Indoor Navigation Using Augmented Reality

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ABSTRACT
Navigation System are very much essential for en-route assistance, indoor positioning etc. For outdoor environment navigation is still better as compared to complex indoor environment. In this research work, we have focused on building an indoor navigation application which uses augmented reality to assist people in navigating at complex buildings and also making a cloud platform (Content Management System) from where the administrator of a particular building can be able to modify and manage the navigation path. We have used Unity3d framework to develop the AR based mobile application. The application can be run on smart-phones. It has been seen that this augmented reality-based application provides better interface and experience than the traditional 2D maps or the paper maps that are displayed outside buildings to help in the navigation. To evaluate the concept proposed in the research, technical evaluations were performed at a hospital building.

CCS Concepts
• Human-centered computing → Mixed / augmented reality

Keywords
Indoor navigation, SLAM, ARKit, AR world mapping, AR Core, Augmented Reality (AR), Visual Odometry, Point Cloud Mapping

1. INTRODUCTION
Navigation is area that has shown an immense importance for the humans. Modern navigation system makes use of global positioning system to determine routes to different places and users location in outdoor environment but this has a disadvantage when used for navigation at indoor places due to lack of signal strength of global positioning system. Apart from this reason, there are a lot of challenges that exist while navigating at indoors like hindrance due to a lot of physical objects, improper lighting conditions and a lot of signal scattering that are make it difficult to find a solution that is viable for indoor navigation [1]. People find it difficult to navigate in indoor places due to homogenous architecture at different parts of the building and also due to lack of landmarks. Display devices like smart phones that have become ubiquitous can be used to provide guiding information for indoor navigation and can be of prime importance for various industries such as transport, healthcare, manufacturing and fire safety maintenance and also for the personal use to reach at various destinations inside large and complex buildings.

User experience is crucial in indoor navigation systems and therefore, Augmented reality (AR) is the budding technology that can be used to provide an appealing and a convenient experience for the users. Considering large indoor places like malls, shopping marts, airports, museums etc., people must figure out the direction shown on the display to the real-world view. With AR, the directions can be superimposed on the real-world path thus reducing the mental stress for the users and making it easier for them to perceive the path and the 2D maps are not comprehensive for users. There is a lot of potential in using AR as it would not only help in navigation by providing a good user experience but apart from that it can be used to capture a lot of other relevant information that can be displayed aside to the location information. In past, AR has been used for indoor navigation and it has been found that it increases the user experience and also provide accurate localization [2]. In AR, there are various options that can be used that are handheld devices and the head-mounted displays. Head-mounted displays have a rapidly growing market [3] but they are in their early stage of development and are not very economical for daily usage. Also, apart from being expensive they come with a huge setup which will be very bulky If a user wears and travels in an indoor place. The focus of this research work is on a mobile application using Augmented reality interface which will assist in indoor navigation. The mobile devices are easily available with everyone and also users have become acquainted with the using mobile applications, so it becomes easy for them to use any application

2. LITERATURE SURVEY
This section will give an overview of the existing technologies used for indoor navigation such as cameras, infrared, Wi-Fi/WLAN, Radio Frequency Identification, ZigBee, Bluetooth, NFC, Radar and other augmented reality-based approaches. Table 1 shows the comparison of different systems that can be used for solving the problem of indoor navigation based on different characteristics such as accuracy, coverage, cost, power consumption and localization principle. The optical indoor positioning system is one of the most accurate systems as the data transmission and computational capabilities have exponentially increased, here camera is used as the main sensor. The camera feed image processing algorithms and the other distance and mechanical sensor can be used for more accurate results. Referencing from the 3D model, it takes the 3D point cloud output of the camera sensor and compares the referencing 3D model for localization. Referencing from images, this approach stores the sequential image along a certain route and compares the camera image for localization. References from deployed coded targets, Optical positioning system is dependent on the natural features present in an image for localization. In this case, dedicated code or physical markers are used to increase the localization. Cameras achieves accuracy levels

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between tens of micrometer and decimeter. The infrared indoor positioning system architecture is based on IR signals; infrared has

Table 1. Comparison of common position systems used for localization. [4]

System	Accuracy	Principles used for localization	Coverage	Power consumption	Cost	Remarks
GPS	6 m – 10 m	ToA	Good Outdoor Poor Indoor	Very High	High	Satellite based Positioning. Processing time and computation is slow.
Infrared	1 m-2 m	Proximity, ToA	Good Indoor	Low	Medium	Short range detection. No invasion of multipath.
Wi-Fi	1m -5m	Proximity, ToA, TDoA, RSSI Fingerprinting, And RSSI theoretical propagation model	Building level (outdoor/ indoor)	High	Low	Infrastructure available Everywhere Initial deployment is expensive. Multipath susceptible slightly.
Bluetooth	2 m -5 m	RSSI fingerprinting and RSSI theoretical propagation model	Indoor	Low	High	Data transfer speed is high. Limitation in mobility.
ZigBee	3m – 5 m	RSSI fingerprinting and RSSI theoretical propagation model	Indoor	Low	Low	Low data transmission rate. Nodes are mostly asleep
NFC	4cm	Near field communication	Indoor	Low	Low	works for short range. Highly secured.

a wavelength longer than visible light and radiation is less than terahertz. There are three methods for deploying infrared-based positioning system. Active beacons, this approach is based on infrared receivers fixed at the known positions throughout the premises and mobile beacons with the unknown position. Active beacons use Angle of arrival technique for distance measurement. Imaging of natural infrared radiation, this approach attains indoor positioning using natural infrared radiation and are also called passive localization system. It uses the sensors operating with the long-wavelength spectrum to obtain a completely passive image of the surrounding environment from natural thermal emission. The Angle of Arrival (AOA) is used as a measurement technique which measures the angle of incidence to the heat source. Imaging of artificial infrared light, optical IR indoor positioning system consists of an array of active IR light source and IR sensitive camera. The active IR light source continuously projects infrared light and infrared camera capture 3D scene information. The accuracy for Infrared approach varies from 1 cm to 6m but this architecture is not scalable. [5]

Wi-Fi is a family of radio technologies used for WLAN devices (Wireless local area network is an IEEE 802.11 standard). Wi-Fi is the most commonly used technology to estimate the position of the mobile device within the network. The Radio signal strength indicator (RSSI) value can be used with WLAN hardware using four strategies that are propagation modeling, cell of origin, fingerprinting, multiple-alteration. Fingerprinting based on Radio signal strength indicator (RSSI) value is used for WLAN positioning. Usually, Wi-Fi access points are fixed in the indoor space on a medium distance of 25-50 meters. The device position is estimated by vectorization and tracking it relative to the location of WLAN access points [6].

Bluetooth is a wireless technology which is used for data ex-change using short-wavelength UHF radio waves over a short distance. Bluetooth approach for indoor positioning system[7] is based on the Radio signal strength indicator (RSSI) along with the triangulation method for calculating the position based on the output of the RSSI. It is a three-stage process first stage is the preparatory phase where in the indoor area is covered on the defined x-y plane. In the second stage using the RSSI function for fitting the environment conditions is measured. In the final stage, the triangulation method is to determine the position concerning the fixed Bluetooth sensors. Bluetooth is highly secured, energy-efficient and cost-effective technology. It also comes with certain drawbacks such as it works over short distance only, therefore larger number of Bluetooth sensors are required for covering larger premises.

Near Field Communication (NFC), it is the set of communication protocol which enables two devices to communicate which are held a few centimeters from each other. The implementation of Indoor positioning system with NFC[8] is done with the touch-based interaction using the NFC Tags and NFC sensor, where the NFC Tags are placed at a fixed position in the indoor area. The handheld devices with the NFC can tap at the NFC Tags to orient them towards the destination. NFC based system provides secure and private navigation as the NFC data is stored on the handheld device.

Augmented reality-based indoor navigation system[9] with external sensors, in this approach external sensors such as a magnetometer, are used for creating a geomagnetic north-oriented coordinate system. In this system, the position of the user is determined with heading and heading-relative bearing. The augmented reality is used to display the path based on relative direction output by the magnetometer.

Augmented reality-based indoor navigation system using physical markers [10], this approach is based on image comparison, in this case, the image can be any picture, QR code, bar code etc. The physical marker is placed all over the indoor area as POI (Point of interest), the complete area is considered as coordinate axis. When the AR camera recognizes the maker, it localizes itself with the co-ordinate of the marker and shows the path from that source to destination given.

Augmented reality-based indoor navigation system using SLAM or visual-inertial odometry [11], this approach is based on feature point and point cloud which is generated by SLAM or visual-inertial odometry. The localization process works when the existing point cloud data matches with the real time point cloud point and feature point from camera feed with a certain threshold. The SLAM (simultaneous localization and mapping) is the technology used in robotics for generating virtual point cloud map based on the sensors and camera feed, whereas the visual-inertial odometry uses the device' s motion-sensing data and computer vision analysis of the camera feed.

3. SYSTEM ARCHITECTURE

The proposed system architecture is mainly divided into two parts i.e. a Content management system (CMS) and a mobile application as shown in Figure 1. The content management system consists of a web application and an administrator mobile application.

The web application part of the Content Management System (CMS) allows to setup and manage the map of the indoor premises. The CMS take the 2D floor plan of the area as input and converts it into a 3D model. The conversion takes place using the height map technique, in which the 3D model is created based on the pixel intensity information. The pixels consist of the elevation data and pixel intensity based on these data the pixels are stacked to form a 3D mesh. Once the model is generated then we add all the point of interests (POIs refers to the various places in the map like toilets, offices, reception etc.) on top of it by the help of functionality available in the content management system. The CMS provide us with the functionality similar to a 3D editor where we can add sources, destinations and path for navigation. As the user perform operations in the CMS such as path creation, deletion or Updation, the changes are recorded and reflected to the back-end. Once the user finishes all the operation and saves the operation, a JSON file is created.

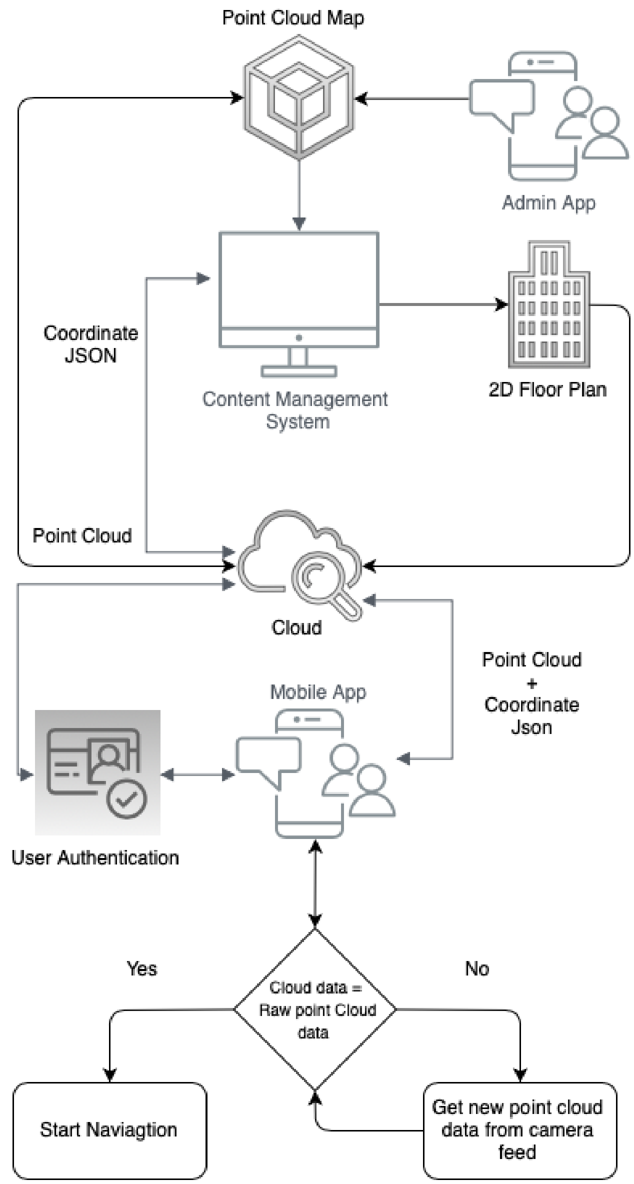

Figure 1. System Architecture

The most important feature of the content management system is the dynamic updation of floor plans and its reflection in the mobile application. The JSON data generated by content management system is stored on a real time database because it provides the capability of reading and writing in the database simultaneously. With the help of this feature provided by the real time database, any changes that are being made in the content management system are synchronized with mobile application in real time.

The administrator mobile application is a part of the content management system which is used for the initial mapping of the indoor premises in order to create the point cloud map or the feature map of the premises. The administrator application starts after the authentication of the administrator. Once the administrator is authenticated, the application provides the administrator with the various set of functionalities like to create a new point cloud, to update the existing point cloud and to delete the existing point cloud data of the premises. The point cloud is the arrangement of points in 3D mapping system which is same as the Cartesian coordinate where a point is represented by x, y and z coordinates with respect to origin. In the application, point cloud represents the feature present in the camera feed with reference to the position of the camera in indoor space. In order to track the position of device in the 3D mapping system the device's orientation, position and movement are taken from the device sensor data. The result of point cloud data consists of the point clouds in 3D mapping space along with the device's position data. Once the point cloud data is generated by the administrator mobile application, the point cloud map data is sent to the real time database in the server.

The user mobile application is the part of the system which assists the user in navigation. Firstly, it does the user authentication and once the user is authenticated, the application provides the user with the choices of the different premises that are available in the application. As the user selects the premises the point cloud map data and JSON file for the particular premises gets fetched from the real time database to the application. After that the user gets the list of all the places where it can navigate in the particular premises. Once the user selects a destination for navigation, the application tries to localize itself with the surrounding, if the localization is not successful the application continuous to localize with new point cloud from real time camera feed frame by frame. The process of localization involves recognizing the position of client's device in the indoor space by taking Euclidean distance of the existing point cloud features as compared with the raw generated point cloud from the client's camera feed. If the Euclidean distance is under a given threshold the position of the device is updated with respect to the 3D mapping system. After the localization is done the distance between the source and destination is calculated by using the A-Star algorithm. As soon as, the distance is calculated the path is rendered on the user interface using the augmented reality.

$$D(n) = A(n) + B(n)$$

$$n = Set\ of\ nodes$$

$$D(n) = total\ estimated\ cost\ of\ path\ through\ given\ node$$

$$A(n) = Cost\ so\ far\ to\ reach\ current\ node$$

$$B(n) = Estimated\ cost\ from\ current\ node\ to\ destination$$

$$Manhatan\ Distance\ Heuristic\ (D)$$
$$= |\ x\ start - x\ destination\ | + |\ y\ start - y\ destination\ |$$

$$Euclidean\ Distance\ Heuristic\ (D)$$
$$= \sqrt{(x\ start - x\ destination)^2 + (y\ start - y\ destination)^2}$$

The A-Star algorithm to determine the shortest path using the waypoints, A-start algorithm is a widely used algorithm for path-finding and graph traversal. A-star algorithm picks the path using the minimum value of the D for each step, the value of D is the resultant of two variable A and B. The value of A is the cost of movement from starting position to the current position following the given path steps. The value of B is the estimated movement cost to move from current position to the destination, it is often referred as heuristic. The actual distance is unknown until the path is determined.

4. IMPLEMENTATION AND RESULT

The Indoor Navigation system was tested at JJ Hospital in Mumbai, India. Testing the system involved evaluation of both the Content Management System (CMS), the administrator application and the Mobile application.

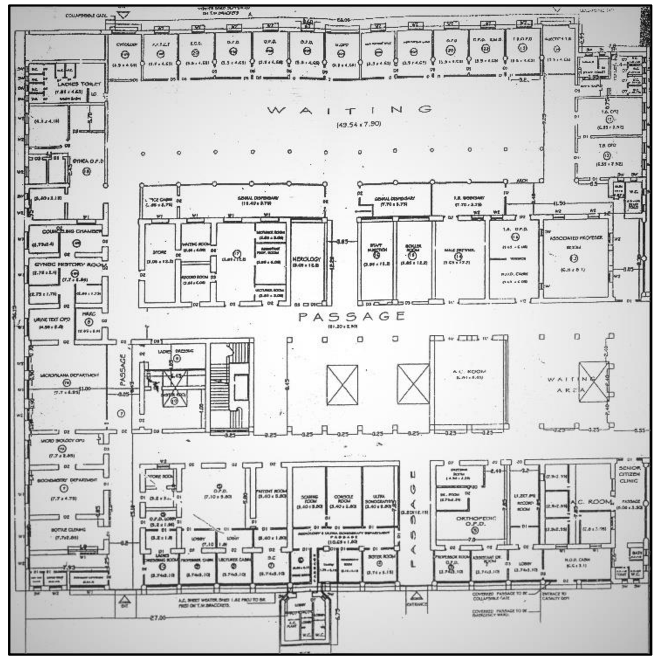

Figure 2. 2-D Map of JJ Hospital OPD

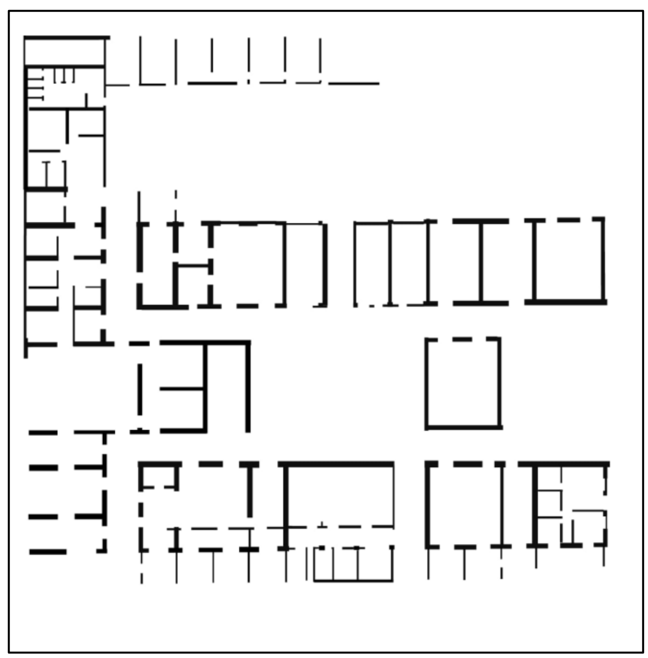

Figure 3. Generalized Floor Plan

Firstly, When the 2D map of the hospital premises was obtained it was very dense and cluttered in terms of the information. For the purpose of indoor navigation, a map with basic infrastructure details was needed. So, the 2D map was converted into a simplified version with the help of computer aided drawing software. As can be seen in figure 2 shows the plan before simplification and the figure 3 shows the simplified floor plan. After that the simplified 2D map of the hospital's OPD (Outpatient Department) was uploaded into the back-end system and it successfully converted the 2D map into the 3D model by using the height-map technique and the model was used as a reference to make the path in the hospital premises and mark the Point Of Interests in the maps (these are points on map like toilet, entrance, exit, reception etc.). Also, the point cloud map data which was collected by the help of administrator mobile application was synchronized with the 3D model of premises to increase the accuracy of navigation and make detection work robustly. Secondly, the mobile application was used for real time pedestrian navigation inside the premise and it was very accurate to recognize the surroundings and provided correct navigation path to the various destination selected by the user. The mobile devices used for testing the navigation application was iPad pro 2017 and iPhone X due to dependency of the application on apple's software development kit (SDK) and the configuration of the hardware devices is mentioned in Table 2. After the test was conducted on both the devices it was seen that iPhone X gave better performance as compared to iPad Pro 2017 due to the difference in the chipset of both the devices. The processor used inside iPhone X is more powerful and gave a better user experience as compared to iPad. Also, the camera of iPhone X is more powerful as compared to iPad and it helped in enhancing user experience.

Table 2. Information about the configuration of mobile devices

Specifications	iPad Pro 2017	iPhone X
Weight	496g	174g
Chipset	Apple A10x Fusion	Apple A11 Bionic
OS	iOS 10.3.2	iOS 11.1.1
Storage	64 GB	64 GB
RAM	4 GB	3 GB
Display	IPS LCD capacitive touchscreen, 1668 x 2224 pixels	Super Retina OLED capacitive touchscreen, 1125 x 2436 pixels
Power	Non-removable Li-Ion 8134 mAh battery	Non-removable Li-Ion 2716 mAh battery
Camera	12 MP, f/1.8, 1/3", PDAF, OIS	12 MP, f/1.8, 28mm (wide), 1/3", 1.22 µm, PDAF, OIS 12MP, f/2.4,52 mm (telephoto), 1/3.4", 1.0 µm, PDAF, OIS, 2x optical zoom

After the completion of testing inside the JJ Hospital's Outpatient department, the application was being tested at the hospital's outdoor campus which lead to the findings about how the performance of the application changes with respect to various attributes. Considering the first attribute i.e. the lighting conditions, as the lighting and climate condition varies throughout the day this leads to difficulties of recognizing the features or comparison of new features with existing point cloud features. The next attribute affecting the performance is the size of premises, as the size of the point cloud data is directly proportional to the area. As, point cloud data generation and its comparison with existing point cloud data is computationally expensive process this leads to exhaustive use of processor resulting in heating of the mobile device.

The architecture is completely dependent on the localization based on the comparison of existing point cloud feature and the raw point cloud feature captured in real time. So, it becomes very important to ensure that the premises consist of sufficient features for point cloud to ease the localization process.

The left image in figure 4 shows the starting screen of the mobile application after the authentication and it shows the premises that can be navigated using the application. After a premise is selected, the user gets the list of places that can be visited in the premises. Then the right image in figure 4 shows the navigating path to a destination.

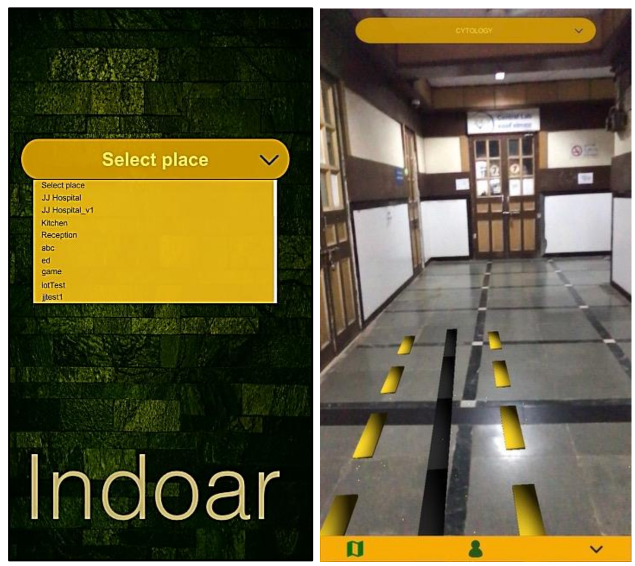

Figure 4. Mobile Navigation Application

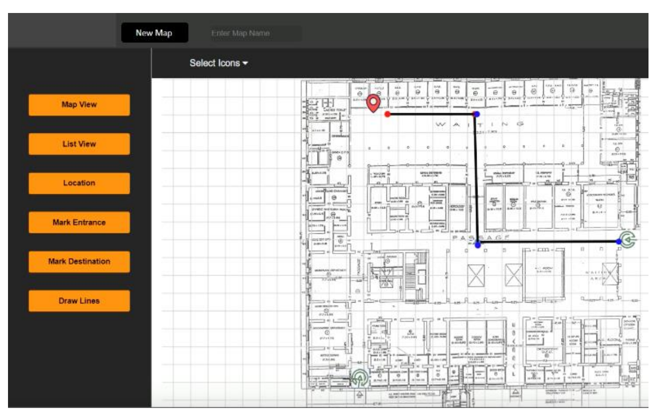

Figure 5. Content Management System

4.1 Frameworks and Tools

ARKit - It is a software development kit (SDK) by apple that is used to create immersive augmented reality-based application for iOS devices. The proposed architecture uses ARKit 2.0 which helps the application to display 3D virtual content such as path and also used for feature detection and point cloud map generation.

Unity - It is a game development engine by unity technologies, which allows the developers to develop cross platform application. It is used to build high quality 3D and 2D games. The proposed navigation mobile application and administrator application (for generating point cloud map data) is built using the unity and exported to XCode.

XCode - It is an integrated development environment (IDE) developed by apple which is used for the developing, managing and publishing of iOS and macOS application.

Three.js - It is a cross-browser JavaScript library used for creating and rendering 3D animated graphic for web pages. The content management system (CMS) is based on Three.js. It helps the Content management system to Create 3D model of the indoor premise from the 2D floor plan and explore the scene in 3D coordinate system. Figure 5 shows the view of the content management system.

Firebase - It is mobile and web development platform by Google. It provides various Application Programming Interface (API) for backend services such as real-time database and user authentication. The proposed architecture uses firebase real-time database to store the json file and point cloud map data.

5. CONCLUSION AND FUTURE ENHANCEMENT

The navigation solution at indoor places which we have proposed using augmented reality in this research work has been proven excellent by the results which we have got. Firstly, In the assessment of the content management system, result shows that conversion from 2D map of indoor location to 3D scene in back-end was achieved and the user is also able to make changes in it as well as add points of interest in the scene. Secondly, In the assessment of the mobile application, result shows that the navigation arrows are properly rendered on the screen and the user is able to interact effectively and efficiently with the application in the mobile device. Additionally, the proposed solution provides a blend of the back-end system that can be used to manipulate the indoor location maps and front-end system in the form of mobile application that can be used to satisfy user requirement to visit different places and also it does not rely on any of the infrastructure as Wi-Fi, NFC etc.

The further research work has to be undertaken to enhance spatial mapping of a place using augmented reality so that the area can be mapped easily and rapidly and also research to capture the point cloud features of an area robustly needs to be done. Also, there can be advancement done in this application by adding voice assistant to help visually impaired people to navigate easily. With the time, the augmented reality glasses or the head mounted displays (HMDs) will be available at economical prices and that can be used to remove the dependency of the mobile devices and helping the user to navigate just by wearing those devices.

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