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Indoor Navigation System

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Abstract: This research article explores the importance of indoor use in modern environments and focuses on their role in facilitating navigation in indoor spaces such as malls, malls, airports, and hospitals. These systems, which integrate various technologies such as smartphones, offer simple and easy solutions to users. Additionally, this article examines the commercial application of indoor navigation systems in retail environments in terms of their ability to direct customers to specific products and promotions. Indoor Navigation System Integrating Scalable Vector Graphics (SVG) and the Quick Response (QR) specification brings a new approach to indoor navigation-related problems. This technology uses SVG to create elaborate and detailed interior design, while QR codes play an important role in determining the exact location. SVG is used to represent internal processes, including floor plans, room layouts, and other details, providing a flexible platform and solution agnostic. Visualization of the indoor environment allows users to fully understand the complexity of the indoor environment by interacting with indoor maps. QR codes can be used as special markers for important places in the indoor environment. Users can identify their current location by scanning QR codes at certain points using mobile devices with cameras. Verifying the accuracy of the field forms the basis of efficient and reliable indoor operation. The user interface is designed to be interactive and user-friendly, allowing users to interact with home maps. Interactive SVG content allows users to click on a specific location or icon to access more information about the location or begin the journey to the desired location. The system enables fast navigation by using a search algorithm to calculate the best path between different points in the interior. Integration with mobile devices with the most advanced applications on Android and iOS platforms is an important part of the system. This provides ample and easy access, allowing users to access indoor navigation functions from their smartphones or tablets.

In summary, indoor navigation systems using SVG and QR technology provide a new way to transform home use experiences, combining accuracy, coordination and ease of use. Thanks to the integration of SVG and QR technology, the complexity of interior design and location analysis is solved and users are offered practical and easy-to-use interior solutions.

Keywords: Indoor navigation systems; Scalable Vector Graphics (SVG); Quick Response (QR) codes; Interior design; User interface; Mobile integration; Commercial applications; Efficiency; Navigation experience; Technology integration

I. INTRODUCTION

Indoor navigation has become crucial in many places like shopping centres, airports, hospitals, and museums. While outdoor navigation using GPS is widely available, indoor settings present unique challenges due to limited satellite signals and obstacles like walls and floors. Traditional indoor navigation methods often rely on static maps, signs, or digital interfaces, which can be tricky to understand, especially for those with visual impairments or who are unfamiliar with the area. As a result, there is an increasing need for more intuitive and accessible indoor navigation systems. Indoor navigation system uses Scalable Vector Graphics (SVG) and Quick Response (QR) code technologies to provide a dynamic and user-friendly experience. By combining SVG graphics with QR codes, users can access real-time navigation information directly on their smartphones or mobile devices. In this paper, we outline the design and implementation of our indoor navigation system, highlighting its key features and advantages over existing solutions. We also discuss potential applications and future enhancements to indoor navigation using SVG and QR technologies.

Mobile users are turning more towards smartphone apps for location services, which rely on GPS technology for precise location and navigation assistance. However, navigating within closed buildings poses a challenge due to the absence of GPS signals. While GPS-enabled navigation apps dominate the market, alternatives such as Bluetooth, Wi-Fi, and AGPS are being explored for indoor navigation. Nevertheless, achieving seamless navigation in all scenarios remains a challenge.

Bluetooth navigation accuracy relies on the number of transmitters used, but setting it up requires expensive and intricate receivers. Similarly, Wi-Fi navigation indoors demands costly access points. AGPS depends on network assistance servers for indoor navigation, but none of these systems offer an optimal solution for indoor navigation. QR Codes present a swift, straightforward, precise, and automated method for data collection. They facilitate efficient and accurate tracking of products at speeds impractical with manual data entry systems. Converting one-dimensional QR codes into two-dimensional ones enhances their benefits, including compact size, high capacity, density, and error detection capabilities.

Once scanned with a smartphone, the QR code reveals the location of the land parcel on Google Earth/Maps. This advancement greatly benefits various land-related activities. By assessing the accuracy of the land parcel's location on Google Earth/Maps using known reference points, it was found to be within a range of less than ±10 meters. Moreover, individuals can locate land parcels from any location by scanning the QR code on the cadastral plan (CP) and land title. These QR codes also serve the purpose of tracking and providing additional information about various products. QR codes are increasingly replacing traditional 1D codes due to their extensive storage capacity, reliability, and speed. Floor maps can be embedded within QR codes, facilitating indoor navigation. Within a building, a QR code containing the floor map allows users to accurately determine their current location using mobile sensors. However, a drawback of this QR code is its inability to directly store images.

II. LITERATURE SURVEY

Previous research emphasizes the difficulties associated with indoor navigation and the necessity of accurate mapping in intricate indoor environments. Studies highlight the significance of effective indoor navigation systems, particularly in locations such as airports, retail centers, and medical facilities. Research examines how important indoor navigation is for improving user experiences and productivity in big indoor spaces. There is a vast and diverse body of research on indoor positioning systems and indoor navigation. Researchers have studied this subject over the years in a number of ways. Thus, the purpose of this study is to investigate various approaches for figuring out indoor navigation. Every year, the amount of time individuals across all age groups spend on their phones rises dramatically, which causes them to use other media less frequently. The number of people who own smartphones and have access to high-speed internet, such as home broadband, 3G, 4G, and 5G, has increased significantly.

Several research centres have conducted surveys, and the results show that 92% of smartphone users are between the ages of 18 and 29, 74% are between the ages of 50 and 64, and even 42% are 65 or older. Mobile application adoption has been fuelled by this trend. According to analytics, people use their smartphones for five hours on average, and 90% of that time is spent using different apps. This report aims to determine the need for indoor navigation and the various gadgets and technologies that can make it possible. In order to gain insight into users' daily practices regarding positioning systems, a user survey was also conducted.[4]

The purpose of indoor positioning systems (IPS) is to locate individuals or items within an interior space. Since IPS technologies make a variety of location-based indoor tracking solutions possible, including those for smart buildings, asset tracking, behaviour recognition, and healthcare, there has been an increase in interest in these technologies in recent years. The number of smartphone users has significantly increased as smartphones become more and more popular. The global positioning system (GPS), which performs well in outdoor positioning, has been used in recent years to develop location-based services for smartphone users, including geographic information, street view, and satellite maps [1].

In recent years, GPS is the most widely used navigational technology. This technique requires a line of sight for the signal because it is dependent on the satellite positioning system. Although it performs effectively in open spaces, its poor performance in indoor environments is attributed to the satellites' signals not having a direct line of sight. Thus, a great deal of work has been done to solve this issue. The downside of this approach is that accuracy is severely constrained by approximation when utilizing the Assisted GPS (A-GPS) technique [2], which uses a data server with reference receiver to help the GPS signals. The system provides 2D information. It involves the expense of infrastructure cost for the provider and the user.

In paper [3], the author outlines a novel navigation method that helps the visually impaired and blind get where they're going indoors. Using active Radio-frequency identification (RFID) technology, the method is based on a prior locating technique [3].

A navigation service that helps both sighted and blind persons get to their desired location by taking the shortest route was developed as a result of this research. The user carried the mobile reader, and tags were disseminated at predetermined locations. Finding the fastest route to the location that a user has indicated is the system's job. The system displays waypoints along the path that, in this case, were represented by active tags, when calculating the shortest path. The consumers are then directed via QR-Code to each of these locations one at a time till they arrive at their final destinations. It was used as a simulation system in an interior setting to direct the user to certain workplaces with a high success rate for shortest path identification and good navigation outcomes. Using NFC technology, the authors of this research [5] have created an indoor map guiding application that helps users locate themselves inside buildings. The basic concept is to use NFC-enabled smartphones with an integrated indoor navigation app to guide users [5]. While the programme uses the user's destination point to orient them, the mobile device uses NFC tags to determine the user's present position and shares that information with the application for coordinates. So, by touching her mobile device to the tags placed throughout the building, a user can find out where she is right now inside. The developed application can determine the shortest route to a chosen location, but it is limited to phones with NFC reading capability and lacks other functionality [5].

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In recent years, positioning systems have gained prominence in both academic and industrial research, with numerous research and commercial products emerging in this domain. Particularly, indoor navigation systems have garnered significant attention due to the limitations of GPS in indoor environments. To address this challenge, various technologies have been explored, leading to the development of innovative designs for indoor navigation. Positioning systems play a crucial role in determining the location of devices and providing location-based services. Understanding the topology of positioning systems is essential for their development. Previous research has identified four main system topologies for wireless positioning systems: remote positioning, self-positioning, indirect remote positioning, and indirect self-positioning. Remote positioning systems involve a mobile signal transmitter and fixed measuring units, with the transmitter's location computed in a master station. Self-positioning systems, on the other hand, utilize mobile measuring units to compute their location based on signals from fixed transmitters. Indirect remote positioning involves transmitting measurement results from a self-positioning unit to a remote side via a wireless data link, while indirect self-positioning occurs when a remote positioning unit sends measurement results to a mobile unit. Indoor positioning techniques can be categorized into network-dependent and device-dependent systems. Network-dependent systems rely on networking technologies such as IR, sensors, ultrasound, WLANs, UWB, Bluetooth, and RFID technologies. In contrast, device-dependent systems, also known as network-independent systems, provide autonomous user positions, with examples including A-GPS as an indoor GPS system.
The utilization of quick response (QR) codes to calibrate mobile augmented reality applications has been a topic of research. Users can scan QR codes placed throughout various indoor locations using their mobile devices. This allows them to download the location data embedded within the QR code. This integration of location data enhances the services provided by the augmented reality application, as it automatically extracts the necessary location information.[8] The complexity of interior layouts and the shortcomings of conventional techniques are the main drivers of the need for indoor navigation solutions. Goals including accurate navigation, user-friendly interfaces, and the incorporation of cutting-edge technologies like SVG and QR codes are all covered in literature. QR codes strategically placed at points of interest help with accurate indoor navigation. The literature discusses the scanning of QR codes with mobile devices equipped with cameras. The literature covers design principles for creating seamless user interactions while ensuring effectiveness. User interfaces designed for simplicity and effectiveness improve overall navigational experiences. Studies investigate user interaction by tapping for information, which provides on-demand details about indoor environments. Interactive elements improve understanding of indoor spaces and enrich the navigation experience. The literature discusses real-time navigation guidance systems that use pathfinding algorithms to find optimal routes. The emphasis on real-time guidance improves the responsiveness of the user interface.

III.METHODOLOGY

A. System Overview

1) SVG-based Indoor Mapping Indoor mapping forms the backbone of the Indoor Navigation System, offering a scalable and visually appealing representation of intricate indoor layouts. Unlike traditional outdoor mapping methods, the system utilizes Scalable Vector Graphics (SVG) to create detailed and adaptable maps for navigating indoor environments. Traditional methods often struggle to capture the complexity of indoor structures, leading to imprecise representations. SVG, however, provides a dynamic solution by offering scalability and resolution independence. This allows for the creation of maps that remain visually clear and accurate, regardless of the level of detail or the size of the indoor space.
2) Flexibility and Resolution Independence One of the key advantages of SVG-based indoor mapping is its flexibility and resolution independence. Traditional image formats may lose clarity when zoomed in or out, but SVG maintains its sharpness regardless of the scale. This ensures that users can interact with the map at any level of detail without compromising quality. The flexibility of SVG extends to adaptability across different screen sizes and devices. Whether accessed on a smartphone, tablet, or computer, the SVG maps remain visually coherent. This adaptability enhances the user experience, allowing for seamless navigation across various platforms. In essence, the SVG-based indoor mapping within the system ensures a visually clear, detailed, and adaptable representation of indoor layouts, overcoming the limitations of traditional mapping methods and contributing to a more precise indoor navigation experience.
3) Interactive Elements and User-Friendly Interface the Indoor Navigation System emphasizes user interaction through interactive Scalable Vector Graphics (SVG) elements, ensuring a seamless and user-friendly interface. Unlike conventional methods, the system's approach fosters an intuitive navigation experience. Traditional navigation systems often lack user engagement, providing static maps with limited interaction. In contrast, the system incorporates interactive SVG elements within its user interface, allowing users to tap on specific areas or icons for actions such as accessing more information or initiating navigation. The user interface, designed for simplicity and effectiveness, ensures that users can interact effortlessly with the

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indoor map. By tapping into SVG's capabilities, the system introduces a dynamic layer to the navigation process, enhancing the overall user experience. This focus on interactivity and user-friendliness distinguishes the Indoor Navigation System, setting it apart from traditional methods. By harnessing the power of SVG and dynamic elements, the system creates an engaging and efficient indoor navigation experience, catering to the diverse needs of users across various devices.

4) Unique Marking of Key Locations In the system's approach, QR codes act as distinctive markers for key locations within the indoor environment. These codes are strategically placed at points of interest, such as room entrances, facilities, or important landmarks. Each QR code corresponds to a specific location, creating a reliable and standardized method for accurate identification. By incorporating QR codes for location marking, the system mitigates the limitations of traditional indoor navigation methods. This innovative approach provides users with a clear and efficient means of identifying their current location within complex indoor spaces.
5) Scanning QR Codes for Location Identification Users can effortlessly utilize their mobile devices to scan QR codes present at key locations. This scanning process is facilitated by the cameras integrated into smartphones or tablets. The system leverages this capability to enable users to accurately identify their current location by decoding the information embedded in the QR code. The scanning mechanism enhances the speed and precision of location identification, contributing to a more efficient indoor navigation experience. Users can simply point their devices at QR codes, initiating the system's ability to determine their position within the indoor environment.

B. Modules

The proposed system uses the combination of various key technologies to make the system work for everyday users. The system uses various modules to perform the job of indoor mapping properly. The system leverages the various advantages of web-based platforms like accessibility, scalability, availability etc with technologies like SVG which are known for their consistency and QR code for location tracking which is simple to use with negligible battery or processor consumption. The following modules are put together to form the whole framework of the given project

1) *Mapping*: The mapping module is one of the key components of the system. The mapping module performs the basic function of taking the map as an input from any user and mapping the point throughout the map. The map taken here should be of SVG form which allows infinite zooming and easier processing techniques. The mapping module is responsible for generation of paths throughout the indoor map. Points are used for mapping of the paths around the map. These points are called as navigation points. The points are assorted three types: 1) Path points 2) Room Points 3) Interchange points. The room points and interchange points are connected to the nearest path points and the path points are connected to the nearest path points. The interchange points are connected to the interchange points of other maps. The mapping system generates a preliminary map by connecting the nearest points according to the properties of those points. We use Euclidean distance formula to calculate the distance between the points. The user is expected to provide accurate data to this system in order for it to work on an intended manner. The user has the responsibility of making correction to the linkages on the preliminary map using an interactive panel. The points and their coordinates are stored in the form of adjacency list. The graph data structure allows us to set the relation between points allowing us to implement path finding algorithms like Dijkstra's algorithm.

$$distance\ (A_z, B_z) = \sqrt{(x_2 - x_1) +^2 (y_2 - y_1)^2}$$

Where: $A_z = (x_1, y_1)$, $B_z = (x_2, y_2)$ and z = Floor number

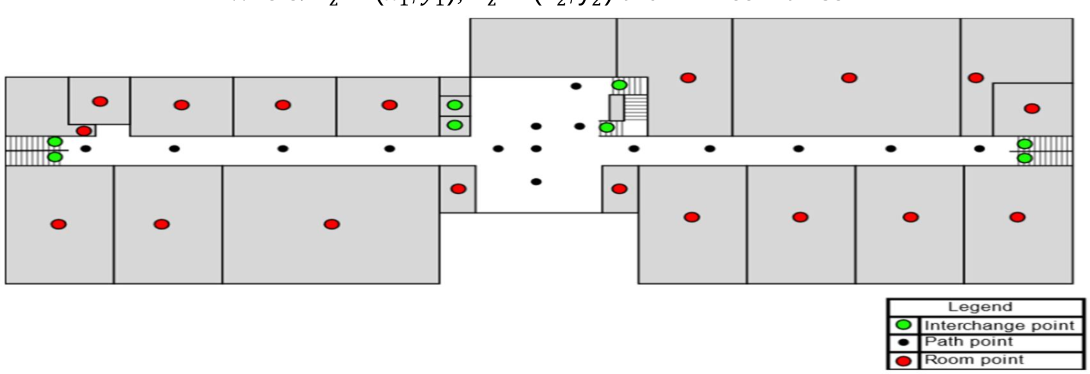

Figure. 3.1 Navigation Points plotted on SVG

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2) *Path Generation*: The path generation mainly occurs using the input stored by the mapping module. The path is stored in the form of an adjacency list. The path construction uses Dijkstra's algorithm to calculate the shortest path to the destination point. Dijkstra's algorithm is a greedy algorithm that finds the shortest path by using greedy methods. It finds the shortest path between a single source node and all other nodes in a weighted graph. It's optimal for finding the shortest path in graphs with non-negative edge weights. The algorithm treats the whole path as a set of points set on the map.
3) *QR Encoding Module*: QR stands for quick response codes. The QR code is a technology in which the text data is converted into 2D image. The QR is easily supported by many devices and can store variety of payload data. The QR encoder module focuses on generation of unique QR codes for every point inputted. The QR codes will contain a URL with GET request that will uniquely identify any point of the system. The encoded QR code is then printed on a paper. The encoded QR shall be displayed across the target campus.

Point URL(a) = URL for the server(X) + Serial Number(a)
Serial number(a) = Unique point identification number
QR image = encoder (Point URL(a))

4) *Decoding Module*: The decoding module is an important part of the QR code system. It's responsible for turning pictures of QR codes into useful information. The user is expected to scan one of these QR codes using the decoding module. As soon as the decoding module is run, the camera is turned on to get a continuous stream of images as input. Each frame of the QR code is scanned by the decoder module to search for the QR code. As soon as the decoder encounters a frame with a valid QR code, the camera feed is cut, and the decoder scans the frame with the QR code for extraction of information from the QR code. The decoder module transforms the QR code's information into text. The text extracted contains a URL with the payload for a GET request. The Decoding module then sends a GET request to the server, and the server reverts the response to the display module. This location helps the server determine the current position of the user and generate a new path from the current point to the destination point. By doing this, the decoding module helps users easily update and track their locations.
5) *Output module*: The display module is responsible for displaying the maps to the user. The display module is responsible for converting all the information being received from the server to the user. The output module is responsible for rendering an SVG map of the indoor space and display rendering of the path by invocation of path generation module using the adjacency matrix returned from the server. The output module also allows the usage of zoom function which basically uses a transformation matrix to zoom into the image.
6) *Server*: The server is the backbone of the system responsible for storage and process requests from the user. The server communicates with the client-side application. The server stores the maps in SVG format and the paths in the adjacency list format. It stores multiple SVG maps each depicting a floor of the internal space.

IV. ANALYSIS

A. *Analysis*

The proposed indoor navigation system was successfully implemented in our college campus, leading to a substantial improvement in navigation times. To determine the efficiency of the system, we considered the following parameters:

1) *Redirections*: The number of redirections represents the time users spend scanning the QR code to update their location on the campus. Our analysis as depicted in figure 4.1 indicates that both older and younger individuals require more redirections than the average user. The frequency of redirections directly correlates with the user's proficiency in understanding the indoor navigation system.

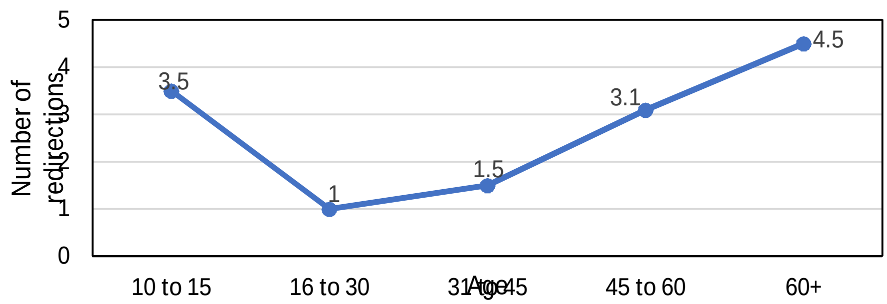

Figure 4.1: Chart comparing number of redirections and age

2) *Time Taken*: The primary goal of the system is to reduce the time consumed. Figure 4.2 shows the time taken by the users to navigate using waypoints versus usage of indoor navigation system. The following data shows the indoor navigation to be better than the waypoints system.

User type	Average time taken using Indoor navigation system	Average time using waypoints
New user	3 minutes 53 seconds	5 minutes 22 seconds
Old user	3 minutes 12 seconds	3 minutes 38 seconds

Figure 4.2: Average time taken from source to destination

3) *Traffic*: Website traffic, representing the number of daily visitors, was monitored after deploying the system. The data collected for the first 15 days of deployment showed an increase in website visits, indicating a positive response to the system. Figure 4.3 shows the traffic of in the first 15 days of its deployment.

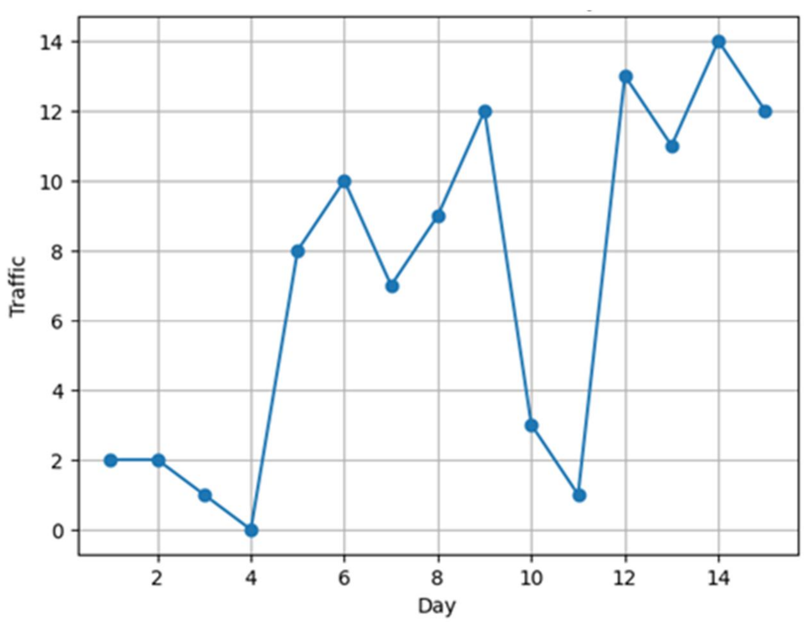

Figure 4.3 Traffic in the span of 15 days

B. Interpretation of Results

1) *User Preferences*: Users prefer an indoor navigation system that is easy to use and intuitive. They value simplicity in design and clear signage in indoor spaces, as evidenced by the increase in website traffic during the initial 15 days.
2) *Navigation Accuracy*: Our analysis suggests a strong link between navigation accuracy and user satisfaction. When users can rely on accurate guidance, their experience is much more positive.
3) *Challenges and Frustrations*: Users over the age of 60 often find these systems challenging to use, leading to a higher rate of redirections compared to other age groups. Factors such as literacy play a role in the design of these systems.
4) *Inclusivity*: Accessibility is crucial for indoor navigation systems. Our findings highlight the importance of making navigation accessible to users with low-end devices or poor internet connectivity. The more the inclusive the system is, the more traffic it is going to generate.
5) *Optimization Opportunities*: Analyzing navigation patterns and spatial relationships has revealed opportunities to optimize navigation routes and enhance the overall user experience. Understanding how users move through indoor spaces can inform more efficient system designs.

V. CONCLUSIONS

In conclusion, the development and implementation of an indoor navigation system are crucial for enhancing user experiences and improving efficiency in complex indoor environments. This report has covered various aspects of indoor navigation, including the system's introduction, motivation, survey of existing systems, summarized findings and research gaps, problem statement and objectives, analysis framework and algorithm, scope of work, and database and dataset details. The indoor navigation system aims to address the challenges of navigating indoor spaces, providing users with precise location information and optimal routes to their destinations. The system's successful development hinges on understanding user needs, deploying suitable sensors and technologies, implementing robust algorithms, and maintaining up-to-date databases. It is important to highlight that while significant progress has been made in the field of indoor navigation, challenges remain, particularly in terms of privacy, security, and adapting to dynamic indoor environments. Additionally, continuous research and development are necessary to improve positioning accuracy, user interfaces, and route optimization. The integration of machine learning and artificial intelligence into indoor navigation systems offers promising opportunities for real-time adaptability and enhanced user experiences. As technology evolves, it is imperative to keep pace with innovations to provide users with efficient and reliable indoor navigation solutions. In conclusion, indoor navigation systems are poised to become an integral part of modern indoor spaces, offering convenience, accessibility, and safety for a wide range of users, from shoppers in large malls to travellers in airports and people with accessibility needs.

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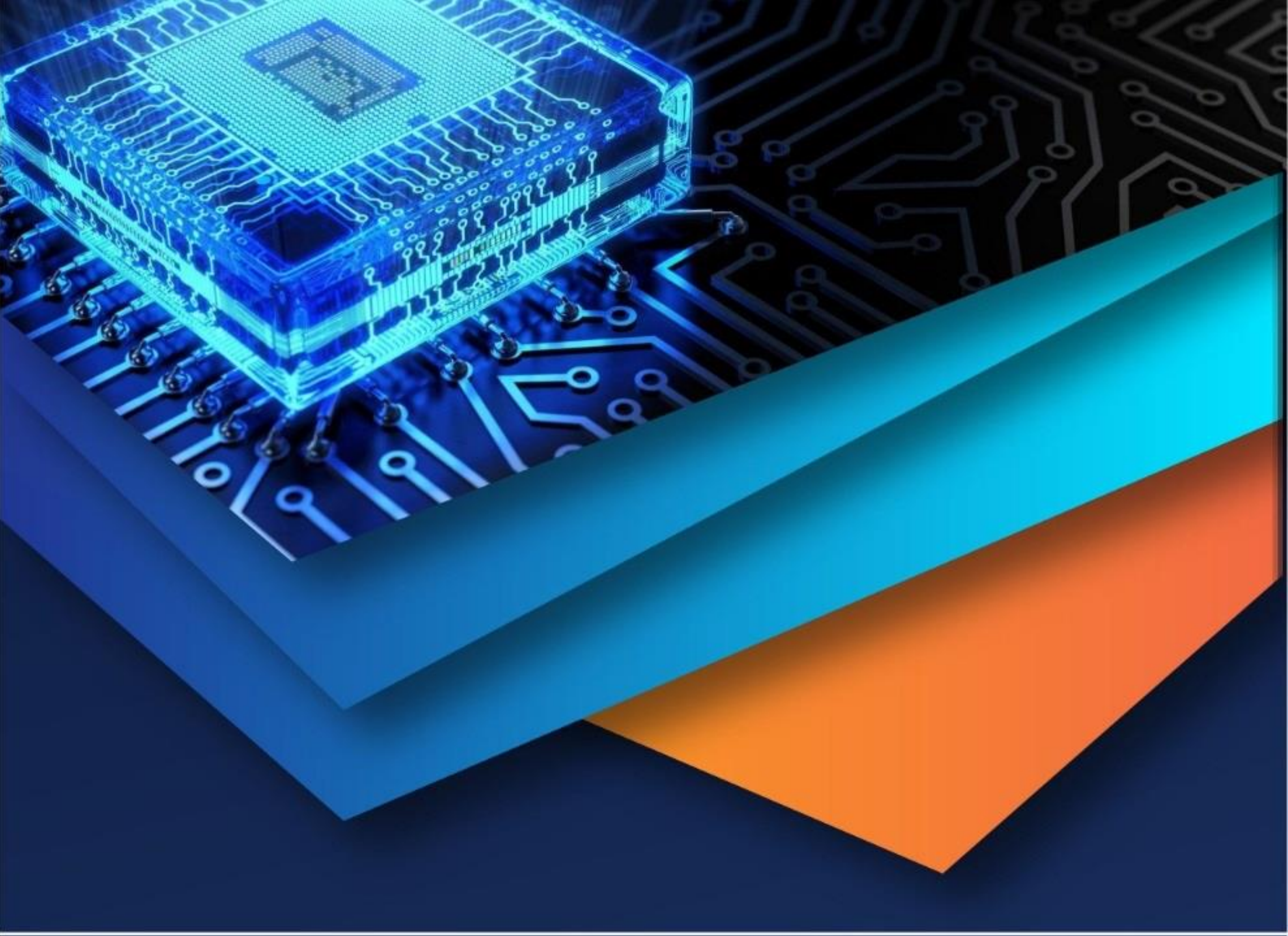

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