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Parking Management Systems and Their Technologies - A Review

S D Prashanth[1], Suneeth Sathyanathan[2], Vaishak N Makam[3], Nagarathna N[4]
[1,2,3,4]*Computer Science Department, BMS College of Engineering*

Abstract*— The number of personal vehicle usage is ever increasing; so is the number of people going to shop in malls. Finding a parking space in most shopping complexes, especially during the rush hours, is difficult for drivers. Thus, there is a need to provide sufficient parking space coupled with plenty of slots to help the user park his vehicle safely, also to ensure that the driver does not end up parking in a non-parking area. Managing huge parking lots is difficult for the parking authorities too, who must ensure that all the parking lots are being used efficiently and cause no problem to the visitors. The motive of a parking management system is to help both the parking authorities and its users. The purpose of this paper is that it reflects the working of different parking management system based on computer technologies. Then, we compare some of the existing parking management systems.

Keywords*— Parking management system; Sensor system; Computer system; Database system; Raspberry Pi;

I. INTRODUCTION

A parking lot management system is used for managing the parking spaces for vehicles in parking lots. An efficient parking management system is the one that allows easier management of parking spaces in parking lots. There are mainly two actors involved in the scene: the visitor, who is driving the vehicle and the parking official, who manages the parking lot. Thus, an efficient parking management system makes the job of both the vehicle parkers and the parking management officials easier. About three decades ago, the number of vehicles seen on road was meagre, and hence, parking spaces could be managed simply by using human resources. But since then, the number of vehicle owners has increased manifold. In such a situation, employing more human resources would lead to more complexity, and would render such a parking management system inefficient. Thus, using human resources only for the functioning of such a system is not an optimal solution to solve the parking problem. Due to increasing size of parking lots, vehicle owners find it difficult to find an empty parking spot for their vehicles. Over the same period of change in number of vehicle owners, there has been tremendous development in computer technologies. Many have chosen computers to solve most of their problems. Even in the case of parking management systems, there are many solutions that make use of computers.

II. GENERIC DESIGN OF A PARKING LOT MANAGEMENT

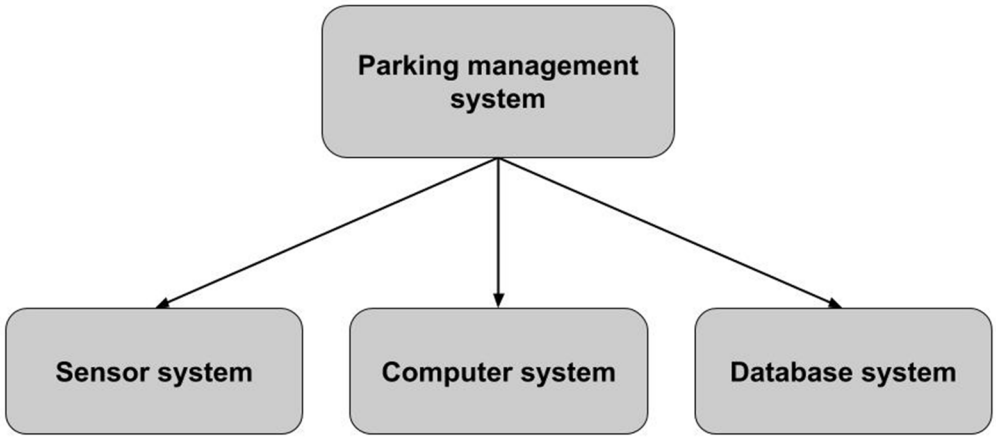


Fig. 1 A generic design of a parking lot management

The high level model of a parking management system includes three primary subsystems: the sensor system, the computer system

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and the database system. The sensor system consists of a network of sensing devices, which are capable of detecting features of vehicles moving though the parking lot. The computer system is an array of computers, that are provides the user with a variety of functionalities that the parking management system has to offer. The database system is a collection of databases, which are used to keep track of various parking activity information. We now describe the functionalities of each of these subsystems in more detail.

III. SENSOR SYSTEM

The sensor system is responsible for sensing the presence of vehicles in the parking lot. It is composed of hardware components such as light sensors, cameras, multiplexers, power sources, etc. It can also identify some features of vehicles present in the parking lot. By attaching object detection sensors at each parking space, it is possible to track the occupancy status space available in the lot. This makes the job of a parking official easier, as he/she can just read the status of each sensor to check the status of each parking lot. Cameras can also be used to check the status of each parking space by processing each and every frame of the image. The sensor system basically consists of a network of devices that can extract details of vehicles in the parking lot. The sensing devices must be chosen carefully. Also, the network of sensing devices should be as efficient as possible, in terms of speed, reliability and accuracy.

A. Choosing A Sensor

Sensors play an important role in managing parking lots. They are used to track the status of each parking space in the lot (whether they are occupied or not). This helps in reducing the human labour required to manage parking spaces. Lee, Yoon and Ghosh (2008) explained the use of sensors for the purpose of detecting vehicles in a parking lot. They compare the available options for sensing along with combinations of them. Ultrasonic, magnetometer, visible light and infrared are the sensor types used for comparison. Ultrasonic sensors are found to be the most reliable and easy for detecting objects. Magnetometers can be used to filter out humans and detect cars. But these sensors are highly location dependant, and use a very complicated detection algorithm. Visible light sensors detect radiation whose frequencies lie within the visible light frequency range. Thus, they are very sensitive, and maximum sensitivity is at daytime. Infrared sensors detect infrared light rays. They can also be used for detecting nearby objects. The combination of ultrasonic sensors with magnetometers is found to be the best choice for sensing the vehicles in a parking lot[8].

B. Sensor Networks

The physical placement of sensors in the parking lot is an important factor that affects the performance of the sensor system. Large parking lots usually have about 500 parking spaces. Of course, using sensors makes managing spaces easy. But, managing the sensors poses a challenge.

1) *Wired Sensors:* Wired sensors are the ones which are connected using cables. Here, each of the sensors is connected using the help of wires. The information flows through the wires to their destination. Using them for small topologies is efficient. But using this, one would end up with a messy network of wires.
2) *Wireless Sensors:* Wireless sensors are definitely worth considering in a place like the parking lot. Akyildiz, Su, Sankarasubramaniam and Cayirci (2001) conducted a study on wireless sensor networks. For a sensor to work wirelessly, they must be placed some distance away from the phenomenon that activates them. Also, the position of these sensors should be carefully engineered for proper communications to take place. The sensors are broadcast in nature, that is, they broadcast their signals wirelessly. So, they need to be scanned continuously. Another factor to be taken into consideration is the failure of a sensor node. Sensors are prone to failures. There must be some way of detecting sensors that are not functioning, so that they can be replaced. Node density in an area also plays an important role in engineering a wireless topology. High node density results in high traffic flowing through the wireless network. This leads to slower operations. Wireless network construction requires careful engineering based on the results we desire[8].

Thus, it seems more efficient to use both wired and wireless components into the sensor system. A couple of wired sensors can be connected to a single wireless multiplexer. The signals transmitted by each of these wireless multiplexers can be then multiplexed by a central multiplexer, which can now output the status of each sensor node in the sensor network[9].

C. Performance Of The Sensor Network

To establish an efficient network topology in a parking lot, it must be equipped with the necessary technologies. Otherwise, the system will fail to deliver the necessary performance. Varshney and Vetter (2000) conducted a survey on the emerging mobile and wireless networks. They came up with four general remarks.

They are:

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First, the channel capacity typically available in wireless systems was much lower than what was available in wired networks due to the limited spectrum, power restrictions, and high noise levels.
Second, noise and interference have more impact on the systems design for wireless systems than on wired systems.
Third, before building a wireless system some sort of frequency allocation is required.
Fourth, security is a greater concern in wireless systems than in wired systems since information may be travelling in free space.
The above four remarks must be viewed as the desired qualities while designing an efficient sensor network topology for the parking lot[11].
Sensing the presence of cars at each parking space in the lot is not mandatory, as the parking official only needs the details of each vehicle in the parking lot at a given time. Thus, the sensor system can be placed at the entry and exit of the parking lot to detect the presence of vehicles that are entering or exiting the parking lot. It helps, if the sensor system can identify some features of the vehicle, such as reading the license number of a vehicle directly from the license plate of a vehicle, or detecting the colour of the vehicle as these features help in uniquely identifying the vehicle.

D. Distributed Sensor System

Pottie and Kaiser (2000) describe a low cost and efficient integrated system for sensing called the wireless integrated network sensors (WINS). WINS provide distributed network and Internet access to sensors, controls, and processors deeply embedded in equipment, facilities, and the environment. The WINS network represents a new monitoring and control capability for applications in such industries as transportation, manufacturing, health care, environmental oversight, and safety and security. WINS combine microsensor technology and low-power signal processing, computation, and low-cost wireless networking in a compact system. WINS acts as a self managing sensor system. It can be configured to have direct access to the sensor database. Thus, it helps reducing the burden on the central computer[10].

IV. COMPUTER SYSTEM

The computer system of a parking management system is responsible for managing all the computational operations taking place within the system. It comprises of a single computer or multiple computers, depending on the size information to be processed. The most important functionality of the computer system is to perform database manipulations. The databases are part of the database subsystem of the parking management system. The computer system is connected to both the sensor system and the database system. For the sensor side, the computer system is responsible for processing the signals coming in from the sensor system to obtain useful information, such as, mapping each signal to the status of each parking space, and grouping features of a particular vehicle. The information obtained after processing is then stored in the databases. The computer system must be entitled to be accessed by the parking officials only and should be accessible within the premises of the parking lot.

A. Services

The computer system can be used for various services that aid the parking official. Services such as adding a vehicle to the database at entry, and calculating the parking fare is managed by the computer system. The central computer is responsible for providing such services to the parking official. Through it, the parking official can monitor the occupancy status of the parking lot, and manage the parking and payment related operations, which require extensive database manipulations. The central computer can be integrated with video surveillance cameras, to provide a visual feedback of the activities happening within the parking lot. The computer can also be programmed to maintain a history of all the vehicles that have parked in the lot over some period of time. This history can be useful for security purposes. The job of parking officials can be made easier by having a software application that provides all the necessary services to the parking official in an easy and intuitive way. Most of the existing parking management systems are equipped with an application that helps in monitoring all the activities of the parking lot.
The computer system need not be beneficial to the parking official only. It can be used in a way that is beneficial to the visitors to the parking lot as well. By programming a mechanism that supports faster entry/exit of vehicles through the parking lot, or offering a service of online payments for settling the debts of parking, benefits the visitors.
Usually the computer system may be a single board computer such as Arduino, Raspberry Pi, etc. The Raspberry Pi is a small computer which has a wide variety of operations such as surfing the internet, send emails, to write letters using a word processor, high definition video playback, play 3D games and much more. The ARM processor is one which does all the hard work so that the Raspberry Pi runs.
The Raspberry Pi board consists of a processor, graphics chip, the RAM and various interfaces, and connectors for external

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devices[22]. The operation of the Pi is same as that of a standard PC, which requires a keyboard for input, a display unit for output and a power supply. It uses SD Flash memory card, configured in a same as a hard drive used in a standard PC[23]. It will 'load the Operating System into RAM'(boot)[28] from this card in the same way as a standard PC boots into Windows from its hard disk.

B. Components Of The Raspberry Pi

SD card having Linux Operating system
USB keyboard, USB mouse
A display unit having HDMI, DVI, Composite or SCART input
Power supply
Video cable suited with the display unit used

V. DATABASE SYSTEM

The database system consists primarily of databases. The database collection must necessarily include a sensor database that monitors the occupancy of the parking lot, and a parking database that stores the details of vehicles coming in to park at the parking lot. The parking database contains the details that uniquely identify a vehicle and can be used to track the duration of parking at the parking lot. This database should be accessible by the parking officials of the parking lot. The parking database contains sensitive information of the parked vehicles, which can be misused. Thus, it must not be accessible by any outsider. However, the parking officials have the right to disclose it, if required, based on security reasons. Such a database is stored in a server located either locally within the premises of the parking lot, or in any online server, which the parking official can access securely.

The sensor database has to be updated periodically, every minute or so. No outsider must be able to modify it, although the parking official can disclose certain parts of the database to the outsiders. If this information is not to be disclosed publicly, it is stored in a server local to the parking lot. Otherwise, it is stored in an online server, which can be accessed by anyone.

A. Database Exploitation

Databases that do not contain sensitive information, such as, the occupancy status of parking slots and an overview map of the parking lot, can be made publicly available in such a way that it aids either the parking officials or the vehicle owners. Applications can be designed to process such publicly available information. By using this application, and knowing the current occupancy state of a parking lot, the users can plan to park their car in the parking lot.

Many services can also be built upon the database system. User services such as advanced slot booking, to book a parking slot beforehand, and online payment services for parking operations can be made available through an application. Mathew, Atif, Sheng and Maamar (2014) describe a method for managing peak time traffic. This method makes use of online parking booking to solve the problem. It allows a user to book a parking space at a mall in advanced, just as he would do to book a movie ticket. The online booking system is web-based. So, booking can be done online. The main aim of this technique is to save time and reduce pollution. The performance evaluation of this reveals that a maximum of 40 % time is saved in finding parking spots, along with 40 % reduction in vehicular pollution[15].

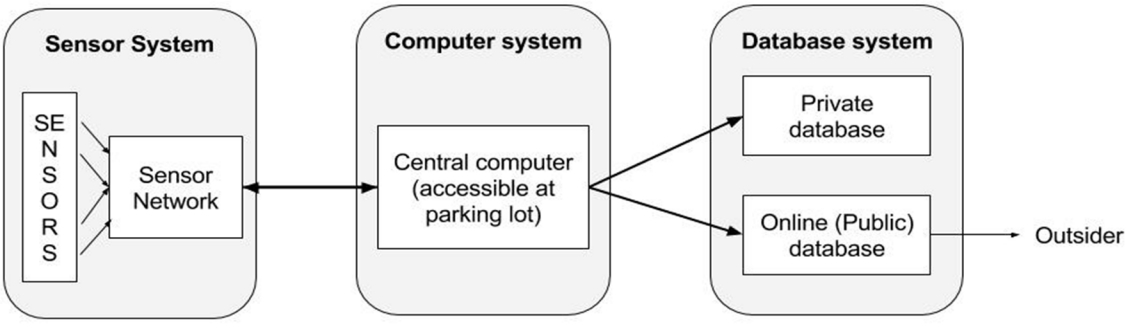


Fig. 2 A design of a parking lot management system

VI. EXISTING MODELS

We now compare the high level model with some of the existing parking management systems.

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A. Intelligent Parking Management System Based On Image Processing

Hilal Al-Kharusi and Ibrahim Al-Bahadly (2014) propose the use of image processing to check availability of slots in a parking lot[27].

1) *Sensor System:* It uses a video camera as the sensor system, which captures images of the parking lot along with their timestamps. The camera can be easily moved in between multiple parking spaces, checking a larger range of parking spaces. It captures the image and uses a transmitter to send the image to the computer system.
2) *Computer System:* The computer system could consist of a simple PC or a shared network of computers depending on the size of the parking lot. The computer receives image sent by the transmitter with a receiver and it converts the image into greyscale and checks for the changes in colour gradient in particular areas in the image. This would indicate if the particular slot in the lot is occupied. This information is sent to the database system.
3) *Database System:* Information about the occupancy of the slots in the parking lot and their location is all stored in a database. The database also stores the time of occupancy of a particular car, and this information is used for billing purposes.

B. A Reservation Based Smart Parking System

Hongwei Wang and Wenbo He (2011) describe a reservation based parking management system[25].

1) *Sensor System:* The system makes use of Zigbee sensors, where each pair is integrated with a wireless mote. The mote provides a 250 kbps 802.15.4 wireless radio, 8 channel A/D and an 8 MHz microcontroller for on board digital signal processing.
2) *Computer System:* The computer system consists of iRev, and its applications consist of a WiFi monitor to check the occupancy status of the parking slots, a reservation authority that verifies the reservation process and the user details, a price decider, that calculates the bill based on time spent on parking spot and mobile payment that allows user to pay their parking fee. This system is used to accept and verify the reservation requests based on availability of parking slots.
3) *Database System:* The database is directly in connection with the sensor network, obtaining occupancy information. The user details along with time of arrival are stored in the Parking repository. This data is synchronised with the computer system for reservation purposes and bill calculation.

C. Modular RFID Parking Management System Based On Existing Gate System Integration

MS Jian, KS Yang and CL Lee (2008) propose the use of Radio Frequency Identification technology to manage the parking lot[26].

1) *Sensor System:* Here the sensor system is the RFID system that consists of RFID antenna and the RFID reader. These have RFID tags that provide discrete ID for vehicles. To check if a vehicle is present in the slot, the RFID reader is used.
2) *Computer System:* It consists of the RFID API which uses socket to get details from the RFID reader. It uses a server which follows Java server socket protocol. This is used to decode the data packets from the reader into useful information and is stored in the database.
3) *Database System:* The database stores the information about the time of arrival of a vehicle at the parking lot, and other required user details. This is also used to check the occupancy status of every single parking slot. This data can be helpful to the parking lot administrators if they are to direct the users to the appropriate vacant spots in the parking lot.

D. Smart Parking Communication System Exploiting Visible Light Communication

Kim, Jing, Zhou and Kim (2014) present a solution for drivers to obtain the status of empty slots in a parking lot by the installation of a Visible Light Communication (VLC) module in their cars[13].

1) *Sensor System:* On entrance, a VLC module in the ceiling scans the module against the VLC module installed in the car, sending the required details of the car to the server. The VLC remains active all the time in the parking lot, thus, making it possible to track the location of the car within the parking lot.
2) *Computer System:* While searching for space to park, the VLC module continuously tracks the car's movements, and LED-powered direction guides, point the car in the direction of a parking space. The guidance system is managed by the central computer.
3) *Database System:* The database stores the arrival time of a car, and is unique VLC module ID. On arrival at the parking spot,

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the VLC module tracks the presence of the car in the parking spot and updates in the server about the occupancy of the parking lot.

E. Design Of Intelligent Parking Management Systems Using License Plate Recognition

With the developments in the field of object recognition in high speed environments, Tian, Guo, Qiao, Wei and Fei (2014) provide a method to capture the license plate of a car, by taking a video frame by frame and choosing the best result[14].

1) *Sensor System:* Includes a high speed camera attached at the entry and exit of a parking lot. The camera captures images and sends it to the computer system periodically.

2) *Computer System:* The computer system is responsible for detecting the licence plate in each of the frames it receives from the sensor system. It must also be capable of selecting the best frame of a car and extract the licence number from it.

3) *Database System:* The license number of the vehicle is used as a unique identifier for a vehicle. Once the number is read from the vehicle, it is updated in the parking database which stores the license number along with the time of entry of the vehicle.

In the above discussion, the different existing models of parking lot management systems, their technologies and their implementation techniques were seen.

VII. CONCLUSION

We have identified the necessity for an efficient parking management system to help the parking lot authority as well as the users. It was also noted that integration of computer technologies in a parking lot management system makes the parking process convenient. With the integration of computer technology, it was identified that any high level design required three subsystems, namely, the sensor system, the computer system and the database system. It was seen that the sensor system is used for detecting the presence of vehicles. The different types of sensing techniques and also different types of sensors that can be used, with their advantages and their disadvantages were discussed. Then, the need for the computer system performing computational operations, more importantly, database manipulations was seen. The example of a Raspberry Pi was taken as a computer system that could help as the interface between the sensor and database system. The database system is responsible for storing the database consisting of details of the vehicles present in the parking lot. It was observed that there can be a public and a private database. The public database would have details of the occupancy status, which should be made available for reference to the other users. The private database consists of vehicle owner details, which would be accessible only for the parking lot authorities.

We have also compared some models for parking lot managements systems which have computer technology integrated into them. The sensor, the computer, and the database system used in these models for comparison with respect to efficiency of the parking lot management systems were also identified.

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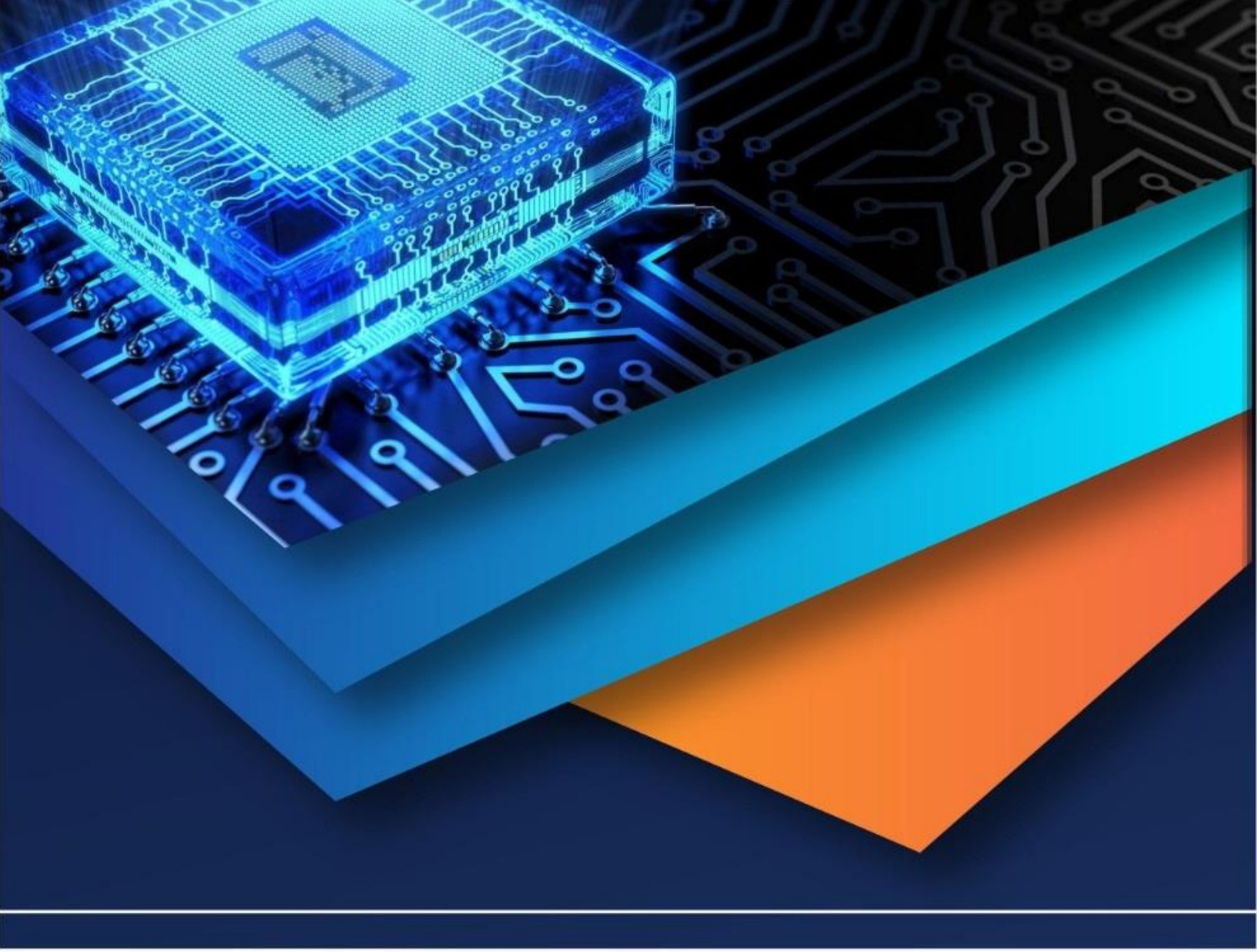
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