A COMPREHENSIVE SURVEY ON INDOOR NAVIGATION SYSTEMS LEVERAGING AUGMENTED REALITY

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ABSTRACT:

Indoor navigation really matters for getting around big places like airports, malls, or hospitals without too much hassle. Thing is, GPS just doesn't work inside, and most systems aren't set up well for folks who can't see, so accuracy and ease of use take a hit. This survey looks at ways to fix that by reviewing AR setups that mix of various approaches to guide you in a natural way. We break down the current stuff into categories like how they locate you, what paths they pick, and the different feedback options they use, pointing out how well they perform, if they scale up okay, and how accessible they are. By comparing the top solutions out there, we spot the strong points, the weak spots, and where more work is needed. In the end, it lays out some paths forward, you know, like making fingerprint databases automatically, keeping AR rendering light for real-time action, and handling user data without messing with privacy, all to build navigation systems that are solid, open to everyone, and able to grow.

Index terms - Indoor Navigation, Fingerprinting, Path Finding, Augmented Reality, Accessibility, Survey.

I. INTRODUCTION

Indoor navigation has emerged as a prominent research area due to its potential to improve safety, efficiency, and accessibility in large and complex environments such as shopping malls, hospitals, airports, and university campuses. Achieving accurate indoor positioning, however, remains challenging. GPS signals degrade indoors because of attenuation and multipath effects, resulting in unreliable or unavailable location information. These limitations can lead to confusion, delays, and safety risks, especially for first-time visitors or individuals with limited spatial awareness.

Traditional solutions—such as static maps, printed signage, and basic mobile applications—are insufficient, as they lack adaptability and cannot deliver personalized, real-time guidance. Many existing systems depend heavily on visual cues, reducing accessibility, while others require costly infrastructure like BLE beacons or camera networks, limiting scalability.

To address these challenges, this survey examines augmented reality (AR)–based indoor navigation systems that incorporate Wi-Fi fingerprinting for localization, K-Nearest Neighbour (KNN) for fingerprint matching, and Dijkstra's algorithm for optimal path computation. Wi-Fi fingerprinting offers practical, sub-room-level accuracy using existing access points; KNN remains popular for its simplicity and robustness; and Dijkstra's algorithm reliably identifies shortest paths in graph-based indoor layouts. AR technologies, such as Unity with ARCore or ARKit, overlay digital cues onto real-world views, enabling intuitive and seamless navigation.

Overall, this review synthesizes recent advancements, compares localization and navigation approaches, and highlights future research directions for developing scalable, intuitive, and accessible AR-based indoor navigation systems capable of enhancing user experiences in diverse real-world settings.

2. Taxonomy of AR-Based Indoor Navigation Systems

A structured taxonomy is essential to understand variations in indoor navigation system design. Existing solutions can be categorized into the following dimensions:

2.1. Localization Techniques

- **Wi-Fi Fingerprinting:** RSSI-based localization using KNN, weighted KNN, or deep learning.
- **BLE Beacon-based Localization:** Uses Bluetooth Low Energy signals and fingerprint maps.
- **Vision-Based Localization:** SLAM, feature-tracking, point cloud localization.
- **Sensor-Fusion Approaches:** Combine Wi-Fi, PDR, IMU sensors, and environmental cues.
- **BIM or GIS-based Localization:** Extracts indoor structural information from building models.

2.2. AR Interaction Models

- **Marker-Based AR:** QR codes or fiducial markers used for pose initialization.
- **Markerless AR (SLAM-based):** Uses environment features for tracking.

- **Edge-Assisted AR:** Offloads computation to edge servers for real-time rendering.
- **Semantic AR:** Integrates ontologies for context-aware AR visualization.

2.3. Path Planning Techniques

- **Graph-Based Algorithms:** Dijkstra, A*, Theta*.
- **Bio-Inspired Algorithms:** Ant Colony Optimization (ACO).
- **Grid-Based Path Planning:** Uniform grids with heuristic-based routing.

2.4. Accessibility Features

- **Spatialized 3D Audio:** Direction-encoded audio cues for visually impaired users.
- **Haptic Feedback:** Vibrational cues (less commonly used in AR studies).
- **Multimodal Guidance:** Combination of AR visuals, speech output, and audio cues.

II. LITERATURE OF WORKS

[1] BIM-integrated AR navigation enables dynamic route adjustment through marker detection, distance computation, and user-specific constraints. Compared with Wi-Fi fingerprinting and Dijkstra-based methods, BIM–AR approaches offer superior scalability, situational awareness, and adaptability in complex environments such as airports, hospitals, and university campuses.

[2] SINS-AR integrates AR, grid mapping, visual markers, and the Theta* algorithm, with localization via QR code scanning. Experiments in malls and universities achieved over 93% accuracy and rapid response times, demonstrating its scalability and efficiency as a lightweight indoor navigation solution.

[3] The AR-based evacuation system combines BIM and GIS for indoor path networks, using Wi-Fi fingerprinting with KNN and PDR for tracking. University trials achieved 85% room-level accuracy and a SUS score of 70.59, confirming strong usability despite dependence on BIM data.

[4] A mobile indoor navigation approach employs Dijkstra's algorithm with digital building blueprints to deliver real-time visual and voice guidance. Validation in a three-story school confirms reliable performance, offering a low-cost and maintenance-free alternative to BLE-, Wi-Fi-, and VLC-based positioning methods.

[5] Indoor positioning is enhanced through BLE beacons combined with smartphone sensors, using fingerprinting for initialization and adaptive filtering to stabilize signals. Graph-based routing ensures reliable navigation, while experiments demonstrate high accuracy, robustness to environmental changes, strong scalability, and low deployment cost across large indoor facilities.

[6] Vivid employs an edge-cloud architecture for vision-based indoor navigation, offloading computation to edge nodes while deep learning maintains updated maps. A grid-map algorithm supports efficient routing. Evaluations report decimeter-level accuracy and strong scalability, though performance decreases in dense crowds and multi-floor navigation scenarios.

[7] AR-based indoor navigation combined with Semantic Web technologies utilizes spatial modelling, ontology-driven data management, and AR visualization. Prototype testing in two school buildings improved room identification and user confidence, showing strong usability, though performance remains sensitive to lighting conditions and smartphone hardware limitations.

[8] Navigation aids and spatial ability were evaluated through a campus study comparing Google Maps and MazeMap. Performance was similar across tools, but participants with higher spatial ability experienced reduced workload and hesitation, emphasizing the need for user-friendly, cognitively efficient navigation systems for complex environments.

[9] Grid-based mapping combined with the A* algorithm streamlines indoor navigation by dividing spaces into uniform cells and identifying low-cost optimal routes. The method offers smooth, reliable navigation with minimal infrastructure requirements and adapts effectively to varied building layouts, including malls, hospitals, airports, and office settings.

[10] Model-based acoustic rendering, presents an analytic sound-field rendering method using plane-wave decomposition to model directional acoustic components and derive loudspeaker driving signals. It supports circular and non-circular arrays, ensures scalable accuracy, and demonstrates performance comparable to advanced techniques through simulations across varied loudspeaker geometries.

[11] ARWAY-based indoor navigation using point cloud localization and A* significantly outperforms 2D maps, completing 92.5% of tasks faster. The solution is low-cost and infrastructure-free but affected by device limits, structured spaces, and marker placement, with future improvements aimed at automation and AR headset support.

[12] Advances in indoor navigation increasingly rely on AI-driven sensor fusion for higher accuracy and 5G connectivity for low latency. Standardization remains essential for interoperability and scalability, enabling practical, real-time deployment across complex environments such as malls, hospitals, airports, and office buildings.

[13] This approach enhances immersive spatial audio by generating individualized gain vectors using an RBF neural network based on anthropometric data. A parallel convolution algorithm ensures efficient real-time rendering. Evaluations show a 12.21% reduction in binaural cue deviation, 27.24% improvement in subjective listening scores, and over 70% reduction in computation time, demonstrating high accuracy, personalization, and scalability.

Comparative Analysis:

Paper Title	Primary Focus	Localization/ Positioning Methodology	Path Planning / Routing	Key Technology/ Model
BIM and AR-based Indoor Navigation	Proposes BIM–AR indoor navigation on smartphones.	AR node detection, feature matching, camera coordinate transformation, inertial navigation; data extraction via IFC standard.	IARA and SPA algorithms; road network built using IFC inheritance relations.	BIM (IFC), Augmented Reality (AR).
RBF Neural Network for Spatial Audio	Real-time individualized spatial audio rendering through loudspeakers.	RBF neural network mapping anthropometric data to Gain Vectors for Loudspeakers (GVL); simulated using HRTFs.	Not applicable (audio rendering). Parallel convolution ensures real-time performance.	RBF Neural Network, Parallel Processing, GVLs.
Plane Wave Decomposition for Acoustic Rendering	Analytical acoustic rendering using plane wave decomposition.	Loudspeaker weights computed using Plane Wave Decomposition and Herglotz density function.	Not applicable (acoustic wave synthesis).	PWD, Herglotz Density Function, Loudspeaker Arrays.
ESINS_AR (A Pathfinding)*	AR-assisted smart indoor navigation using grid-based mapping.	QR-based localization; PDR via accelerometers and gyroscopes.	Updated A* algorithm with grid-based mapping.	AR, QR Codes, Grid System.
AR & Semantic Web Methodology	Framework integrating AR and Semantic Web for indoor navigation.	QR-based initialization; AR-framework positioning (CV tracking).	Dijkstra's algorithm.	AR, Ontology, Semantic Web, Graph Space Model.

Paper Title	**Primary Focus**	**Localization / Positioning Methodology**	**Path Planning / Routing Algorithm**	**Key Technology / Model Used**
Indoor–Outdoor Navigation Comparison	Examines navigation aids and spatial ability in campus wayfinding.	Commercial app positioning (GPS, Wi-Fi IPS).	Routing from Google Maps and MazeMap.	Controlled Experiment, Statistical Analysis, Spatial Ability Tests.
BIM–GIS Emergency Evacuation	AR-enabled evacuation navigation using BIM and GIS.	Hybrid: Wi-Fi fingerprinting (KNN) + PDR with smartphone sensors.	GIS-based shortest path over BIM-derived graph networks.	BIM (Revit/IFC), GIS (ArcGIS/GDB), AR.
SINS_AR (Theta* Pathfinding)	AR-based smart indoor navigation with optimized routing.	QR-code visual markers for positioning and recalibration.	Theta* algorithm with line-of-sight optimization.	AR, QR Codes, Revit–Unity Integration.
Vivid (Vision + Edge Computing)	Vision-based indoor navigation using edge-cloud architecture.	ORB-SLAM2 (monocular mode) integrated with edge computing; deep learning for map maintenance.	Grid-based routing using Dijkstra, Bellman-Ford, or Floyd-Warshall.	Edge Computing, SLAM, Deep Learning.
Point Clouds Localization	AR-based navigation using markerless point-cloud tracking.	Point Cloud Localization using environmental features.	Shortest Pathfinding algorithm.	PCD, AR, Unity ARWAY SDK.
Indoor Navigation Review (PLAN)	Survey of positioning, localization, and navigation techniques.	Covers UWB, Wi-Fi RSS, angle-based, INS/PDR, KNN/ANN/DRL fusion methods.	Discusses navigation components conceptually.	Multi-sensor Fusion, GNSS/INS Integration, 5G, IoT, HD Maps.
Dijkstra's Algorithm Navigation	Indoor navigation emphasizing shortest-path computation.	Outlines trilateration, fingerprinting, proximity, dead reckoning.	Dijkstra's algorithm.	Client–Server Architecture.
ARBIN (Lbeacon / RSSI Waypoint)	AR-based navigation using BLE waypoint guidance.	RSSI distance models; orientation via IMU + ARCore VIO.	Waypoint navigation using proximity.	BLE (Lbeacons), ARCore, RSSI Modeling.

III. CHALLENGES

The widespread adoption of indoor navigation systems and the growing demand for inclusive wayfinding solutions present several unresolved challenges that must be addressed to ensure scalability, reliability, and accessibility.

A. Localization Accuracy

Wi-Fi fingerprinting for figuring out where you are. It's pretty sensitive to stuff like signals bouncing around or the environment shifting. Even with people moving, keeping things accurate to under a meter in places that change a lot. That's still a big headache for researchers.

B. Fingerprint Database Creation

Building those fingerprint databases takes forever. And updating them is no picnic either. If the layout shifts or access points get moved, accuracy drops fast. So, you need ways to automate it or get crowds to help collect the data.

C. Real-Time Performance

Real-time stuff like AR overlays and figuring paths, plus handling spatial audio. All that eats up phone resources. Getting it to run smooth on basic smartphones without the battery dying quick or the thing getting hot and laggy. That's the tricky part.

D. Multi-Floor Navigation

Navigating multi-floor spots or weird layouts. Most systems fumble with stairs and elevators. Detecting when you're switching floors right, and getting the vertical position spot on. Not much work done there yet.

E. User Accessibility and Inclusivity

For users who can't see, spatial audio helps guide them. But you often need to tweak the Head-Related Transfer Functions just for that person. If it's generic, the spatial cues get off, and usability suffers.

F. Scalability and Cost-Effectiveness

Scaling up without breaking the bank. Lots of fancy setups need BLE beacons or LiDAR gear, costly for big buildings. Better to lean on what's already there, like existing networks, for cheaper, easier roll outs. the spatial cues get off, and usability suffers. It is challenging to separate significant features in automotive environments due to noise without erasing signals associated with anomalies. Furthermore, it is still difficult to integrate heterogeneous sensor data with different frequencies and contexts, and model performance is frequently harmed by misalignment

IV.METHODOLOGY

A. Survey Scope

This survey looks at the latest research on AR systems for navigating indoors. It zeros in on approaches that mix Wi-Fi fingerprinting with KNN for figuring out where you are. Then there's Dijkstra's algorithm to find the best paths. And spatialized 3D audio to make things more accessible, you know. I pulled together a bunch of papers from places like IEEE Xplore, ACM Digital Library, and Scopus. They came out between 2019 and 2025. That way, it covers the newest stuff in tech advancements.

B. Derivation of Proposed Framework

The literature insights helped shape this general AR setup for getting around indoors. We picked Wi-Fi fingerprinting paired with KNN for figuring out where you are. It is simple enough, scales well, and has shown good accuracy in actual indoor spots. Dijkstra's algorithm came next for pathfinding. It always finds the best route in those weighted graph maps of building floors. Plus, it runs fast for real-time use. Unity handled the visuals as the main tool. Its cross-platform setup works great, and it ties right into ARCore and ARKit without hassle. Visually impaired folks can pick up on directions through sound alone, no sight needed. They show better orientation and finishing tasks when audio is spatialized like that.

V. DISCUSSIONS

This survey looks at combining Wi-Fi fingerprinting with KNN for figuring out where you are, plus Dijkstra algorithm to find the best paths, and AR stuff for showing the way. It shows how these hybrid setups for indoor navigation can make positioning more accurate and the whole experience better in tricky buildings. You know, the papers out there point out that Wi-Fi fingerprinting is pretty cheap because it uses the access points already there. KNN keeps it simple but solid for real-time spot-checking, and it deals okay with those RSSI changes in places that are not too crazy busy. Dijkstras gives you the shortest path for sure on those indoor maps that are like graphs. That means reliable directions even if there are lots of choices or stuff blocking the way. Mix in AR overlays using Unity or ARCore and ARKit, and navigation gets way more natural. Digital arrows and markers pop right into what you see, which cuts down on thinking too hard and helps you get a better feel for the space. For folks who cant see, the research backs up that HRTF-based 3D audio really helps with getting oriented. It uses sounds that come from directions naturally, so you can navigate without hands and feel more on your own. This multimodal thing stacks up well against just using cameras or QR codes. It hits a good balance on accuracy, how it scales, and being easy for everyone, without needing big setups like BLE beacons everywhere or LiDAR gear. Still, there are hurdles, like keeping the fingerprint database up to date. AR can lag on weak phones. Multi-floor switching needs to be smooth too. And privacy with all that location tracking, you have to think about it carefully, pushing for stuff like processing data right on the device and making it anonymous. Looking ahead, research could dig into crowdsourcing to grab fingerprint data automatically. Or lighter ways to render AR so it runs smooth on mobiles in real time. Personalizing HRTF for better audio aim too.

VI. CONCLUSION

In Indoor navigation in big places like facilities really needs solutions that are accurate and can scale up, plus they have to work for everyone, you know. This survey looks at the latest stuff out there, things that mix Wi-Fi fingerprinting with KNN for figuring out where you are, Dijkstra's algorithm to find the best paths, AR for showing you visuals, and HRTF-based spatial audio to make it accessible for folks who can't see. What we found is that combining these approaches boosts how precise the positioning gets, makes the whole experience better for users, and helps people with visual impairments get around easier. Still, there are some big hurdles, like keeping those fingerprint databases up to date, dealing with changes in the environment that mess things up, making sure AR runs smooth in real time, and not invading people's privacy along the way. Looking ahead, the next steps ought to zero in on automating how fingerprints get collected, slimming down AR rendering so it's not heavy, doing computations that protect privacy, and tweaking spatial audio to fit each person's needs. All in all, this points to a solid path for building indoor navigation that's tough, doesn't cost a ton, and feels natural to use in smart setups.

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