form an integral part in real-time objects. Further, the obstacle taken into account for the work is a regular hexagon in which all sides and angles are of equal measure. To generalize the type of obstacle avoidance, a magnetometer module, HMC5883L is interfaced with an Arduino UNO and communication between Arduino UNO and FPGA is established. Both FPGA and Arduino UNO are connected as pin-pin connection.

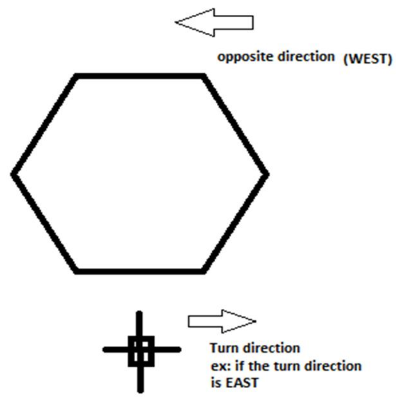

Fig 2. Obstacle avoidance model

The ultrasonic sensors used to keep track of the position of the polygonal obstacle give the distance at which the obstacle is positioned.

Fig 3. HMC5883L

The magnetometer HMC5883L is a 3-axis digital compass module that has a 12- bit ADC that gives out the X, Y and Z axis data. The data is accordingly converted as a heading angle. The heading angle starts from 0 degrees to 360 degrees. The data is divided into 8 directions i.e. EAST, WEST, NORTH, SOUTH, NORTH-EAST, NORTH-WEST, SOUTH-EAST and SOUTH-WEST. The idea is to maneuver around the polygonal obstacle till the direction changes to the one opposite to the first turn direction. When the direction is opposite of the original turn, one can say that the obstacle is avoided.

III. IMPLEMENTATION

The implementation is carried out in Verilog HDL and Arduino IDE environment. The control logic describes the required action at every instant of time. The functioning of the design is illustrated in the RTL shown below

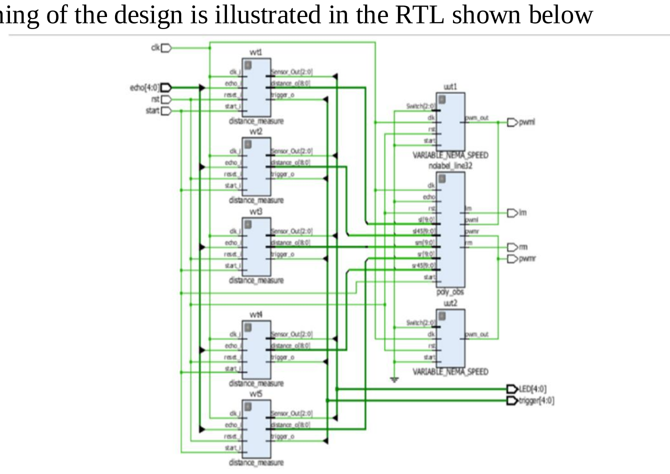

Fig 4. RTL Design

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The module distance_ measure for ultrasonic sensors to estimate the distance from the obstacle at every iteration of echo sensing set as core module for implementation. NEMA_SPEED that generates continuous controlled PWM signal for left and right stepper motors individually. The proposed method of obstacle tracing and avoidance incorporated with the above module. The required control signal for synchronizing and driving sensor and motor modules provided through this module. System clock (CLK) i.e.125 MHz, reset and start are common inputs for all the modules set by top module. To produce different PWM signals that effect the stepper speeds generated form the proposed logic through switch signal for both the stepper motor modules.

A. State Transition Diagram

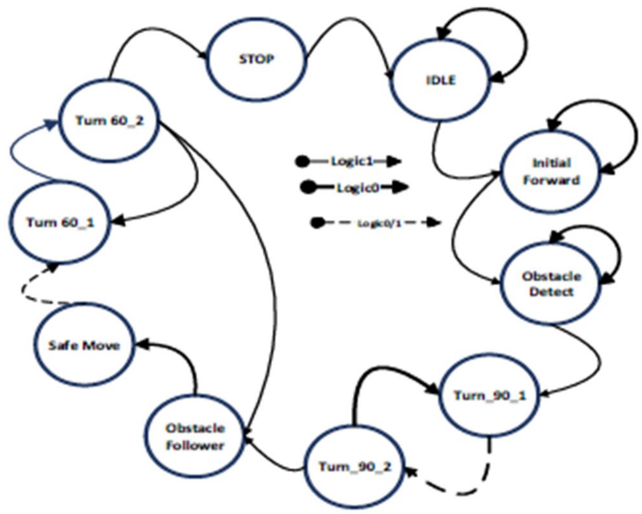

Fig 5. Finite State Machine

The execution starts from IDLE state where the machine is waiting for the start signal. Once the start signal is received, the machine checks the position of the polygonal obstacle. It moves forward till it reaches a defined threshold distance. This threshold remains the same throughout the avoidance. It reaches the OBS_DET state where the UV sensors give the data either to take a left or a right turn. The magnetometer records the first turn direction. It can be any one of the eight directions. The logic goes into FOLLOW state where the robot travels along the edge of the obstacle. When the edge is crossed, it makes a safe move so as to prevent collision any further. After the safe move is done, it goes into TURN_60 degrees state where the robot turns itself to 60 degrees so as to make the sensors detect the edge. The magnetometer records the direction of movement at every turn. Once the robot makes enough turns and maneuvering, it reaches a point where the magnetometer gives the exact direction opposite to that of the initial 90-degree turn. At this point, the robot decrements the distance initially followed to cross the first edge. Hence, the obstacle is avoided.

IV. RESULTS

The simulation results and hardware implementation are illustrated below.

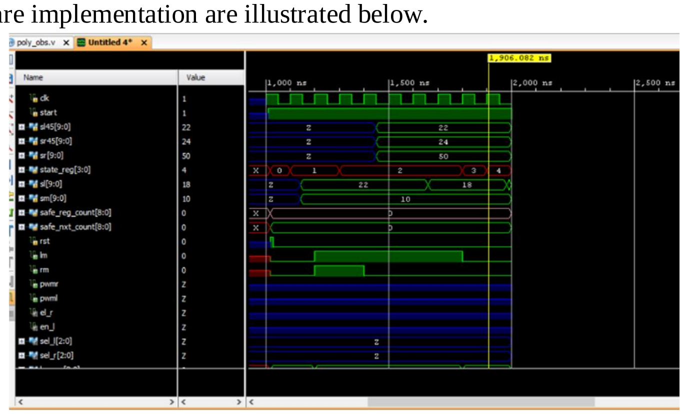

Fig 6. Simulation result

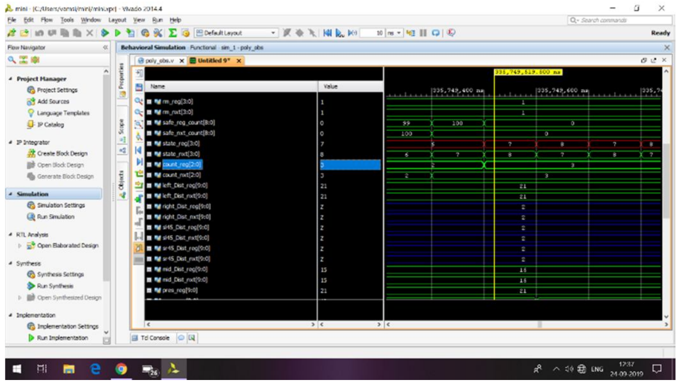

Fig 7. Simulation results

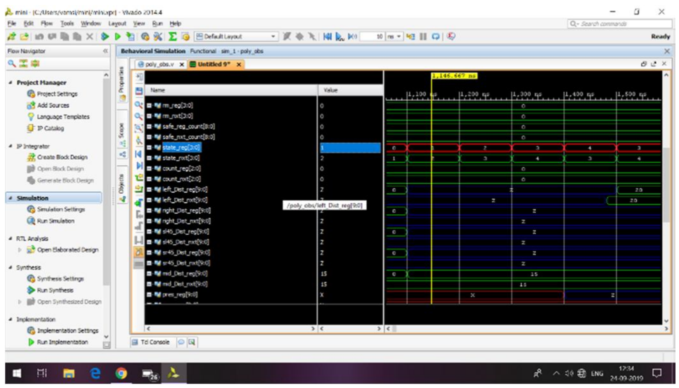

Fig 8. Simulation result

The above simulation results in Verilog HDL show the state transition from one state to another. When the obstacle crosses the three corners of the hexagon an if the direction shown by the magnetometer is opposite to that of the original turn, the obstacle is avoided. Here are the results of the magnetometer. The heading angle is shown and the corresponding direction is indicated.

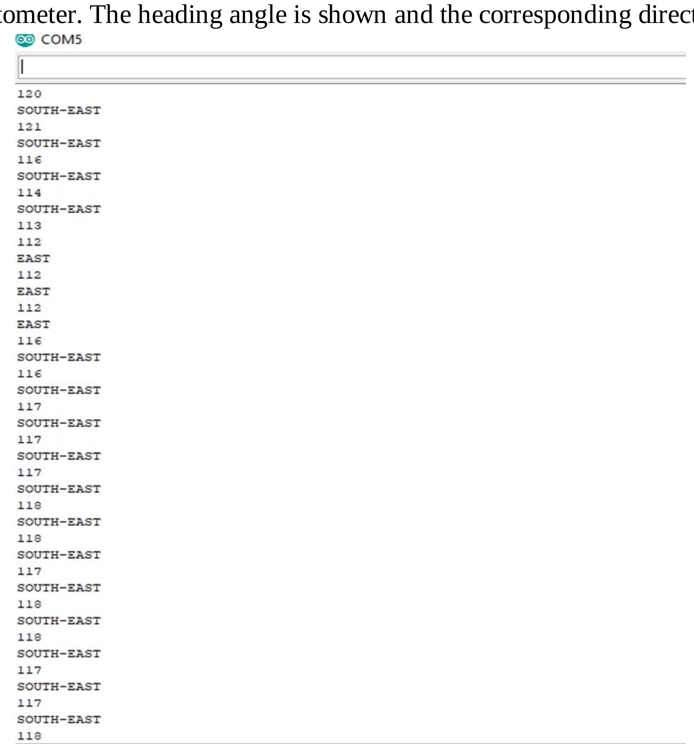

Fig 9. Magnetometer data on serial monitor

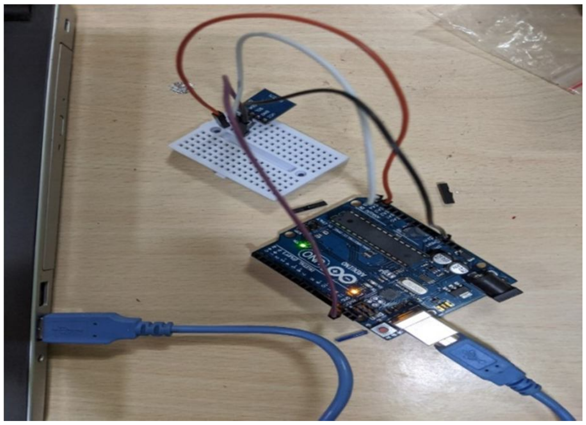

Fig 10. Magnetometer interface with Arduino

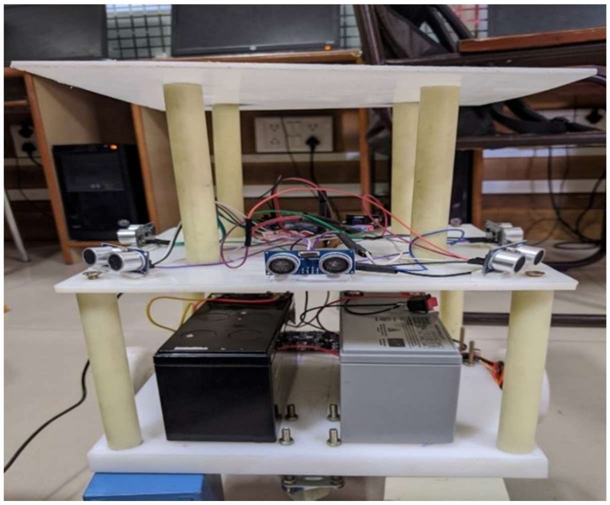

Fig 11. Robot equipped with sensors

As shown above in fig. 9, the data is seen in the serial monitor of Arduino. The Arduino is connected to FPGA through pin connection. It transmits data for every 1/16MHz of time. The FPGA takes this input for obstacle avoidance of the robot.

V. CONCLUSION

The work done through this project is obstacle specific. The magnetometer used in the project generalizes the obstacle type. In the sense that, for any regular polygon, be it octagon or hexagon, the direction opposite to that of the original direction indicates that the obstacle is avoided. This novel approach can be used as a low cost and decent way for avoidance of polygonal obstacles in indoor environment.

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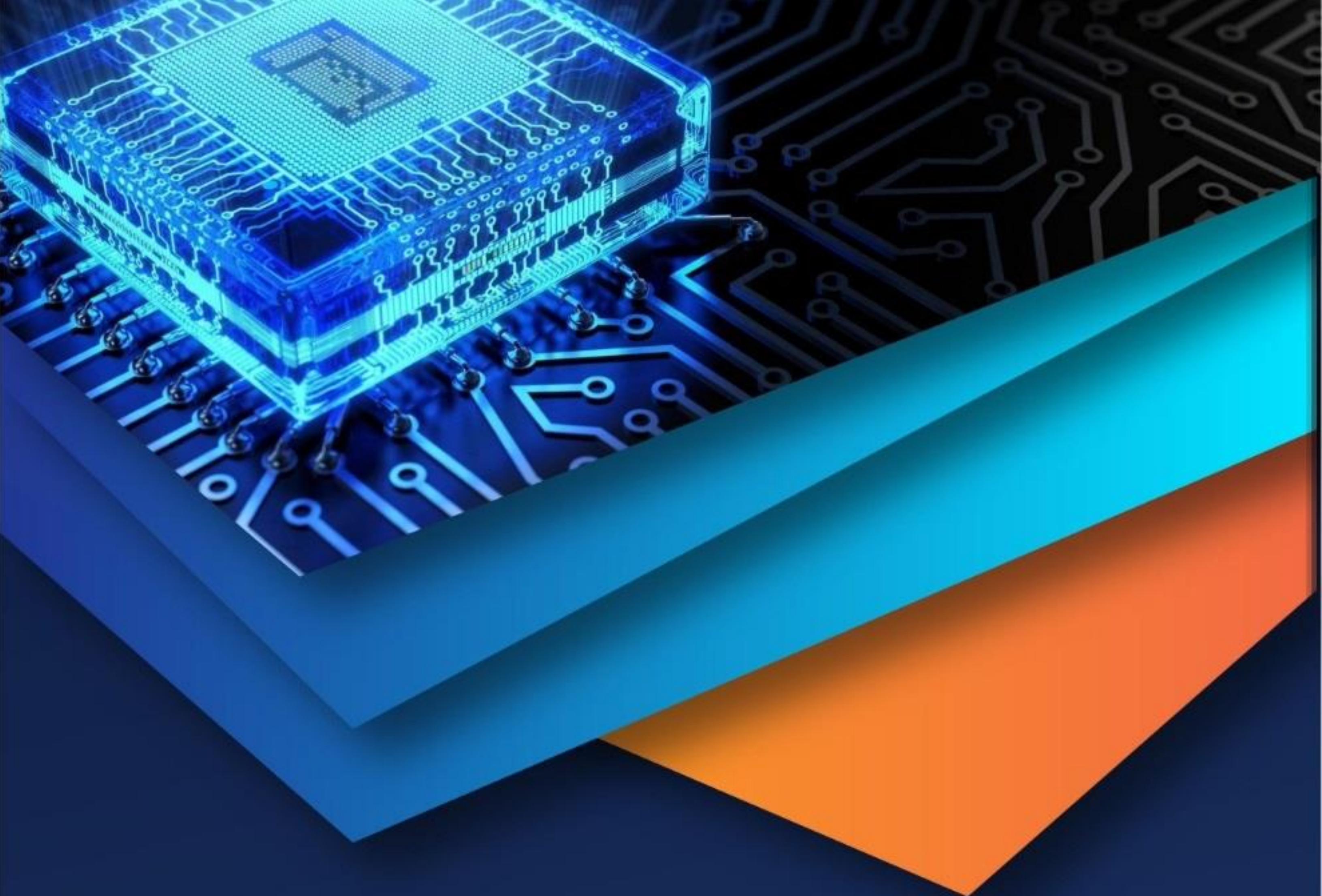

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