IJEAST

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

VOLUME : 6 ISSUE : 9 Print / Issue Publication Date: 01-Apr-2022

ISSN : 2455-2143

DOI : 10.33564/IJEAST.2022.v06i09.009

Indexed In

International Journal of Engineering Applied Sciences and Technology, 2022
Vol. 6, Issue 9, ISSN No. 2455-2143, Pages 67-77
Published Online January 2022 in IJEAST (http://www.ijeast.com)

AUGMENTED REALITY BASED INDOOR NAVIGATION USING POINT CLOUD LOCALIZATION

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Abstract - People of various ages may find it difficult to navigate complex building structures as they become more prevalent. The future belongs to a world that is artificially facilitated, and Augmented Reality will play a significant role in that future. The concept of Indoor Navigation using a smartphone-based Augmented Reality technology is explored in this research. Using readily available and affordable tools, this study proposes a solution to this issue. We built an Augmented Reality-based framework to assist users in navigating a building using ARWAY, a software development toolkit. To find the shortest paths, we used the Point Cloud Localization and A* pathfinding algorithms. A shop inside a shopping Centre, a particular room in a hotel, and other locations can be easily located using this app, and the user is given fairly precise visual assistance through their smartphone to get to his desired spot. The proposed framework is based on augmented reality, and point clouds are the most important components. The application allows the user to choose their desired destination as well as change their destination at any time. To find the results from the technical, subjective, and demographic responses, we used hypothesis testing and validation with statistical analysis and exploratory data analysis methods.

Keywords: Augmented Reality (AR), Virtual Reality (VR), ARWAY, Point Clouds, A*

I. INTRODUCTION

Some people, at some point in their life, may get lost inside a large auditorium, struggled to find their exit point at the airport, or may get late to a lecture because they couldn't find the right lecture hall (Ajith et al, 2020). But this way of getting lost could soon be a thing of the past in complex and large venues. Applications for indoor navigation for mobile devices are now popular and people need them to locate destinations within large buildings and many other places, institutions. Indoor navigation is very complicated in terms of difficulty. Compared with outdoor navigation, it is distinct. In the instance of millions of people already use outdoor navigation, technology such as GPS is available, as it takes a great deal of performance. Built-in GPS and maps are presently found in Smartphones and advanced smartwatches. In outdoor settings, navigation systems are commonly used, but indoor navigation systems are still in the early stages of growth. GPS, Bluetooth, Wi-Fi, RFID and Sensor Chip technologies make use of the latest available devices. The technology for Bluetooth is affordable but has limited range and accuracy. We need to set up Bluetooth hotspots in the building for efficient position monitoring and navigation using this technology. For other technologies, such as Wi-Fi, RFID and Sensor chips, the same applies. The expense of installation and repair is outrageously high with all these tools, and a shift in weather conditions will affect the signal intensity of the hotspot if one system breaks down. These technologies also require physical infrastructures, such as technologies that are common solutions for localization, have difficulty estimating the direction of the user, and are thus not suitable for AR applications. In contrast, machine vision methods are more suited for AR-based applications, and recent tests have shown computer vision solutions to be more reliable in addition to Wi-Fi based fingerprinting. A widely studied indoor positioning solution focused on vision includes picture recognition from live camera feed of the real world.

Applications of Augmented Reality (AR) allow a user to communicate on top of a physical world with digital entities, often connecting real objects to digital content. This method of linking involves understanding an environment's semantics, a job that proves to be challenging. The localization of digital twins is one solution to this problem. If the precise position in the world of the computer is known, then a digital twin will provide the environment with semantics. Localization or pose prediction is called determination of this spot.

This research is about proposing a methodology for navigating an indoor area in student living apartments using an augmented reality (AR) application. For this research, the software is designed, which is using cloud based Augmented

Reality Tool Kit and SDK based on the real-world view direction to quickly get the desired location around student living at 50 Lisgar street.

II. LITERATURE REVIEW

When compared to the outdoor positioning, indoor positioning faces multiple problems and has specific requirement. Satellite signals such as GPS are more difficult to track in indoors because radio frequency signals are attenuated by barriers such as walls in a building. In comparison, indoor positioning is commonly associated with more specific locations than outdoor positioning (Mautz, 2009). For e.g., GPS has an accuracy of 10-20 meters measured as a root mean square error (Dardari et al., 2015), and on the other hand some indoor positioning systems can achieve accuracies of few centimeters only. In addition, indoor positioning systems besides the planar location, are usually involved in the user's altitude which indicates both discrete details such as the floor of the building, as well as the exact height of the unit from the actual floor of the user. If consumer mobile devices are used for indoor real-time positioning systems, then the positioning algorithm's efficiency, speed, accuracy, and computational load play a crucial role in the system's functionality and flexibility.

2.1 Literature review on point cloud localization as a method for indoor positioning used in this study

In the last several years, various reviews on as-built modelling from point clouds have been released (Volk, Stengel and Schultmann et.al. 2014) (Patraucean, Armeni, Nahangi, Yeung, Brilakis and Haas et.al. 2015) (Liu and Zlatanova et.al. 2013). The majority of the works focused on the effective reconstruction of structural building components (Oesau, Lafarge and Alliez et.al. 2014) (Mura, Mattausch and Pajarola et.al 2016) (Tran, H.; Khoshelham, Kealy and Díaz-Vilariño et.al. 2019) and openings, while the correct modelling of floor elements, the modelling of free space, and the modelling of obstacles received less consideration, considering their significance for indoor path finding.

Several recent works have discussed the thorough simulation of floor components. In indoor conditions, point clouds and handheld laser scanner trajectories were combined to segment and identify floors into stairwells, stairs, and flat surfaces (Staats, Diakité, Voûte, and Zlatanova et.al. 2017) (Balado, Vilariño, Arias, and González-Jorge et.al. 2018). The process begins with a projection in the point cloud discretized into a voxel-based model and an area rising, which is then accompanied by a projection in the point cloud discretized into a voxel-based model. Outdoors, the trajectory direction was used to identify road regions and, as a result, define ground components into curbs, sidewalks, ramps, and stairs based on geometrical and topological features (Balado, Vilariño, Arias and Soilán et.al. 2017) (Vilariño, Verbree, Zlatanova and Diakité et.al. 2017).

Mortari et al. suggested a network-generation approach that takes challenges in indoor scenes into account. Obstacles were depicted as 2D geometry in the floor plane, and the process was based on predefined models. Since 2D floor plans were abstracted at various height ratios, the result was a 3D network. Xiong et al. suggested a framework for designing 3D indoor paths using semantic 3D models contained in LoD4 CityGML. System takes obstacles into consideration; the method was checked on models that did not have any obstacles. Lui et al. (2018) invented a system for real-time indoor navigation based on grid models derived from 2D floor plans with predefined obstacles. Rodenberg et.al (2016) suggested an octree representation of indoor point clouds as a basis for indoor pathfinding. The A* pathfinding algorithm, which relies on heuristics to direct the search, was used to navigate through empty nodes, avoiding obstacles. Li et al. (2018) also recently presented a path-planning method for drones indoors based on occupancy voxel maps, and on which the navigable space was composed of the empty voxels.

We used Point cloud Localization with A* pathfinding algorithm because of the following reasons.

1. Scalability: It is highly scalable.

2. Reliability: It provides high reliability and efficacy.

3. Accurate: It is able to accurately guide a user to its destination.

4. Easy-to-deploy: It does not require any indoor map or dedicated indoor localization system deployment initially.

5. Infrastructure-free: It is independent of any infrastructure, such as Wi-Fi access point, Bluetooth beacons etc which is usually unnecessary for indoor environment to offer such infrastructures.

6. Robust: It is robust to environment variations and crowds and also able to detect deviation events to notify the users.

7. Universal: It is able to guide a user to any destination from its current location, rather than from a few predefined locations.

2.2 Literature review on alternate indoor positioning methods

The optical and vision-based positioning system uses a mobile sensor or camera in a user's mobile device to assess the location of an individual or an object within a building by locating a marker or image that is within range (Mautz & Tilch, 2011; Klopschitz, Schall, Schmalstieg, & Reitmayr, 2010). A marker is a static target with markings that can be used as a reference within the field of view of an imaging sensor like a cell camera (Mautz, 2012). Barcodes, QR codes, and fiducials are only a few examples of identifiers. Marker-based and Augmented Reality (AR) are the two most popular methods for optical and vision-based positioning.

According to Chang, Tsai, Chang, and Wang (2007), Mulloni, Wagner, Schmalstieg, and Barakonyi (2009), and Raj, Tolety, and Immaculate (2009), a cell phone camera gets visual information using identifiers, such as QR codes (2013). A mobile computer with a monitor, a QR code, and a server make up the machine (Raj et al., 2013). The mobile device's camera is used to collect data by scanning the QR code's pattern, while the server is used for tracking and storing information including floor plan map data for retrieval as appropriate (Barberis et al., 2014; Chang et al., 2007; Mulloni et al., 2009).

While Chang et al. (2007) focused on monitoring people with neurological impairments in smart settings, Mulloni et al. (2009) focused on searching and reviewing real-time location details in an area to aid continuous navigation. To put it another way, Chang et al. (2007)'s research would not allow for real-time navigation like Mulloni et al. (2009)'s, but it can monitor users' movements over time.

However, in this situation, navigation is not real-time. In comparison to the previous positioning systems mentioned, the QR code's ease of use makes it a feasible indoor positioning system. It is simple to deploy, according to Chang et al. (2007), because of its low cost. Furthermore, user privacy is covered because certain implementations, such as Raj et.al. research do not include real-time positioning and alerts via a server (2013). Despite the fact that the mobile device is being monitored, the consumer location is not real-time in certain other solutions (Chang et al., 2007; Mulloni et al., 2009). The marker's location is decided by the user's position.

The markers are spread across the navigation area, and their location is determined by positioning the mobile device next to the marker (J. Kim & Jun, 2008). Real-time navigation is still possible with some other solutions, as shown by Barberis et. al. report's (2014). Furthermore, the system's accuracy is measured by the distance between the marker and the device, which is determined by the device's camera's resolution (Raj et al., 2013). If the camera resolution on the platform is insufficient, it may have a negative impact on the system's accuracy and performance (Ibid.).

Barberis et al. (2014), on the other hand, may not need knowledge of the device's camera's resolution or properties. However, because of the extra infrastructures, these networks become more complicated and costly. As a result of these problems, the AR approach was established as an alternative. Augmented Reality (AR), like marker-based approaches, uses a handheld system with a camera, a marker, and a server (Raj et al., 2013). The data is captured by scanning the pattern of the marker with the mobile device's sensor, while the server is used for location estimation, position determination, and real-time monitoring and navigation (Chang et al., 2007; Mulloni et al., 2009). AR (Möller, Kranz, Huitl, Diewald, & Roalter, 2012) is the overlay of simulated objects with the physical world using visual markers or photographs for orientation, tracking, and navigation.

Klopschitz et al. (2010), Mulloni, Seichter, and Schmalstieg (2011), and Möller et al. (2012) propose that AR obtains visual knowledge by smoothly overlaying a user's vision with position information connected to an image store in a centralised location or server. Optical marker identification, image sequence matching, position recognition, and location annotation are all performed by the server (Klopschitz et al., 2010; J. Kim & Jun, 2008). According to Mautz and Tilch (2011), the server sends the recognised location data to the mobile user, allowing for real-time positioning and navigation. Mulloni et al. (2011) and Möller et al. (2012) based their research on improving efficiency focused on the interface of an AR indoor navigation system so that navigation in indoor environments can be made better.

While navigating, users are guided by activity-based guidance and information points such as markers positioned in the area to assist accurate positioning and efficiency. As a consequence, navigation errors are greatly minimised. Robustness, simplicity, and accessibility are considerations that are taken into account during the deployment process to accomplish this (Möller et al., 2012; Mulloni et al., 2011). While most positioning and navigation systems use a marker-based approach, Klopschitz et al. (2010) use a new "markerless-based" approach in their research. For matching and monitoring purposes, this method makes use of existing image features.

Since matching image features in real time can be difficult, the markerless approach makes certain assumptions about the mobile device's sensor (Klopschitz et al., 2010). Furthermore, when more markers and a server are used, real-time positioning and navigation is accurate with AR (Möller et al., 2012). Despite the advantages of AR over marker-based systems, image matching can demand a large amount of computational power, raising the difficulty and affecting efficiency (Klopschitz et al., 2010). Furthermore, updating the server could result in an increase in both the cost and the cost of maintenance.

III. UI DESIGN

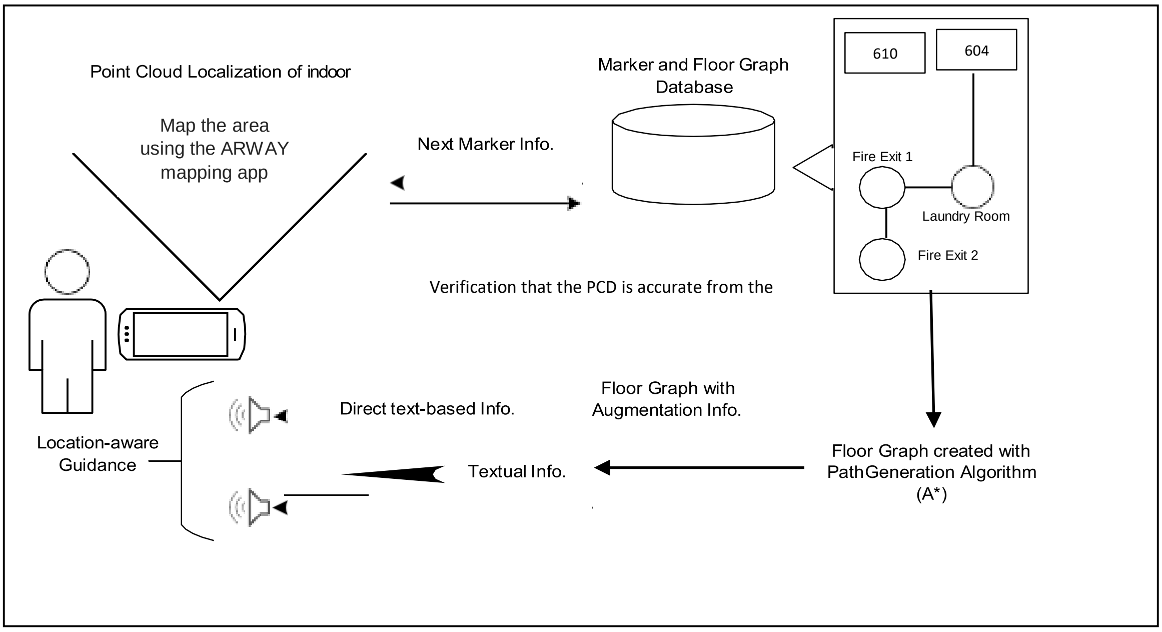
3.1 AR based indoor navigation application

The proposed indoor navigation APP's primary technology is the A* algorithm, which aids in deciding the shortest distance to the destination among the paths stored in the maps for various routes. Through walking and dropping way points on the road, we first save the routes to various destinations inside a 6th floor lobby of apartment building. ARWAY SDK stores our guides, waypoints, and their positions in the cloud. The A* algorithm is used in a recursive loop to find the best possible route by comparing the distances between nodes starting at the beginning and ending at the end. The user's surroundings are first traced on a screen and then downloaded to the cloud (Azhar, Murtaza, Yousaf and Habib et.al. 2016). Many of the beginning and ending points are mapped first in this manner. The user learns his or her position inside a building by looking up the GPS coordinates of that location on the cloud during navigation, and then uses the map to navigate to the target location using way points (Wenge and Nan et.al. 2015).

3.2 Application methodology with user interface

The key aim of this research is to create a device that is simple to use, low-cost, and achieves reliable results with a small amount of computing power. The proposed scheme is depicted in the diagram below, in which a person uses a smartphone application to communicate with point clouds and provides location-based guidance information to the user. This data is saved in the form of a textual summary of the area.

Block Diagram 1. Overall system for user guidance within an indoor environment.



The proposed system has the following key aspects.

1. We designed a low-cost navigation system that uses point cloud localization. The point clouds are developed for each unique position for the places in different areas such as Rooms, and corridors, Laundry Room and Fire Exits.

2. The system automatically generates path by detecting and connecting the point clouds with the help of a smartphone camera and creates a graph in the phone by connecting the point clouds.

3. The system has textual information displayed to guide the user upon the recognition of each marker.

4. The user is guided toward a given destination by following a shortest path inside a single or multi-floor building.

5. The system is dynamically extendable. It provides a way to edit an already generated path, and to

extend it for incorporating newly deployed markers in the building.

Steps for AR Mapping using ARWAY

1. Initially, map the area using the ARWAY mapping app, which is available on both Android/IOS.

2. After creating the map, verify if the created Point Cloud Data stored in the server on the application gives high localization accuracy.

3. After getting localization works, create a pathway using ARWAY web studio.

4. Finally, import SDK in unity and designed the application for end-user's usage.

The below experimental map shows the five different locations on the 6th floor surrounding in ARWAY web studio with the created Point Cloud Data (PCD). Finally, using developer unity ARWAY SDK, we made changes on features and performed experiments remotely under the permissions of the department during the COVID19 regulations. The image of the other maps is also available on the application as a user click on it and image will be displayed.

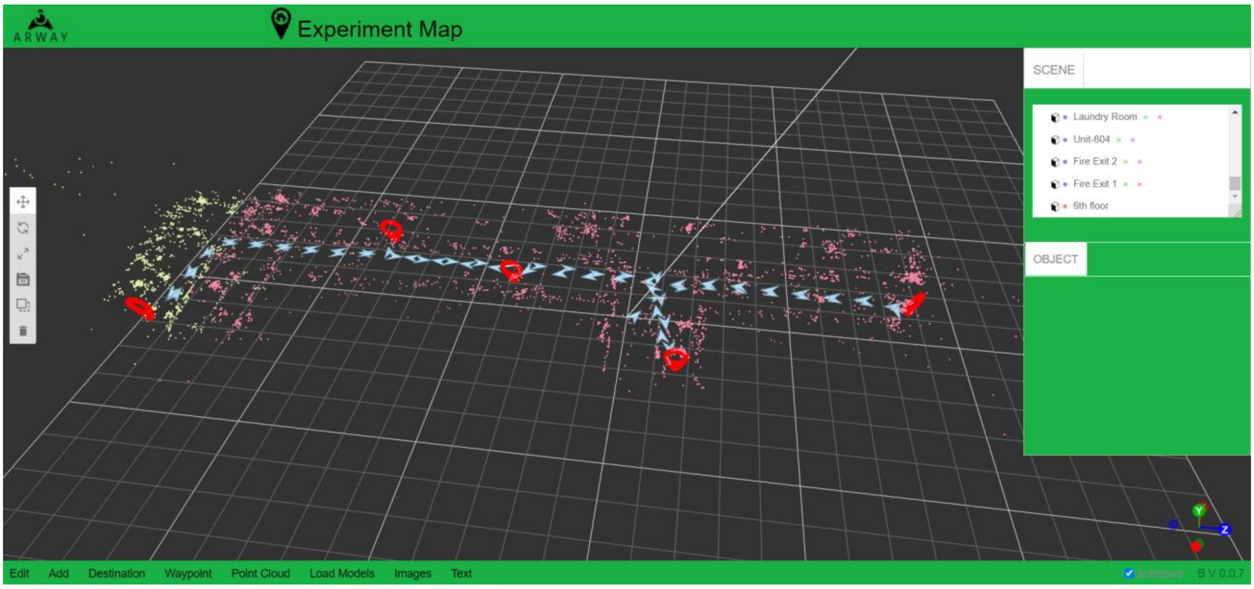


Figure 1 Experimental Map

International Journal of Engineering Applied Sciences and Technology, 2022
Vol. 6, Issue 9, ISSN No. 2455-2143, Pages 67-77
Published Online January 2022 in IJEAST (http://www.ijeast.com)

Figure 2 Initialization of Application

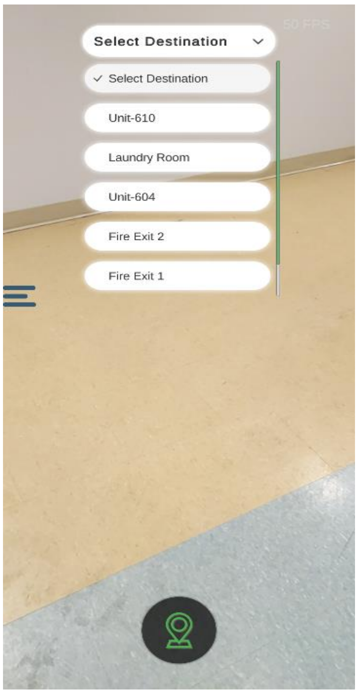


Figure 3 Navigational Options available to users after Mapping Mode

Figure 2 and 3 shows screenshots from the smartphone of the application, describing various modules and modes of the proposed system. In the administrative mode the system requires login information. The administrator can do different activities such as to extend the point clouds, delete the maps and update the maps. The other mode is for the end-users to access the locations via their smartphone and navigate in the building through the guidance provided by the application. Different modules of the proposed system are described in the next chapter in details with results and experimentation. Some of these modules are concerned with installation, while others are executed at user side.

IV. METHODOLOGY

4.1 Objective

In the study, we presented an augmented reality-based indoor navigation application that uses localized environmental features and marker less tracking technologies, as well as the Shortest Pathfinding algorithm with Point Clouds Localization, to help people navigate in indoor environments. The application can be implemented on mobile devices such as a smartphone, providing both visual and textual instructions.

To thoroughly test our system and methods, we conducted both a technical assessment study and a human factors study. The technical evaluation assessed the AR application's effectiveness and dependability. The human factors research looked at things like perceived accuracy, navigation time, subjective ease, subjective workload, and route memory retention. We also wanted to see if Augmented Reality-based navigation system aids were superior to paper maps in terms of navigation time, workload, and comfort, or if Augmented Reality navigation caused poor route retention. These findings may provide scientific evidence to support future indoor navigation system designs. In the final section of our research, we will explore the implications and future research.

The study's key purpose is to distinguish between two indoor navigation techniques: one that uses a 2D-map of the floor and the other that uses an AR mode of navigation. To determine which navigation method would be more effective in getting to the destination in the shortest amount of time.

4.2 Hypothesis

We conducted the research based on hypothesis statement and its validation to support the research idea and answer the research questions in statistical manner with data driven decision and evidences. A hypothesis will formulate our findings and answering our research question. For some research projects, we might have to write several hypotheses that address different aspects of our research question. Here, we came up with the hypothesis validating which method of indoor navigation is found best by the users through the experiments we conducted.

Hypothesis H1

Null Hypothesis: There is no significant difference in timings (to reach from starting point to destination point) between using a mobile based AR navigation method and a physical map.

Alternate Hypothesis: There is a significant difference in timings (to reach from starting point to destination point) between using a mobile based AR navigation method and a physical map.

4.3 Approach and Validation

Numerical Analysis: During the application evaluation, we looked at things like the time it took to get to the destination from the beginning key point.

Subjective Analysis: We performed a subjective study to analyses the user's views regarding the proposed system. In this case, we used a common method of system assessment known as the system usability scale (SUS), which involves applying a 7-point Likert Scale Questionnaire to the various aspects of the application and associated measures, culminating in data that reflects the overall usability of the application.

4.4 Participant's recruitment

Participants recruited through sending a poster to a group of people and through social media and phone calls. (Due to COVID-19 to perform experiment remotely, there are some requirements for participants. Any interested person who has an android phone with the requirement of (https://developers.google.com/ar/devices) supported to AR core and a stop watch or for those who are in AR group can also use screen recording of their phone when they start their experiment or a stop watch. Because they have to note timing to perform each task on the side on their notes and submitted to researcher after they completed their task. So those have a stopwatch/smartwatch can participate for 2d map and if they are comfortable using phone timer then they can use it. And AR group can use screen recording or stop watch anything. All the details to the interested person send it through an email. If they have following requirements fulfilled those will be selected.

After getting group of people using random selection methods researcher divide those into two groups, so there were total 24 participants, 4 participate for pilot study and gave a feedback and from remaining 20 participants 10 chose 2D map 10 chose AR based navigation. To complete a task each participant took a maximum of 5-7 min with filling out all the questionnaire. So, there is 15-minute difference between each participate timing.

Steps to perform task with 2D Map

1. Fill out demographic questionnaire.

2. Then clicking on 2D map on app which will navigate them to 2D floor image.

3. From starting position to unit -610, from unit-610 to laundry room, to 604, to fire exit.

4. When they start performing the task had to start stop watch and note the timing when they reach to 610 first then 610-laundry room and so on. (Note timing of every path they are navigating) All the participants use stop watch/smartwatch during the task.

5. After completing the task, they have to fill out 7-point Likert scale questionnaire and send those notes to researcher who is available on zoom they have to just click on link it will navigate them to researcher and send those timing.

Steps to perform experiment with mobile based AR application

1. Fill out demographic.

2. Open the application and click on experiment map from list of available maps.

3. Start screen recording/smart watch.

4. Click on localize button.

5. Start navigate their given task.

6. After completing the task, they have to fill out 7-point Likert scale questionnaire and send those notes to researcher who is available on zoom they have to just click on link it will navigate them to researcher and send those timing.

Selected Paths

Path 1: This path goes from the elevator on 6th floor up to unit-610.

Path 2: From unit 610 participant need to follow path to the laundry room on the same 6th floor.

Path 3: It goes from laundry room to unit 604. (On 6th floor)

Path 4: This path goes from unit 604- to exit stair-B (Fire Exit-B)

PATH	DISTANCE
PATH-1	8.57m
PATH-2	11.15m
PATH-3	4.75m
PATH-4	7.36m

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Vol. 6, Issue 9, ISSN No. 2455-2143, Pages 67-77
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Table 1 Selected Paths

V. RESULTS AND ANALYSIS

In the methodology section, we discussed the hypothesis that we will validate to answer our research questions, the methodology and complete procedures for setting and collecting the data for the experiments with all the steps.

In this chapter, we will be discussing the results of the experiments we conducted for the evaluation of our mobile based AR application. There were total 20 number of participants, out of which 10 chose to use the Physical 2D map indoor navigation and 10 chose AR based application. From Total of 20 participants, it can be seen that 16 users were from age group 19-25 and 4 users were from the age group 26-39. There were 10 males and 10 females in the survey. There were 8 people with Bachelor's degree, 8 people with High School degree and 4 people with Master's degree in the survey. Out of all the people 8 have already used AR based application while 12 people haven't used AR based application. Out of 20 people 10 people have already used Google Map AR functionality. Also, the majority of our survey participants uses map frequently. 10 people had experience of using AR headset, 8 people didn't even know about AR headset, on the other hand, there were two people who knew about the AR headset by never used it before.

Based on results of time to complete each task we calculated the time differences among the users for each path while using AR application and 2D physical Map. The figure 4 and 5 below shows the comparison of time taken for each path by all the users while using AR application and 2D physical Map. It can be concluded that AR map users find it very efficient and time saving while navigating using the application as compared to the 2D physical maps, as the difference is positive for 92.5% measured readings. For some of the readings, there is quite much difference because navigating from one to place to another using a physical map doesn't provide any assistance and the user has to search for the right directions looking at the structure of the path, on the other hand in case of an AR based assisted navigation, it is a whole different situation where user has to just select the initial and final point and then look for the assistance and information shared by the application.

USER ID	PATH	TIME TAKEN(S) - AR APP	TIME TAKEN(S)- 2D MAP	Time Difference (AR App - 2D Map)
User 1	PATH-1	14.3	16.57	2.27
	PATH-2	6.44	27.71	21.27
	PATH-3	4.74	15.26	10.52
	PATH-4	8.8	11.22	2.42
User 2	PATH-1	10.12	11.98	1.86
	PATH-2	13.76	38.38	24.62
	PATH-3	6.23	8.65	2.42
	PATH-4	5.52	24.69	19.17
User 3	PATH-1	8.93	10.75	1.82
	PATH-2	10.4	19.16	8.76
	PATH-3	5.73	9.3	3.57
	PATH-4	8.53	13.11	4.58
User 4	PATH-1	12.92	12.7	-0.22
	PATH-2	12.05	17.01	4.96
	PATH-3	7.65	8.33	0.68
	PATH-4	12.48	19.1	6.62
User 5	PATH-1	9.52	9.06	-0.46
	PATH-2	9.81	21.93	12.12
	PATH-3	4.92	11.1	6.18
	PATH-4	9.51	16.4	6.89
User 6	PATH-1	14.86	18.14	3.28
	PATH-2	9.95	26.53	16.58
	PATH-3	7.52	17.94	10.42
	PATH-4	13.05	15.84	2.79
User 7	PATH-1	13.98	17.94	3.96
	PATH-2	12.1	24.71	12.61
	PATH-3	8.24	12.23	3.99
	PATH-4	12.4	16.72	4.32
User 8	PATH-1	14.38	19.4	5.02
	PATH-2	14.11	22.15	8.04
	PATH-3	7.4	15.56	8.16
	PATH-4	19.96	15.22	-4.74
User 9	PATH-1	12.4	17.57	5.17
	PATH-2	15.21	21.71	6.5
	PATH-3	7.23	13.28	6.05
	PATH-4	10.52	15.32	4.8
User 10	PATH-1	11.27	16.57	5.3
	PATH-2	15.76	27.71	11.95
	PATH-3	5.23	15.26	10.03
	PATH-4	9.52	11.22	1.7

Figure 4 Comparison of Time Taken for each path while using AR application and 2D physical Map

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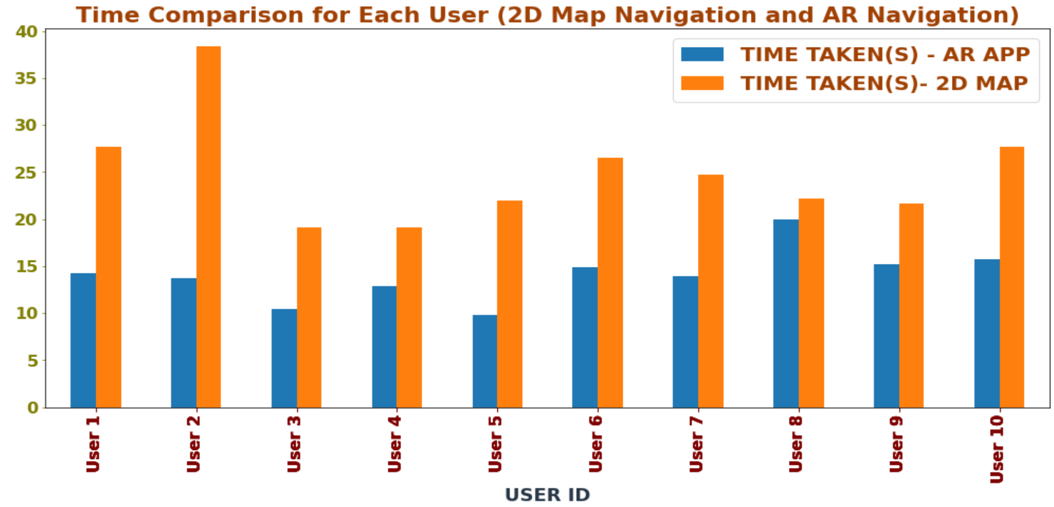

Figure 5 Comparison of Time taken on a bar-graph

Figure 6 shows the descriptive statistics of the three columns time taken while navigating with the AR App, time taken while navigating with the 2D map and the time differences. It can be seen that the mean of time taken using the AR map is 10.43 seconds whereas for the 2D map it is 17.08 seconds, which depicts there is almost double time taken in general while navigating with the 2D physical Map. The similar statistic is shown by the standard deviation which supports the above evidence. The other quantile statistics such as min, 25%, 50% and 75% quantiles also represent the same scenario which validates that there is a huge difference between the time taken while navigating with 2D maps and AR application.

Variable	count	mean	std	min	25%	50%	75%	max
TIME TAKEN(S) - AR APP	40	10.4363	3.5168	4.74	7.6175	10.035	12.953	19.96
TIME TAKEN(S)- 2D MAP	40	17.0858	6.2151	8.33	12.583	16.485	19.22	38.38
Time Difference (AR App - 2D Map)	40	6.6495	5.9852	-4.74	2.6975	5.095	9.0775	24.62

Figure 6 Descriptive statistics of AR app and 2D map

The subjective analysis of the responses recorded through questionnaire for the 2D physical Map Based navigation on Likert scale from 1-7, we chose 66.6% as the reference line for considering the responses to be highly positive or highly negative.

We also conducted the statistical analysis on the time differences and time taken using the AR application and 2D maps. Statistical significance tests are used to determine if the discrepancies between the groups under study are meaningful or merely coincidental. As a result, we looked at statistical analysis of the experiment's results to see if there was a statistically meaningful discrepancy in the mean values of the output parameters obtained. To assess the presence of these statistically important output variations, a one-way study of variance, or ANOVA, was used. To check for data normality, a qq-plot was produced, which suggests that the data is normal and has homogeneous variances and no outliers.

If no statistically meaningful difference is present in the mean value of the output measures for the various models under analysis, the null hypothesis (H0) that there is no significant difference in timings (to reach from starting point to destination point) between using a mobile based AR navigation method and a physical map is accepted. If a statistically relevant performance difference ($P < 0.05$) is discovered, the alternative explanation (H1) is accepted and H0 is refused. To conduct statistical analyses, we used a Python script. We conducted independent sample T-test for the time differences. The t test (also called Student's T Test) compares two averages (means) and tells if they are different from each other. The t test also tells how significant the differences are. In other words, it lets us know if those differences could have happened by chance.

A large t-score tells that the groups are different. A small t-score tells that the groups are similar. We found the following results while running the t-test on time taken for AR application and 2D map navigation.

t-statistics: -5.889177893067742
D.O.F.: 78
CV: 1.6646246444385238
P-Value: 9.294049241326263e-08
t=-5.889, df=78, cv=1.665, p=0.000

Based on the p-value, we rejected the null hypothesis that the means are not equal, there is significant difference across the models. Finally, we conducted the one-Way ANOVA for which also the p-value was found to be to very low than confidence interval of 0.05. Hence, we can reject the Null Hypothesis and accept the alternate hypothesis – that there is a significant difference in timings (to reach from starting point to destination point).

VI. CONCLUSIONS

The main objective of an indoor navigation and localization system is to reliably and accurately localize users in an indoor environment and to direct them from point A to point B in an effective and straightforward manner. We asked users to navigate through four different paths in our experiments. The system's robustness is ensured by comparing the AR app's time differences with the 2D map navigation. Similarly, the efficiency can be measured via counting the time differences to reach a destination. Subjective analysis also helped to evaluate other qualitative features of the system which we did in the later part of our research.

Figure 4 and 5 shows the results of our experiments. Ten users performed the experiments by navigating through four different paths using 2D physical maps while 10 people performed the experiments while navigating using the AR application. For 92.5% of the observations, the time taken while navigating with the AR application was considerable lesser than the time taken for the navigation with the 2D maps. So, the time taken by each user for each path was also satisfactory as compared to the 2D maps. The results revealed that the proposed methodology is efficient, robust and accurate. The user satisfaction, system usability, ease of use and freedom in mobility were evaluated through subjective analysis through the surveys and questionnaire. For the subjective analysis, it was found that 90% of the users rated the proposed system reliability as excellent. The participants were asked about their satisfaction while relying on the proposed system and the guidance provided for indoor navigation.

Similarly, the system was evaluated with Likert Scale questionnaire, which showed the overall usability of the system and yielded a high positive response from the overall results indicate the significance of the proposed method and its ease of use. The system was evaluated by a sample of participant. Changing the users may yield somehow different results.

Limitations and future work

1. In our system, the user holds the smartphone in his/her hand, which is still not easy while navigating in the environment. This issue can be resolved by integrating an AR headset.

2. The localization of the point clouds can be made automated and less time taking.

3. One limitation of our work is that it directs the users in four directions including forward, backward, left, right. It requires a structured indoor environment. The marker placement is required to be parallel to the corresponding paths. In future, we are planning to solve this issue.

4. In the future, we plan to add a point of interest (POIs) with a name showing when users reach their destination and a virtual guide with audio/text speech.

Data Availability

The data that support the findings of this study are available from the corresponding author, [Patel], upon reasonable request.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

Funding statement

The author(s) received no specific funding for this work.

Acknowledgments

I would like to express my deepest gratitude and appreciation to my supervisor and co-author of the study, Dr. Ratvinder Grewal, who gave me the opportunity and possible support to make this research success. Also, I want to thank my technical coordinator, Nikhil and Baran Korkmaz, for providing all the server requirements for the training phase. They were always available and supported all the dependencies required in the environments. Finally, most significantly, I offer special thanks to my parents, brother, and friends who encouraged me and helped me fulfil my dreams.

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