

Smartphone-Only High Accuracy Indoor Self-Localization and Navigation system for Non-GPS Environments with Patrol Free Floor Plan Based Map Creation

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Abstract –

Accurate indoor self-localization remains a fundamental challenge in environments where GPS signals are unavailable, such as construction sites, underground facilities, indoor spaces, and tunnels. This paper presents a smartphone-only indoor self-localization and navigation system that uses only sensors embedded in standard smartphones. The proposed system utilizes smartphone cameras and inertial sensors to achieve continuous indoor positioning without relying on external infrastructure or additional hardware. A key contribution is a patrol free floor plan-based map creation method using Map Creator, which generates navigable indoor maps directly from existing 2D floor plans without prior site surveys or environment scanning. Based on these maps, a smartphone-based indoor navigation application was developed to support real-time navigation and self-localized image acquisition with embedded position and orientation information. Experimental evaluations conducted in multiple indoor environments demonstrate an average relative localization error of 0.5–0.9%, confirming that high-accuracy indoor positioning can be achieved using only a standalone smartphone without external infrastructure. The proposed system offers a lightweight, scalable, and easily deployable solution for indoor localization and navigation in construction and facility management applications.

Keywords – Autonomous drone, Floor-plan mapping, Indoor localization, Indoor Navigation, Non-GPS, Smartphone-only

1. Introduction

Accurate indoor self-localization and navigation are essential for a wide range of construction-related activities, including inspection, progress monitoring, and safety management. While the Global Positioning System (GPS) is widely used for outdoor positioning, its performance degrades significantly in indoor and underground environments due to signal attenuation and blockage. As a result, reliable positioning in non-GPS environments such as construction sites, tunnels, and large buildings remains a critical research challenge [1,2].

To address this issue, various indoor localization technologies have been developed. These include wireless-based approaches such as Wi-Fi, Bluetooth, and ultra-wideband (UWB), as well as vision- and LiDAR-based methods such as simultaneous localization and mapping (SLAM) and feature-based localization [3–7]. In addition, visual-inertial sensor fusion using cameras and inertial measurement units (IMUs) has been increasingly adopted for mobile indoor positioning [8].

Recent studies have explored smartphone-based indoor localization as a practical and cost-effective alternative to infrastructure-dependent approaches, leveraging the widespread availability of consumer devices equipped with cameras and inertial sensors. These approaches have demonstrated sufficient accuracy for applications such as indoor navigation and spatially indexed image acquisition in non-GPS environments [9].

However, despite these advances, many existing systems still require additional preparation, including artificial marker-based initialization, deployment of wireless positioning infrastructure, or environment-dependent configuration processes such as prior feature database construction and repeated site patrol for mapping [10,11].

Such requirements limit scalability and practical

deployment, particularly in dynamic construction environments where indoor layouts frequently change and system reconfiguration is required. Therefore, achieving scalable and easily deployable indoor localization using only widely available consumer smartphones, without reliance on external infrastructure or site-specific preparation, remains an important research challenge.

To address this limitation, this paper proposes a smartphone-only indoor self-localization and navigation system that integrates floor-plan-based map creation with visual-inertial localization. The proposed approach enables navigation-ready indoor maps to be generated directly from existing 2D architectural floor plans without requiring site scanning or patrol-based mapping [12]. By constraining visual-inertial localization results using floor-plan-derived spatial information, the system improves localization accuracy while reducing setup effort and enhancing adaptability to layout changes.

Experimental evaluations conducted in representative indoor environments demonstrate that the proposed system achieves sub-1% relative localization error. These results confirm that high-accuracy indoor positioning can be achieved using standalone consumer smartphones without external infrastructure, making the proposed approach suitable for construction and facility management applications in non-GPS environments.

2. System Overview

This section presents the architecture and operational concept of the proposed smartphone-only indoor self-localization and navigation system. A standard consumer smartphone is defined as a device equipped with an RGB camera, inertial measurement unit (IMU), and onboard processor for visual-inertial computation. The proposed system performs indoor positioning and navigation in non-GPS environments using only these embedded sensors, without relying on external infrastructure or additional hardware.

To demonstrate device independence and applicability to widely available consumer hardware, experiments were conducted using both a recent smartphone model; iPhone 15, and a compact consumer-grade device: iPhone SE, confirming that the proposed approach does not depend on high-end sensing capabilities.

2.1 System Architecture and Components

The proposed system consists of three components: (1) a floor-plan-based map creation module, (2) a smartphone-based localization and navigation module, and (3) a smartphone-centered movement control interface. Their relationships are illustrated in Figure 1.

The first component, Map Creator, generates navigation-ready indoor maps directly from 2D

architectural floor plans. Floor-plan-based mapping approaches have been shown to reduce deployment effort compared with scan-based or patrol-based methods, particularly in environments with evolving layouts [13,14]. In the proposed framework, Map Creator defines spatial reference parameters such as scale, orientation, and anchor points to derive walkable regions and connectivity relationships.

In practical construction environments, discrepancies often arise between design drawings and as-built layouts due to ongoing changes during construction. To address this issue, the proposed patrol-free map creation approach allows users to directly update walkable paths, connectivity relationships, and reference information on the floor plan without requiring additional site surveys or remapping. This enables efficient adaptation to layout changes while maintaining coordinate consistency.

The second component is a smartphone-based indoor localization and navigation module that performs continuous positioning using visual-inertial sensor fusion. Smartphones equipped with cameras and inertial measurement units (IMUs) have been shown to provide sufficient sensing capability for indoor motion estimation without external infrastructure [15,16]. In the proposed system, device pose is estimated by integrating visual features tracking from image sequences with inertial measurements, and the resulting trajectory is constrained using floor-plan-derived spatial topology to ensure consistency with indoor layouts.

The third component is a smartphone-centered movement control interface that converts localization and navigation output into motion commands for mobile platforms. Smartphone-centric control architectures have been shown to improve portability and system flexibility by decoupling localization from platform-specific control systems [17,18]. The proposed interface enables localization results generated on the smartphone to be reused across different navigation and autonomous movement applications without modification of the core algorithm.

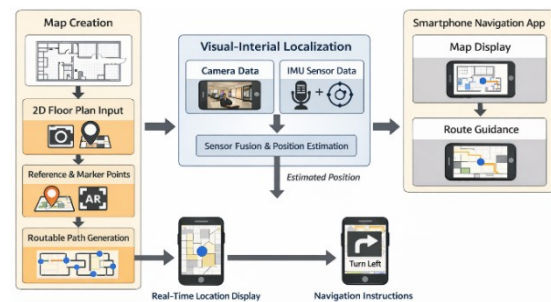


Figure 1. Overall architecture of the smartphone-only indoor localization and navigation system.

2.2 System Operational Flow

The operational flow ensures integration between

map creation, localization, and navigation. The sequence is illustrated in Figure 2.

The process begins with map creation using Map Creator, where a 2D floor plan is converted into a map by defining spatial reference information, walkable paths, and connectivity. The map is then transferred to the smartphone application.

During operation, the smartphone initializes its coordinate system and performs localization using camera and inertial data. The estimated pose is continuously updated and constrained using floor-plan-based spatial information. Based on the updated localization, navigation routes are computed and guidance is provided, as illustrated in Figure 2.

The operational flow of the proposed system is designed to ensure seamless integration between map creation, localization, and navigation execution. The overall operational sequence is illustrated in Figure 2.

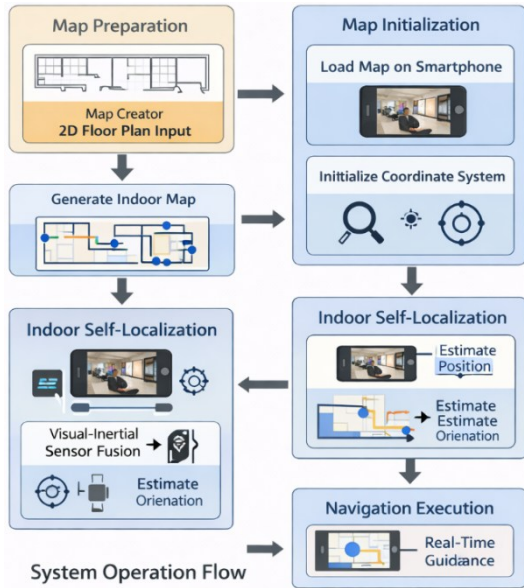


Figure 2. Operational sequence of the proposed smartphone-only indoor navigation system.

2.3 Data Flow and Information Exchange

The data flow separates static spatial information from dynamic sensor-driven data. The map creation module outputs static map data, while the smartphone modules handle real-time sensing, localization, and navigation.

The map creation module provides:

- Indoor coordinate reference information
- Walkable path networks and connectivity graphs
- Reference marker or anchor point data

These data are loaded into the smartphone application, where camera and inertial inputs are used to update localization results during operation. The interaction between static map data and dynamic localization is illustrated in Figures 1 and 2.

3. Patrol-Free Floor Plan based Map Creation System

This section presents a patrol-free indoor map creation method that generates indoor maps directly from 2D floor plans without site scanning or traversal. Spatial information is explicitly defined on architectural drawings, enabling efficient and repeatable map creation suitable for dynamic indoor environments. The workflow is shown in Figure 3.

To enable systematic indoor navigation representation, the walkable indoor environment derived from the 2D floor plan is formally modelled as a connectivity graph $G = (V, E)$, where V denotes discretized navigable nodes and E denotes feasible movement transitions between adjacent nodes. The graph is constructed from user-defined route segments on the floor plan, and connectivity is determined through reachability analysis. This graph-based representation supports route computation and serves as a constraint for localization by restricting estimated positions to valid navigable regions.

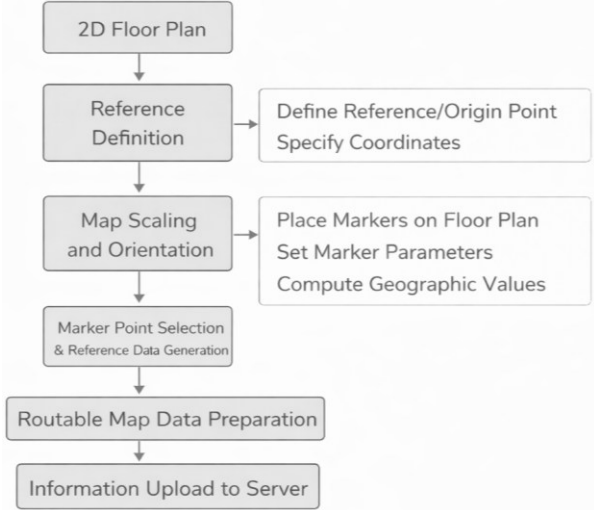


Figure 3. Patrol free indoor map creation workflow using Map Creator.

3.1 Floor-Plan-Based Spatial Definition and Coordinate Alignment



Figure 4. Map Creator screen with Floor Plan and associated geographic information.

Map Creator uses a 2D floor plan as the input for indoor map creation, where spatial relationships are derived directly from image geometry rather than sensor measurements [19].

A reference point is defined on the floor plan to establish the indoor coordinate system and enable alignment with real-world coordinates. The reference point is selected on the floor plan, and associated spatial parameters such as geographic position, orientation, and scale are defined in Figure 4.

By associating this reference point with known geographic coordinates, the indoor map is transformed into a globally consistent coordinate system without requiring on-site calibration [20].

Once the reference point is defined, all subsequent spatial elements, including marker points, walkable routes, and navigation coordinates are computed relative to this origin. This explicit reference-based approach enables repeatable and scalable map creation while maintaining consistency across devices and sessions

3.2 Marker Point Configuration and Reference Data Generation

Map Creator supports marker points that act as spatial anchors for indoor localization by linking the indoor coordinate system to real-world coordinates.

A single marker is sufficient for localization initialization; however, multiple markers can be used to improve robustness [21]. Marker configuration and reference data generation are illustrated in Figure 5. The system supports both artificial and natural visual features as markers, allowing flexible deployment without requiring dedicated marker installation [21].

Marker points are defined on the floor plan, and their spatial attributes are used to automatically compute geographic coordinates and orientation based on the reference point and map parameters. Marker data are stored for localization initialization. After initialization, continuous operation does not require persistent marker visibility, maintaining patrol-free operation.

3.3 Routable Map Generation

After defining the indoor coordinate system and marker reference information, Map Creator generates routable map data that represents valid movement paths within the indoor environment. Walkable routes are defined on the 2D floor plan as a red line segment to represent traversable paths as shown in Figure 6. These routes are connected to form a network of walkable paths, distinguishing traversable and non-traversable regions.

Once the walkable routes are defined, Map Creator applies a maze-based algorithm to analyze the connectivity of the red line network. The algorithm treats the connected red lines as traversable cells within a maze-

like structure and automatically determines reachability between path segments. Through this process, valid routes, intersections, and alternative paths are identified based on the connectivity shown in Figure 6 [22].

The resulting routable map includes path nodes and connectivity relationships that are later used by the indoor localization and navigation application for route computation. This approach enables patrol-free and easily updatable route generation. When the indoor layout changes, the user can simply modify the red route lines on the 2D map, and the routable data can be regenerated without additional data collection or site traversal.

4. Smartphone-Based Indoor Localization and Navigation

This section describes the smartphone-based indoor self-localization and navigation system developed in this study. The system is designed according to a localization-first concept, in which indoor positioning is treated as the fundamental function, while navigation is implemented as an optional layer that operates on top of localization results. This design allows the system to function both as a standalone indoor positioning system and as a navigation system when route guidance is required. The flowchart illustrating the smartphone based indoor localization and navigation is shown in Figure 7.



Figure 5. Marker point configuration and automatic generation of reference coordinates in Map Creator.



Figure 6. Routable path generation in Map Creator using the 2D floor plan.

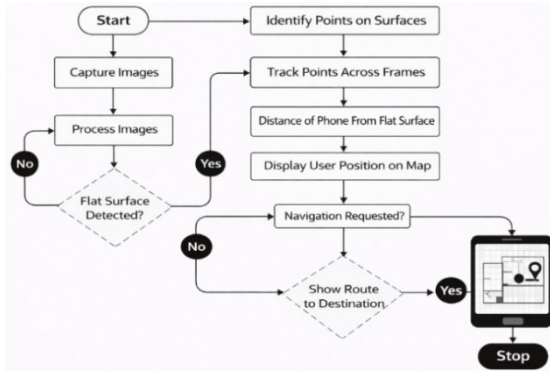


Figure 7. Flowchart illustrating the smartphone based indoor localization and navigation



Figure 8. Smartphone-based indoor self-localization results visualized on the floorplan.

4.1 Indoor Self-Localization

Indoor self-localization is formulated as a visual-inertial pose estimation problem in which the smartphone trajectory is incrementally estimated using sensor fusion. Relative motion between consecutive positions is computed by tracking sparse visual features extracted from sequential monocular RGB images, while inertial measurements from the accelerometer and gyroscope provide short-term motion propagation and orientation stabilization. Localization updates are performed at approximately 2 Hz, corresponding to the experimental image acquisition interval of 0.5 m.

At the start of operation, localization is initialized using a single reference marker whose known position establishes alignment between the smartphone coordinate frame and the floor-plan coordinate system. After initialization, continuous localization proceeds without requiring persistent marker visibility.

To suppress long-term drift, the estimated pose p_t is projected onto the nearest feasible location defined by the floor-plan-derived walkable graph:

$$p'_t = \arg \min_{p \in \Omega} \|p_t - p\|$$

where Ω represents the set of valid walkable positions. This constraint ensures topological consistency between localization results and indoor layout structure while reducing accumulated positional deviation during extended indoor trajectories. The overall localization pipeline therefore consists of feature tracking, inertial motion propagation, pose fusion, coordinate initialization, and floor-plan feasibility projection.

Localization results are visualized directly on the indoor map, as shown in Figure 8, where the blue point represents the real-time estimated smartphone position and the green square box with arrow inside represents the position of the image captured in the direction of arrow.

4.2 Indoor Navigation using Smartphone

Based on the indoor localization results described in

section 4.1, the proposed system performs smartphone-based indoor navigation using floor-plan-derived connectivity information. Navigation is executed directly on the smartphone, and all route planning, guidance generation, and position updates are computed using the estimated device position on the indoor map.

The navigation process follows a structured workflow, as illustrated in Figure 9. First, the user selects a target floor map and specifies a destination point on the map. After the destination is set, the system searches for reference markers and generates an optimal navigation route based on predefined walkable paths and connectivity information. Once the route is generated, indoor navigation starts, and the device position is continuously updated in real time as the user or mobile platform moves. During navigation, the system provides guidance until the destination point is reached.

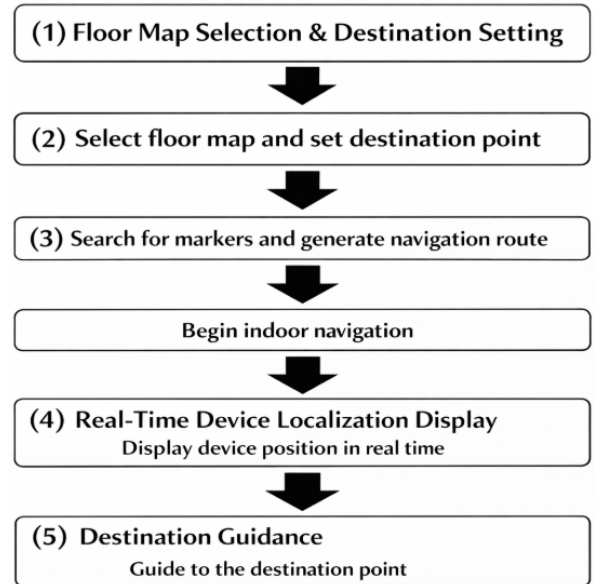


Figure 9. Workflow of smartphone-based indoor localization and navigation

The real-time navigation behaviour is visualized on the smartphone interface, as shown in Figure 10. The indoor floor plan is displayed together with navigation-related information, including the current estimated position, destination point, reference marker positions, and the planned route.

In Figure 10, the blue dot inside a blue circle represents the real-time estimated position of the smartphone, which is continuously updated based on the localization results. The destination point is shown in blue dot inside a red circle, the red dot inside a blue circle is the reference marker point. The route connecting the current position to the destination point is displayed on the map with blue line, providing intuitive visual guidance.



Figure 10. Smartphone screen showing the interface for indoor navigation

5. Experimentation and Evaluation

5.1 Experimental Setup and Localization Accuracy Results

Experimental evaluation was conducted to assess the accuracy and robustness of the proposed smartphone-only indoor self-localization and navigation system in non-GPS environments. Experiments were performed in two representative indoor environments at Waseda University. Environment A was a confined classroom space (Building 65, Room 504), while Environment B was a large open atrium area (Building 55, first floor). The experimental environments and predefined measurement paths are illustrated in Figure 11.

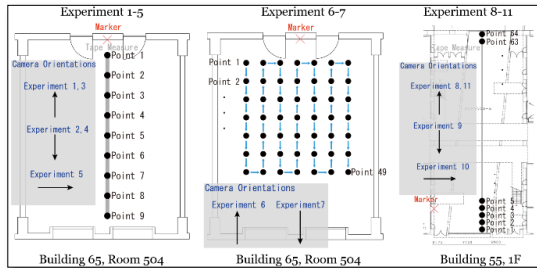


Figure 11. Experimental environments and predefined measurement paths used for accuracy evaluation

For localization initialization, a reference marker was placed at a known position in each environment. During experiments, images were captured at regular intervals of approximately 0.5 m along predefined walking paths. Most experiments were conducted using an iPhone 15, while one experiment was performed using an iPhone SE to examine the influence of device characteristics on localization performance.

A total of eleven experiments were designed to evaluate localization accuracy under different motion patterns and spatial scales. Experiments 1–5 focused on short straight-line motion with a total travel distance of 4 m. Experiments 6–7 evaluated grid-based motion following a 7×7 grid pattern to analyze accumulated positional drift. Experiments 8–11 involved long-range straight-line motion with a total travel distance of 32 m, representing extended indoor navigation scenarios.

Localization accuracy was evaluated using two quantitative metrics. First, relative localization error (%) was computed by comparing estimated step distance with the ground-truth step distance of 0.5 m. Second, accumulated positional drift was evaluated by measuring deviation from ideal grid reference positions in grid-based experiments. In addition, absolute positioning accuracy was quantified using the two-dimensional Euclidean error between estimated coordinates and tape-measured ground-truth positions.

The experimental results are summarized in Table 1, while detailed localization accuracy results for Environment A and Environment B are presented in Table 2 and Table 3, respectively. Figure 12 illustrates the distribution of relative localization errors across all experiments.

Table 1. Summary of Experiments for Indoor Localization

Exp. No.	Environment	Walking pattern	Travel distance	Purpose
1–4	Bldg. 65, Room 504	Straight (forward/backward)	4 m	Short-range accuracy
5	Bldg. 65, Room 504	Straight (sideways)	4 m	Direction sensitivity
6	Bldg. 65, Room 504	7×7 grid	24 m	Drift evaluation
7	Bldg. 65, Room 504	7×7 grid	24 m	Camera orientation effect
8	Bldg. 55, Atrium	Straight (forward)	32 m	Long-range accuracy
9	Bldg. 55, Atrium	Straight (backward)	32 m	Motion robustness
10	Bldg. 55, Atrium	Straight (sideways)	32 m	Motion robustness
11	Bldg. 55, Atrium	Straight (forward)	32 m	Device dependency

Table 2: Localization Accuracy Results in Environment A (Room 504)

Experiment	Motion type	Evaluation metric	Result
1–4	Forward / backward	Total relative error	0.6–0.9 %
5	Sideways	Total relative error	1.53 %
6	Grid	Mean step-wise error	0.88 %
7	Grid	Mean step-wise error	0.87 %

Table 3: Localization Accuracy Results in Environment B (Atrium)

Exp. No.	Motion type	Device	Total relative error
8	Forward	iPhone 15	0.61 %
9	Backward	iPhone 15	0.18 %
10	Sideways	iPhone 15	0.27 %
11	Forward	iPhone SE	0.94 %

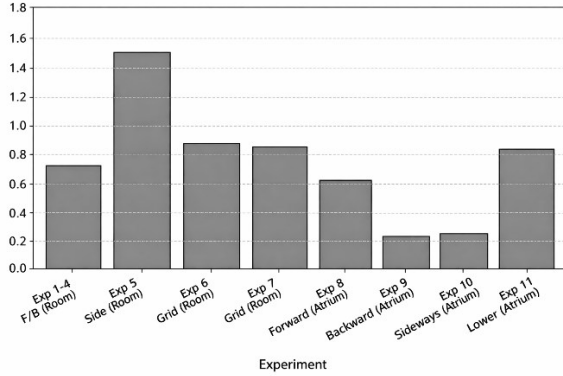


Figure 12: Localization Accuracy from Experiment 1-11.

5.2 Baseline Comparison and Drift Growth Analysis

To further contextualize the localization performance observed in both experimental environments, a baseline comparison was conducted with unconstrained smartphone visual-inertial odometry (VIO). The localization accuracy results reported in Table 4 for Environment A and Table 5 for Environment B indicate that the proposed floor-plan-constrained approach maintains low relative error and controlled drift across different spatial configurations. These results are therefore compared with typical drift characteristics of infrastructure-free smartphone VIO to analyze the effectiveness of spatial constraint integration.

Because visual-inertial odometry provides relative pose estimation, accumulated positional drift generally increases with travelled distance. Engineering benchmarks suggest that consumer smartphones may exhibit approximately 0.3-0.8 m positioning error over short indoor trajectories (5-10 m), increasing to approximately 1-3 m after several tens of meters depending on motion conditions and visual feature availability.

To further validate drift growth behavior, an additional corridor experiment exceeding 50 m travel distance was conducted. Under stable motion conditions, the proposed method demonstrated approximately 0-1 m maximum drift relative to ground-truth references, whereas increased dynamic disturbances resulted in drift values approaching 3 m. The results indicate that floor-

plan-derived spatial constraints significantly suppress drift accumulation during extended indoor navigation.

Table 4: Drift Growth Comparison between Baseline VIO and Proposed Method

Travel Distance	Baseline Smartphone VIO Drift (m)	Proposed Method Drift (m)
5-10 m	0.3-0.8	<0.2
20-30 m	0.8-2.0	0.2-0.4
>50 m	1-3	0-1

Table 5: Representative Indoor Localization Accuracy Comparison

Method	Typical Absolute Horizontal Error	Remarks
Smartphone GPS / generic mobile positioning	10-20 m	Indoor signal attenuation
Wi-Fi / BLE beacon systems	2-5 m	Requires infrastructure
Smartphone visual-inertial odometry	1-3 m (after ~30-50 m)	Drift accumulation
Proposed method	~0-1 m	Infrastructure-free

6. Discussion and Conclusion

This paper presented a smartphone-only indoor self-localization and navigation system for non-GPS environments that integrates a patrol-free, floor-plan-based map creation method with smartphone-based visual-inertial localization. Experimental results demonstrated that the proposed system consistently achieved sub-1% relative localization error across both confined and large indoor environments without relying on external positioning infrastructure, environment scanning, or specialized hardware. The results further showed that localization accuracy is influenced by motion direction and camera performance, while floor-plan-based spatial constraints effectively suppress accumulated drift during navigation.

In addition, the feasibility of extending the proposed smartphone-based localization and navigation framework to autonomous indoor mobile platforms was verified using a commercial off-the-shelf drone, demonstrating the platform-independent nature of the approach. Overall, the proposed system provides a lightweight, scalable, and easily deployable solution for

indoor localization, navigation, and spatial data acquisition, making it well suited for construction, facility management, and other indoor operational environments.

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