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Literature Survey: Indoor Navigation Using Augmented Reality

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Abstract

Location-based services are an important aspect of living, as these not only provide time benefits but also save a lot of energy. With the increase in complex building structures, people of different ages may find it difficult to navigate within such structures. When we say different age groups, it includes the age groups from little ones who don't understand directions to the older ones who are in an urge to find places early due to getting drained out easily. Indoor navigation is not only an asset to sighted people but for the impaired ones too. Indoor navigation when integrated with voice assistants allows the impaired people to navigate hassle-free. For this, an Indoor navigation system is required which localizes the user, takes the account of their current location, and then corresponding to the destination point, guides the user through the path.
The literature survey takes into account the different localization approaches considered by different researchers in indoor localization and the necessary positioning algorithms to reach the destination for the paths. This paper also reviews the plus points and limitations of the research work that has been done in Localization and Pathfinding algorithms.

Keywords :
Augmented reality, A algorithm, Marker-based localization, PDR systems, Vision-based localization*

1. Introduction

Outdoor navigation and indoor navigation are the two types of navigation available. Indoor is performed within a building or institute, whereas Outdoor is performed outside, such as on roadways. The main reason for the difference is that we utilize a satellite-based Global Positioning System for outside navigation, but we can't use the same technique for inside navigation since radio signals can't penetrate solid walls and discover an exact position. Using current technology, there are a number of solutions to address the challenge of indoor positioning. Bluetooth beacons, WIFI graphs, and other technologies are among the technologies employed. The fact is that it is critical for a developer to solve this issue because it is one of the most common issues consumers encounter when visiting a new indoor setting.

People today are so focused on themselves in this evolving time-centric environment that they can't even waste a single second asking questions and navigating through a large Institute or Building. Rather than just roaming and searching for a particular destination, they can use an application that is self-efficient and can not only guide them but also provide a better navigation experience. Due to the massive construction, many consumers will visit the Institute, Mall, or Supermarket for the first time, only to be disappointed when they are unable to discover their ideal destination, resulting in a decrease in the popularity and mark that a user-friendly organization must leave.

An Indoor Navigation System (INS) is a technology that assists users in navigating in an indoor environment by displaying a path to their destination from the user's current location. This has a variety of applications and uses, such as in an emergency situation where users must escape an unknown institute in the event of a fire or earthquake, this can assist the user in locating the path. Assistance for older persons who need to take the shortest route possible because energy is more important than time. Another instance where this can be a lifesaver is in the event of a medical emergency.

Indoor positioning technologies for providing indoor navigation services are themselves very diverse. Typical indoor location systems involve natural phenomena such as geomagnetic data and inertial measurement unit (IMU) sensors installed in smart devices, as well as Wi-Fi or Bluetooth technologies.

The following is an example of how augmented reality navigation might work:
1. Obtain a user's point of view of the real world.
2. Gather location data in order to monitor the user. GPS coordinates are usually included in this information.
3. Create virtual world data based on the real-world perspective and location data.
4. Create an augmented reality by registering the virtual information generated with the real-world perspective and displaying it to the user.[29]

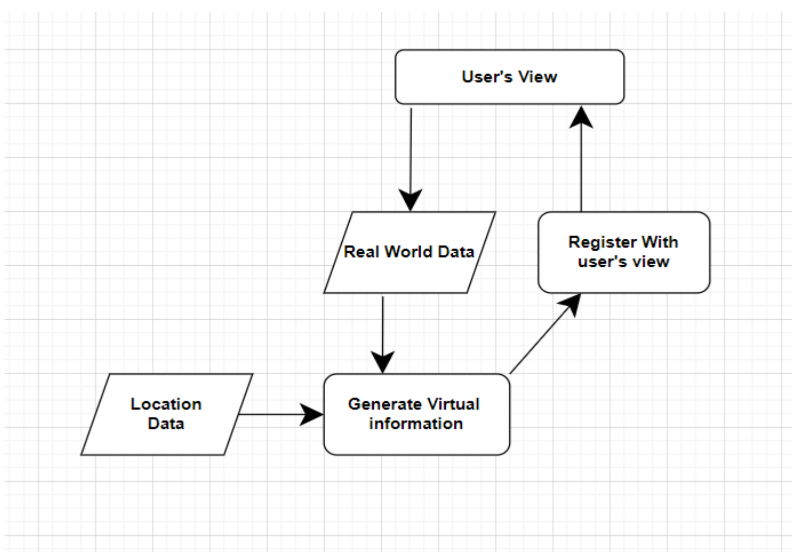


Figure 1. A Simple System for AR Navigation

Figure 1 shows the basic actions required for having an AR Navigation system.[29]

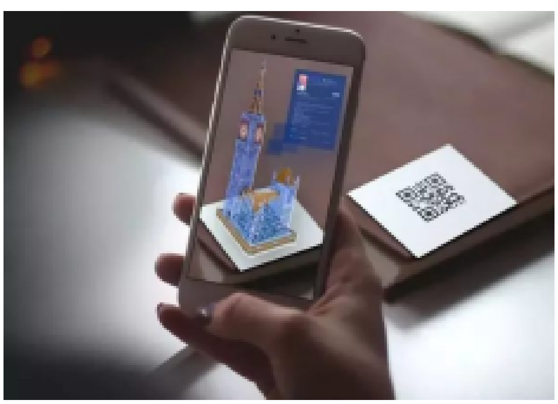
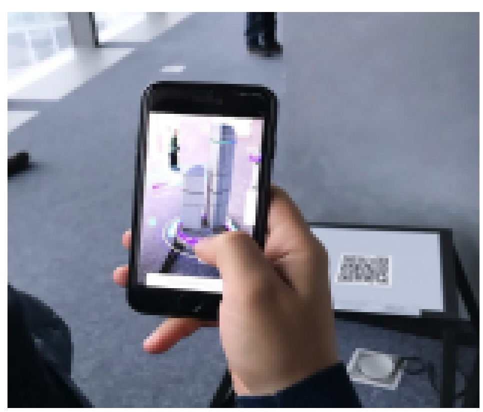
The next section focuses on a literature survey that explains the approaches for Localisation, Indoor Navigation, and Pathfinding Algorithms to reach the destination which are implemented generally. Section 3 presents our analysis, viewpoints, and summary. We present our conclusion in section 4.

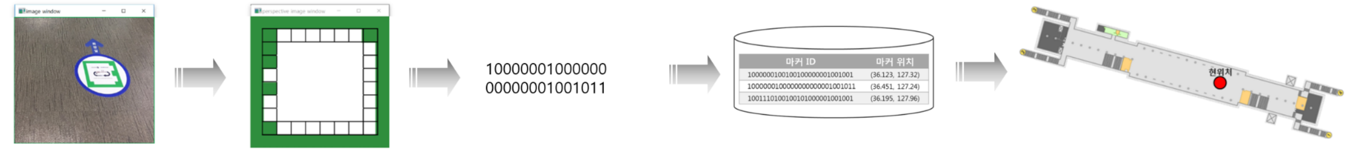
2. Literature Survey

This section focuses on the previous work done on various localization systems and navigation algorithms. Also, it tries to understand the different approaches and limitations as described below. The subsection focuses on localization techniques whereas the next subsection focuses on the Pathfinding Algorithms.

2.1 Marker Based Indoor Localization

Lee, G., & Kim, H.[1] explained that Marker-based AR needs a marker to activate an augmentation. Markers are distinct patterns that cameras simply acknowledge and method, and are visually free of the surroundings around them; they have to be paper-based or physical objects that exist inside the globe. Maker-based AR works by scanning a marker that triggers associate increased expertise (whether an associate object, text, video, or animation) to look at the device. It continuously needs a package inside the sort of associate app, that allows users to scan markers from their device and mistreat its camera feed. Below we'll see however it truly works.



(a) Image capture (b) Extract marker (c) Extract marker ID (d) Extract marker location from DB (e) Present current location

Figure 2. Marker Recognition Process for Positioning

So once we tend to choose a destination inside the app and once the chosen application screen is born-again to the camera screen, the user scans the marker with the camera, and thus the marker recognition program acknowledges it. So as shown in figure 2[1], once the marker is recognized, the app captures an image of it, as shown within the 1st image Next, the captured image is born again into the HSV color model to reduce the influence of sunshine and extract the definition of the marker then to the grayscale image once the marker boundary is 1st detected. Border space thresholds are wont to realize potential markers in binary pictures mistreatment the strategies planned by [2] and edge detection strategies [3] are wont to determine marker boundaries. To extract the distinctive ID of the marker, here the adaptive thresholding technique was used to verify the changes in image illumination. This technique shows the individuality of every} object at each place with totally different illumination. It conjointly permits objects to be classified per their chance of turning into a marker region when characteristic changes in image illumination. When the conversion is complete, the recognized marker ID and destination are passed to the info. The info stores the binary info of the analyzed marker ID aboard the marker ID and marker location. We tend to check whether or not the recognized marker ID exists inside the info, then extract the marker location from the info to specific its current position, as shown within the on top of Figure. Thus overall within the system, many such markers are placed either on the bottom or on a wall and unfold across the situation. they may be positioned notably within the least entrances and everybody and different points of interest so that the appliance will simply determine them. Custom markers are usually scanned, these custom markers are usually scanned from any angle and mistreat the camera of the user's smartphone. On scanning, the user is directed to his/her destination-Upon scanning, the user is directed to his/her destination to mistreat the visual displays shown on their phone.

According to Lee, G., & Kim, H.[1],to increase the performance following are the measures to be followed :

The mounted size of the marker inside the frame, that depends on the area from the camera to the bottom and conjointly makes it quicker to hunt out the marker, resulting in improvement inside the police investigation speed. Somewhat uniform background pattern of the bottom, which can be used to improve the decipherment speed of the rule.Chances for the marker to be at the higher part of the frame, since the user moves forward whereas navigating. Marker positions ought to be glorious beforehand so that the presently decoded marker ought to get on.

The Vuforia technology was utilized by Romli et al. [4] to provide marker-based indoor navigation services in libraries. When registering images of significant areas within the library and AR objects similar to them within the system for this study, the AR object guided the users when they projected the registered photos. Multiple markers are frequently detected at the same time in the Vuforia system, and objects are usually registered without the use of extra markers. Once there are many target photographs, however, just AR object expression studies and surveys are carried out, and further experiments are required before true navigation services can be provided.

Khan et al. [5] devised an internal navigation system based on the ARToolKit markers produced in the preceding study. The offered application was Android-based and had two modes of operation: an associate administrator mode that registered a marker on an indoor map when a marker was attached to the ceiling, and a user mode that probes for directions while recognizing the marker as a mobile device. This technology is simple to integrate into automation applications, use, administer, and expand, and provides ease through voice and text steering. The direction of the marker, on the other hand, should be parallel to the passageway's direction, therefore the mobile device should face the ceiling as a result of the marker being suspended from the ceiling. As a result, this technique may have difficulty inserting markers, resulting in an unfavorable strain on users.

Using marker-based localization, Hübner et al. [6] converted the augmentation and placement of the indoor environment into virtual indoor model data in an AR device (HoloLens). Building information modeling data was superimposed after defining the pose of the AR device for the frame of reference of the important physical world. Heya et al. [7] proposed an indoor location system based on OpenCV and Python image processing. In this study, each participant was allocated a single hue, which they displayed on a smartphone strapped to their shoulders. The user's position was determined by detecting colors with a camera affixed to the ceiling and converting the results location into a matrix of locations Meanwhile, Lightbody et al. [8] suggested a novel marker and a positioning system based on it. To the old WhyCon circular marker, the new marker incorporated encoded information based on the concept of binary necklaces. The ID of the marker and thus the rotated angle may be established simultaneously in the process of recognizing the marker. Due to the decoding process, these tests revealed advantages such as high accuracy and low computational cost, but also disadvantages such as computational overhead and expensive installation costs.

2.2 Vision-Based Indoor Localization

Localization can be defined as the process of estimating an object pose (position and attitude) relative to a reference frame, based on sensor inputs.[9]

Visual-Based Localization (VBL) is a computer vision task that involves extracting a camera's pose from a query image captured by the camera. Visual information allows the human brain to infer position and viewpoint. When we look at a photograph of the Eiffel Tower, we can immediately tell that it was shot in Paris and we can guess where it was taken from.

Vision-based localization is a new technology and is receiving great research attention over the past years. It has a wide range of applications including augmented reality, indoor navigation, self-driving vehicles, and 3D reconstruction.

VBL stands out from GPS-based localization in terms of accuracy. That is GPS based localization performs poorly in crowded areas.

To make the user's navigation in the environment easy and practicable, a location positioning system for indoor and outdoor contexts should be as small, light as possible. To achieve the goal of localization, the technique should use the bare minimum of hardware, which is a smartphone with a camera.

Apart from these, Image matching using feature extraction can be a great alternative. With this technique, query images, captured by the localization system, are matched with reference images based on discriminative descriptors (so-called features). The known location of the most similar reference image is then used as a location estimate. [10]

J. Brejcha and M. adk. classified VBL depending on the environment in which the particular method acts. [11]
They divided the environment criterion into three classes:

- Global: unrestricted visual-based localization at the planet scale
- City-Scale: Visual-based localization in urban environments
- Natural: Visual-based localization in non-urban environments

JongBae Kim and HeeSung Jun presented an augmented reality-based interior navigation vision-based location positioning system. [12] The proposed system detects a location by overlaying location information smoothly over the user's perspective, and it provides augmented reality by detecting a place using image sequences of indoor surroundings. They constructed a picture database and an interior environment location model, which comprises places and paths between them, to recognise a location. The position is established using prior knowledge of the arrangement of the indoor environment. A wearable mobile PC with a camera captures the image sequence, which is then forwarded to remote computers for processing. Marker detection, image sequence matching, and position identification are all done by distant PCs. The wearable mobile PC receives the detected location information from the remote PCs. The system can search the image database for similar sites and display information about them. To acquire accurate and efficient location placement, several vision-based techniques are applied.

Omid Mohareri and Ahmad B. Rad have presented a vision-based localization system for humans and humanoid robots to navigate in indoor settings using Mobile Augmented Reality (MAR) and Mobile Audio Augmented Reality (MAAR) techniques. [13] The device recognises a user's location from a picture sequence of an inside space using its built-in camera. Location information and navigation instruction content are added to the user's perspective in the form of 3D objects and audio sounds using augmented reality. Prior knowledge about the environment's layout and the positioning of the AR markers is used to identify the position.

Kray et al. have explained how to route instructions can be displayed on mobile devices.[14] Textual and spoken directions, 2D sketches, 2D maps, and pseudo-realistic 3D views are among the types of interfaces they distinguished between. Each of them can be categorized based on their suitability for various levels of localization accuracy. In a user study, 3D was chosen over 2D because it included landmarks that helped users locate themselves on the route.

Andreas Möller, Matthias Kranz Lule, Robert Huitl, Stefan Diewald, and Luis Roalter have developed a mixed-reality interface of Virtual Reality (VR) and Augmented Reality (AR) elements with indicators for communication and proper localization.[10] They discovered that while AR was favored in cases of reliable localization, navigation instructions were regarded to be more accurate in cases of localization and orientation mistakes in a study with 81 participants. The extra indicators suggested that consumers might be more likely to select distinctive reference photos for accurate localization if they were given more options.

Another approach is based on two-dimensional maps that can be adapted to the user’s walking speed [15]. If the user walks faster, the map zooms out to show a wider view of the environment for convenience.

Liu et al. [16] suggested an indoor navigation system in which the smartphone uses overlay directional arrows, textual navigation directions, and audio. They discovered that the capacity to modify the UI to the preferences of the consumers is crucial.

AR was employed by Miyashita et al. [17] for a museum guide system. Exhibits were enhanced with new information using augmentations. When visitors looked for the next AR object with their phone, they were routed along a predetermined course within the museum.

In a study by Walther-Franks and Malaka [18], they evaluated how AR navigation systems are better than Map-based navigation. As way directions, the system utilized floor-projected arrows and lines. The graphical work required to produce a full 3D scene is reduced when an environment is represented with omnidirectional (i.e. panoramic) images.

2.3 PDR Based Indoor Localization

Positioning is very important to know the object's location. So, Pedestrian Dead Reckoning is another technique to identify the latest position of an object with estimated displacement from starting position. Displacement is represented by total step count and step length. Since step length varies from person to person. This is done by using accelerometer sensors. [19]

I. Bylemans, says that the PDR technique requires oriented projection, filtering, step detection, and step length estimation. [21]

Yunye Jin, actually explained all the necessary steps for implementing the PDR system. So, firstly, oriented projection is a projection of coordinates in the x,y, and z-axis. The projection indicates acceleration values in the up-east-north using accelerometer sensors. After, projecting the value it should filter the acceleration. Hence, here comes the filtering process. Filtering is the process to obtain desired output signal i.e gravity-free and noise-free signal. Gravity signal is the low-frequency signal component that causes the y-axis to have a value of $9.8m/s^2$. To eliminate the influence of gravity, the signal is filtered with high-pass filtering. As a result of this filtration process, we get a signal which is free from gravity and minimum noise as shown below. [20]

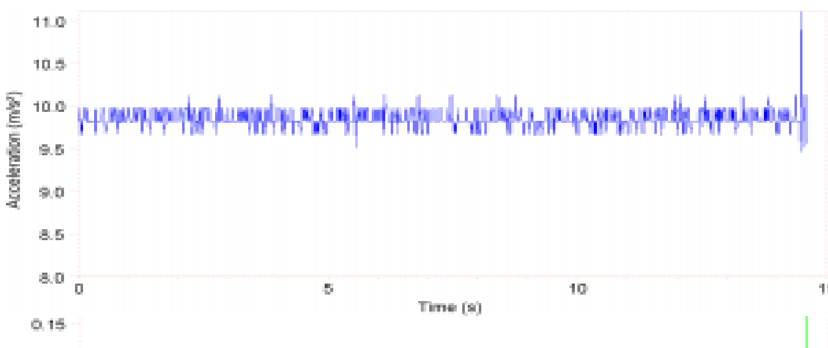


Figure 3: Filtration process

Figure 3 shows the filtration process of acceleration [22]

Now the next step is the detection of steps. It is very necessary to detect steps accurately in order to get estimated displacement. As a result, there are two typical methods for detecting steps: peak detection and the detection of zero-crossing.

Peak detection: According to Jeong Won Kim, vertical acceleration peaks correspond to step occurrences because vertical acceleration is generated when the foot strikes the ground. As a result, relative threshold detection is employed to detect steps. When there is a legitimate maximum peak (maxima) and minimum peak (minima), as illustrated in the diagram below, it recognizes a step. An interval time difference between maxima and minima is also calculated empirically to assure a legitimate step and must be between 120ms and 400ms.[23]

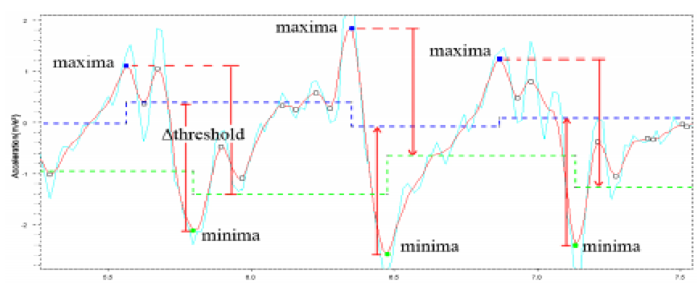


Figure 4: Peak Detection Method

Figure 4 shows actual maxima and minima for each step using Peak Detection Method [22]

Zero crossing detection; This method counts signal crossing zero levels to determine the occurrence of steps. This method is not appropriate to detect the user's steps, because it requires a certain time interval threshold to make a decision whether the zero-crossing represents a valid step or not.[22]

Step Length Estimation is the final step. Estimating step length in each valid detected step can be used to determine the total traveled distance. There are two types of methods: static and dynamic. The static technique only considers valid steps of the same length, but the dynamic method considers valid steps of varying lengths. In the dynamic technique, there are three approaches for estimating the length: the Weinberg approach, the Scarlet approach, and the Kim approach. [24]

The length of each step in the Weinberg method is proportional to the peak-to-peak differences at each phase. The scarlet approach, on the other hand, finds a link between the maximum, minimum, and average acceleration of the step length. The Kim approach, on the other hand, provides a relationship between step length and average acceleration during each step. [22]

Once the position and location of the user have been determined then will continue to track the user's movement through a PDR system. In order to track the user's position an optimized PDR system featuring which is a pseudo-pedometer function is developed in C# in Unity 3D by using the sensor data collected from the accelerometer and compass.

If the original path is lost while routing, then it will provide a rerouting option. So that it will again show an alternative path to the intended destination. It is possible to use an object recognition technique complemented by a PDR system to achieve a high level of accuracy to track a user's movement and location using mobile devices.

2.4 Positioning Algorithms

There are several algorithms for finding the shortest path between current location and destination, like Dijkstra's, best-first search (BFS), and A* algorithm. Out of this, the finest pathfinding algorithm is A* which gives the result of combining these two algorithms.[25]

Ostrowski, D., Pozniak-Koszalka, I., Koszalka, L., & Kasprzak,[26] In single source shortest path problem Dijkstra's algorithm is used. It can find the path between an initial vertex and every vertex in the graph. It can also determine the shortest path between a single vertex and a single destination point by stopping the algorithm after the shortest path has been found.

In the A* algorithm, approximate distance is found by the heuristic function and represents the minimum distance between the current location and goal. Once the initial path is found it ensures the algorithm eliminates the longer path.[27] The heuristic function is -

$$f(n) = g(n) + h(n)$$

Sanchez, J., Yumang, A., & Caluyo, F.[28] have proposed that an over here n is a start sector. It has to put it on an open list. According to the cost function, calculate f(n) examines the lowest heuristic cost which will give the summation of the exact cost of the path from the starting point to any vertex n, and the heuristic estimated cost from vertex n to the goal. After calculating heuristic cost, remove the value of f(n) from the open list and put it on the closed list, and save the index of sector n which has the smallest cost i.e. f. Which means it will be ignored for checking the lowest cost. If n is the target sector then terminate the algorithm and use the pointers of indexes to get an optional path. If No**,** then detect all successor sectors of n which do not exist in the closed list. Calculate cost f for each sector then repeat from step 3 up till getting the target sector. The following flowchart shows the A* algorithm. [25]

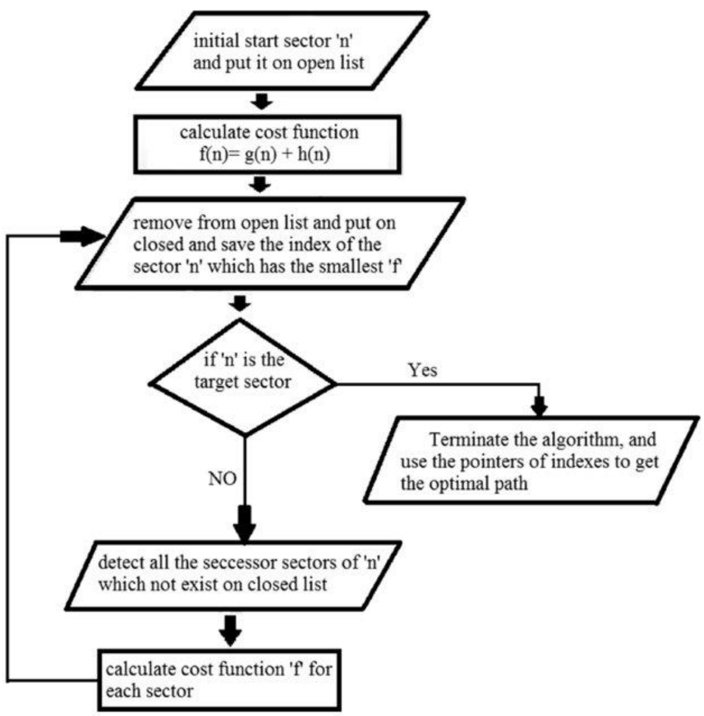


Figure 5: Flowchart of A* algorithm

3. Discussion and Summary

With the steady rise of technology, Augmented Reality has turned out to be one of the most exciting and promising technologies the world has ever seen so far. Looking at the developments in indoor navigation so far and studying all the approaches, the basic requirement these days is less the hardware and more convenient the system is. The localization techniques presented in the literature survey have the minimum requirement of a mobile camera, but at the same time in marker-based systems when the mobile camera is moved away from the marker, the AR experience disappears and the marker has to be scanned again. Also in vision-based systems, the camera has to be held in the same pose which is not convenient for the user. On another hand in PDR systems, hardware requirements include accelerometer, compass (magnetometer), and camera which is relatively more than the other two as we discussed before. Another feature that has to be taken care of in marker-based localization is that scanning will not work if markers reflect light in certain situations. Thus the markers have to be scanned in perfect light conditions. In the vision-based system, the drawback is maintaining the quality of query images, that is they should be good for feature extraction and image recognition.

Pedestrian Dead Reckoning (PDR) is a pedestrian positioning method that involves adding distance traveled to the known beginning position, as detailed in the paper. An accelerometer sensor can be used to detect steps and measure displacement, allowing the distance traveled by a pedestrian to be calculated. To record the acceleration, an accelerometer sensor must be mounted to the body. [10] Contrary to popular belief, identifying displacement might be difficult due to individual differences in walking patterns. In addition, without a calibration process, step detection in diverse walking patterns yields an average inaccuracy of 2.925 percent. Error reduction is a difficult task.

From the research papers we have studied, the A* algorithm has proved to be the most efficient and accurate method for Pathfinding. But the drawback here is it provides the navigation in 2D maps only. For 3D maps, it is difficult to implement the A* algorithm. But in the coming future, this can be a scope of improvement.

Overall, based on our research, we recommend using the marker-based localization technique because, if the marker image is properly prepared, marker-based AR content provides high-quality experiences and tracking is very stable, the AR content does not shake, and it is simple to use because detailed instructions are not required for first-time users.

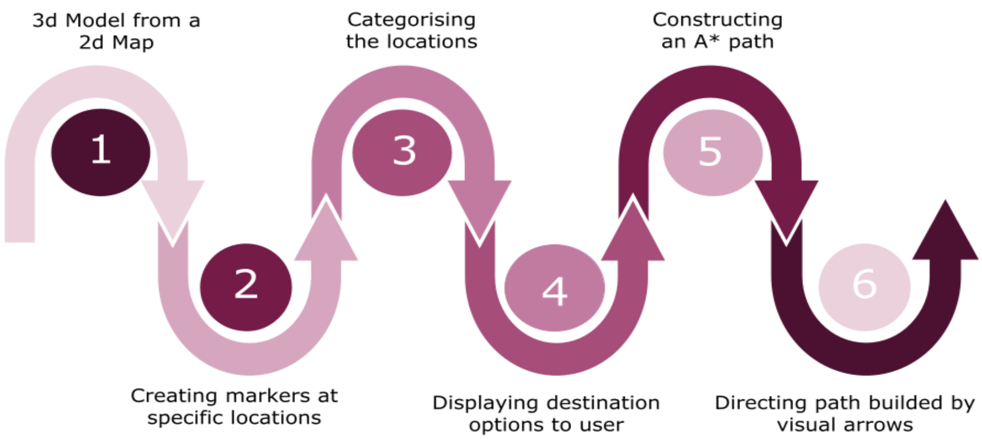


Figure 6: Proposed System workflow

4. Conclusion and Future Scope

The paper has tried to understand and analyze the approaches of various kinds and the developments which have taken place to make the localization and navigation for the convenience of the user. Most of the existing navigation systems are unable to provide routes accurately as well as further information of the building within a region such as a campus, shopping mall, hospital, etc.

The authors propose to implement a system using the literature presented in this paper. We can develop an indoor navigation system that is independent of any other hardware or low connection issues with a great visual display for user interaction using augmented reality consuming less time for finding indoor places.

Apart from all the approaches we have studied, we suggest integrating voice assistants for visually impaired people. Enhancing UI features to match users' goals and intentions would carry more attraction of users towards the application. For further advancement, we can also have to substitute images as input rather than selecting destinations. And finally, indoor and outdoor navigation can be merged in the coming future. All these will apparently give the user high productivity with the combination of hassle-free navigation.

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