Functional Specification of LOC-INDOOR (Indoor Localisation)

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Line-Based Floor Navigation with AR Integration

Project Name: Indoor Navigation System with AR Integration

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1. Introduction

1.1 Purpose

This functional specification document outlines the detailed requirements and system design for an indoor navigation application that utilizes Augmented Reality (AR) and Bluetooth beacon technology. The system aims to solve the challenge of navigating complex indoor environments by providing intuitive, visual guidance through a mobile application.

1.2 Project Scope

The project encompasses the development of a mobile application for Android (with plans to expand to iOS) that provides real-time, line-based navigation guidance in indoor spaces where traditional GPS is ineffective. The system will utilize Bluetooth beacons for positioning and Augmented Reality to overlay directional guidance on the user's view of the physical environment. The beacons are placed at specific locations in the building, moreover, they come with their SDK, containing all the desired functionalities. While the basic concept of indoor navigation with beacons exists, our app uses augmented reality to show a clear line on the real floor, guiding people step by step inside buildings. Unlike apps that only use maps or arrows, this is much easier to follow, especially in big places like malls, hospitals, or airports. We use beacons to ensure the line stays in the right place and works well. This makes the navigation more accurate and useful in many different locations.

1.3 Intended Audience

- Development team
- Project stakeholders
- Potential venue partners
- Investors and funding partners

2. Project Overview

2.1 Problem Statement

Users frequently struggle with navigation in complex indoor environments such as airports, shopping malls, hospitals, and large public buildings, This is because the satellite can not detect someone's position inside a building because of walls. Traditional navigation solutions that rely on GPS are ineffective in these spaces.

2.2 Solution Description

The solution will implement a marker-based floor navigation system with AR overlays, inspired by racing video games like Forza Horizon in Unity. When users select a destination within a venue, the application will display a directional line on the floor through their device's camera view, guiding them seamlessly to their chosen location. Bluetooth beacons strategically placed throughout the venue will provide precise location data to ensure accurate navigation. The question is why choosing this technology, after a great reflection I find out that other solution make use of 2D view indoor navigation, but since I wanted something more user friendly, The decision of implemening it in Unity AR was the best option.

- Unity has AR Foundation, a cross-platform framework that supports both ARKit (iOS) and ARCore (Android).
- Unity is generally lighter and better optimized for mobile devices, especially low to mid-range smartphones.
- For indoor AR navigation (which needs smooth performance), Unity is less resource-intensive than Unreal Engine.
- Unity has a large ecosystem with many ready-to-use plugins for:
  - Bluetooth beacon integration.
  - Indoor positioning.
  - 2D/3D floor plans.
  - AR UI tools.

3. User Personas

Persona 1: Traveler - Sarah Thompson
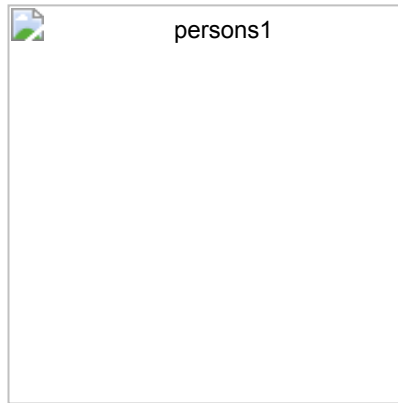
persons1

Persona 2: Mall Shopper - Marcus Johnson

persons1

Persona 3: Accessibility User - Elena Vasquez

persons1

Persona 4: Hospital Visitor - Robert Chen

persons1

Persona 5: First-time Visitor - Mei Chen

persons1

4. User Stories

1. **Airport Navigation**

   - As a traveler in an unfamiliar airport, I want to easily find my connecting gate so that I don't miss my flight.
   - As a passenger arriving at an airport, I want to find the nearest restroom, restaurant, or baggage claim area quickly.

2. **Shopping Mall Navigation**

   - As a shopper, I want to find specific stores or services within a large mall without checking physical directories.
   - As a mall visitor, I want to find the closest exit from my current location.

3. **Hospital/Healthcare Facility Navigation**

   - As a patient or visitor, I want to find specific departments or rooms within a hospital complex.

4. **Special Needs Users**

   - As a user with mobility challenges, I want clear guidance that takes into account accessibility routes.

5. Use Cases

5.1 Core Use Cases

UC-1: Airport Navigation

Primary Actor: Traveler (Sarah) **Preconditions:**

- User has installed the application
- Airport has deployed beacon infrastructure
- User has granted necessary permissions

Main Flow:

1. User opens the application upon arriving at the airport

2. System detects user's location and displays available airport map

3. User searches for their departure gate number

4. System displays gate location on map

5. User selects "Navigate to Gate"

6. System activates AR view showing line on floor to follow

7. User follows the line, which adjusts in real-time as they move

8. System provides notifications for turns and level changes

9. System confirms arrival when user reaches the gate

Postconditions:

- User arrives at intended destination
- System logs successful navigation for analytics
- System prompts user for optional feedback

UC-2: Shopping Mall Navigation

Primary Actor: Mall Shopper (Marcus) **Preconditions:**

- User has installed the application
- Mall has deployed beacon infrastructure
- Mall directory is updated in the system

Main Flow:

1. User enters the mall and opens the application

2. System detects location and displays mall layout

3. User searches for a specific store by name

4. System highlights store location on map

5. User selects "Navigate" option

6. System activates AR view with floor line

7. User follows the displayed path

8. System provides distance updates and directional guidance

9. User arrives at the store

Postconditions:

- User arrives at store.
- Navigation session is stored in history.

UC-3: Accessible Route Navigation

Primary Actor: Accessibility User (Elena) **Preconditions:**

- User has installed application and set accessibility preferences

- Venue has accessible routes mapped in system
- Beacon infrastructure is installed

Main Flow:

1. User opens application in venue
2. System automatically applies accessibility profile
3. User searches for destination
4. System calculates route prioritizing accessible paths, elevators, and ramps
5. User initiates navigation
6. System displays AR guidance with additional accessibility information
7. User follows path optimized for mobility needs
8. System provides advance notice of elevators, ramps, and potential obstacles
9. User successfully navigates to destination

Postconditions:

- User arrives at destination via accessible route
- System logs route effectiveness for accessibility
- User can provide feedback on route accessibility

UC-4: Hospital Visitor Navigation

Primary Actor: Hospital Visitor (Robert Chen) **Preconditions:**

- User has installed the application
- Hospital has deployed beacon infrastructure
- Visitor has basic patient room information

Main Flow:

1. Visitor arrives at hospital parking area and opens the application
2. System detects user's location and displays hospital overview
3. Visitor enters patient information (room number)
4. Visitor selects "Navigate to Patient Room"
5. System calculates optimal route from current location, including entry point selection
6. System activates AR view showing floor line to follow
7. System guides visitor through building entry, security checkpoints, and elevator/stair usage
8. Visitor follows the guided path with clear indicators for building transitions
9. System provides estimated arrival time and notifies visitor upon reaching the correct room

Postconditions:

- Visitor successfully locates patient room
- System creates a "frequent route" for easy access during future visits
- Navigation history allows quick return to previously visited locations

5.2 Additional Use Cases

UC-5: Multi-Destination Planning

Primary Actor: Mall Shopper (Marcus) **Preconditions:**

- User has application installed
- User is in mapped venue
- User has multiple destinations to visit

Main Flow:

1. User opens application and selects "Plan Visit"
2. User adds multiple destinations to visit list
3. System suggests optimal order based on layout
4. User confirms or adjusts order
5. System generates route visiting all destinations efficiently
6. User initiates navigation to first destination
7. Upon arrival, system prompts to continue to next location
8. Navigation continues until all destinations are visited

Postconditions:

- User completes all planned destinations
- System logs complete journey
- User can save route for future visits

6. Functional Requirements

6.1 Core Functional Requirements

FR-1: User Location Detection

- The system determine the user's precise indoor location using Bluetooth beacon technology.
- The system update the user's position in real-time (minimum refresh rate of 1 Hz).
- The system achieve positioning accuracy of at least 0.7 meters in areas with proper beacon coverage.

FR-2: Destination Selection

- Display a searchable directory of available destinations within the venue.
- Users can select destinations from categories (Restaurants, Stores, Services, Rooms).
- The system support saving favorite or frequently visited destinations.

FR-3: AR Navigation Guidance

- The system displays a continuous directional line on the floor leading from the user's current position to their destination.
- Adjust the displayed path in real-time as the user moves.
- Provide visual cues for turns, elevators, escalators, and other navigation decision points.
- The system display distance to destination and estimated arrival time.

FR-4: Multi-floor Navigation

- The system shall guide users between different floors using appropriate vertical transportation (stairs, elevators, escalators).
- The system shall clearly indicate floor transitions in the AR guidance.
- The system shall automatically detect floor changes based on beacon data.

FR-5: Route Customization

- Offering route preferences (e.g., shortest path, accessible path).
- Allowing users to avoid specific areas or types of areas.

6.2 Additional Functional Requirements

FR-6: Offline Functionality

- The system shall provide navigation functionality even when internet connectivity is limited.

FR-7: User Profile and Settings

- The system allow users to create and manage profiles.
- The system support customization of navigation preferences.
- The system shall remember frequently visited locations.

FR-8: Accessibility Features

- The system shall support high-contrast modes for visibility.
- The system shall prioritize accessible routes for users who indicate mobility requirements.

7. Non-Functional Requirements

7.1 Usability Requirements

NFR-1: User Interface

- The user interface shall be intuitive and require minimal training for basic navigation tasks.
- The system shall be usable with one hand during navigation.
- Text elements shall adhere to minimum contrast ratios of 4.5:1 for normal text and 3:1 for large text.
- The application shall support portrait and landscape orientations.
- The AR view shall include clear visual cues that are distinguishable even in varied lighting conditions.

NFR-2: Accessibility

- The application shall be compatible with screen readers.
- All interactive elements shall be accessible via alternative input methods.
- The application shall comply with WCAG 2.1 AA standards where applicable.
- Cognitive load shall be minimized during navigation tasks.
- Text size shall be adjustable to accommodate users with visual impairments.

NFR-3: Learning Curve

- First-time users shall be able to successfully navigate to a destination with 90% success rate within 5 minutes of initial app use.
- The onboarding tutorial shall be completable in less than 2 minutes.
- Error messages shall be clear and provide actionable guidance.

7.2 Reliability Requirements

NFR-4: System Stability

- The application shall have a crash rate of less than 0.1% per navigation session.
- The system shall maintain functionality despite temporary loss of individual beacons.
- Recovery from loss of all beacon signals shall be graceful with clear user notifications.
- The application shall maintain state information to resume navigation after unexpected closure.

NFR-5: Availability

- The core navigation system shall be available 99.9% of the time when within beacon coverage.
- Beacon battery replacement shall be staggered to prevent simultaneous failure.
- System updates shall not disrupt active navigation sessions.

NFR-6: Fault Tolerance

- The system shall continue to function with degraded accuracy if up to 30% of beacons are non-functional.
- The system shall automatically recover from intermittent connectivity issues.

7.3 Performance Requirements

NFR-7: Response Time

- The application shall launch and be ready for navigation within at most 10 seconds on target devices.
- Route calculation shall complete within 3 seconds of destination selection.
- AR overlay shall render within 100ms of camera frame capture.
- Position updates shall be processed within 200ms of receiving beacon signals.
- UI interactions shall respond within 150ms to maintain perception of immediacy.

NFR-8: Resource Utilization

- The application shall use no more than 200MB of RAM during typical operation.

- Battery consumption shall not exceed 15% per hour of active navigation.

- Disk storage requirements shall not exceed 100MB excluding cached venue data.

- CPU utilization shall remain below 30% during normal operation.

- Network data usage shall not exceed 10MB per hour.

NFR-9: Scalability

- The system architecture shall support up to 10,000 concurrent users per venue.

- The backend shall handle up to 100 venue deployments without significant performance degradation.

- Database design shall accommodate venues with up to 10,000 distinct navigation points.

- API endpoints shall scale to handle 1,000 requests per second during peak usage.

7.4 Supportability Requirements

NFR-10: Compatibility

- The mobile application shall support Android 10.0 and newer (initially).

- The mobile application shall support iOS 14.0 and newer (future release).

- The application shall function on devices with minimum specifications: 2GB RAM, Quad-core 2.0 GHz processor.

- The application shall adapt to different screen sizes from 4.7" to 12.9".

- The AR components shall be compatible with ARCore 1.20+ and ARKit 4.0+ (future release).

NFR-11: Localization

- The user interface shall support easy translation to multiple languages.

- The application shall initially support English, French.

- Text expansion in translations shall not break UI layouts.

- The system shall support right-to-left languages in future updates.

7.5 Security Requirements

NFR-12: Data Protection

- All personally identifiable information shall be encrypted using industry-standard encryption (minimum AES-256).

- Location history shall be stored on the device with optional cloud backup.

- Users shall have the ability to clear all personal data from the application.

- Compliance with GDPR, CCPA, and other relevant privacy regulations shall be maintained.

NFR-13: Authentication

- User accounts shall require strong password policies.

- The system shall support multi-factor authentication for administrative access.

- OAuth 2.0 integration shall be supported for social login options.

NFR-14: Security Testing

- The application shall undergo penetration testing before each major release.

- Automated security scanning shall be integrated into the CI/CD pipeline.

- API endpoints shall be protected against common attacks (SQL injection, XSS, CSRF).

- Security vulnerabilities shall be addressed with critical priority.

8. System Architecture

8.1 High-Level Architecture

The system will follow a client-server architecture with the following components:

1. **Mobile Application (Client)**

   - AR Navigation Interface
   - Positioning System (Bluetooth Beacon Integration)
   - Map Rendering Engine
   - User Interface Components
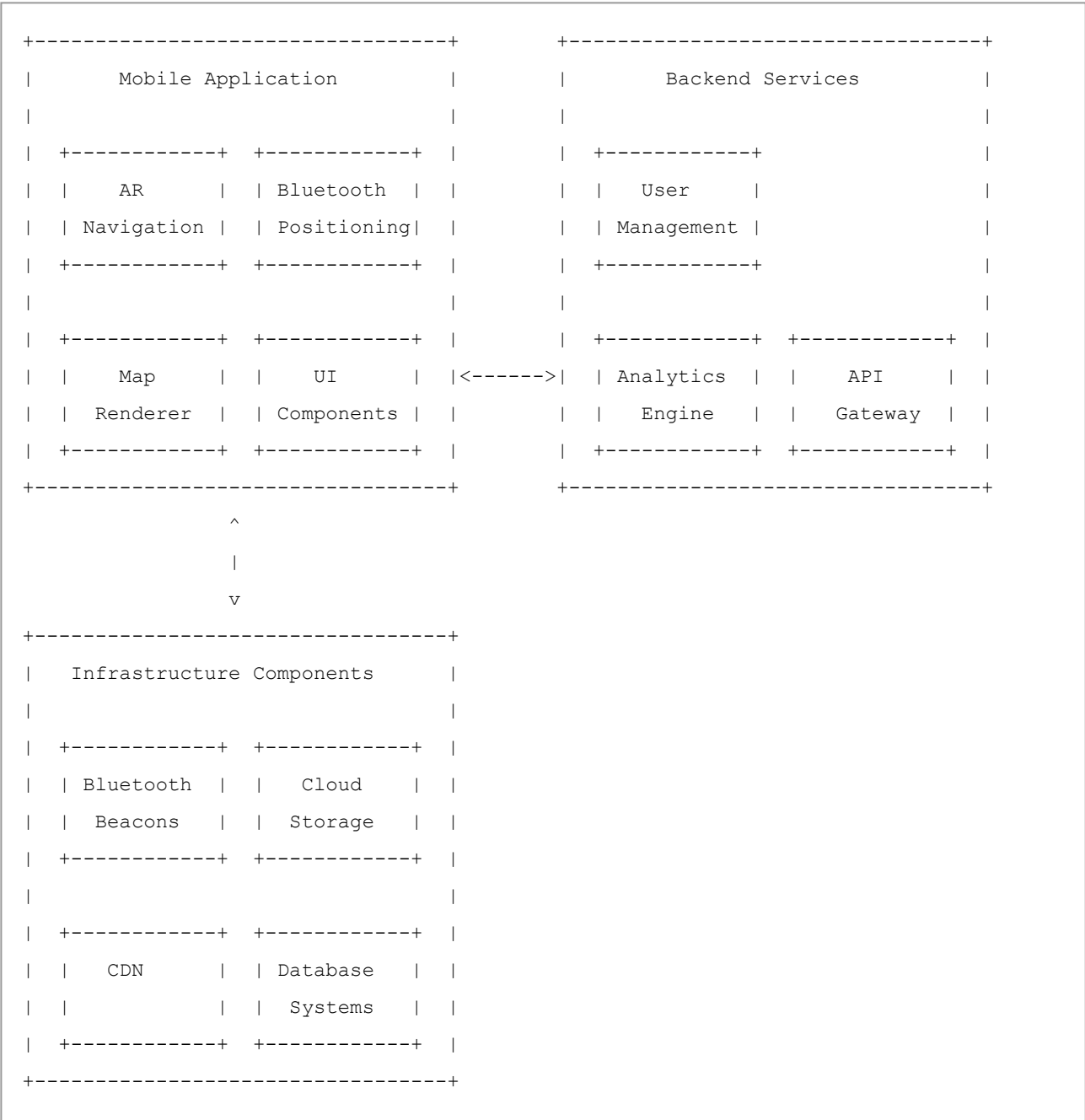
2. **Backend Services (Server)**

   - User Management
   - Venue Data Management
   - API Gateway

3. **Infrastructure Components**

   - Bluetooth Beacons Network
   - Cloud Storage
   - Content Delivery Network
   - Database Systems

8.2 Architectural Diagram

```
+-------------------------------+        +--------------------------------+
|      Mobile Application        |        |       Backend Services         |
|                               |        |                                |
|  +-----------+  +-----------+  |        |  +-----------+                 |
|  |    AR     |  | Bluetooth |  |        |  |   User    |                 |
|  | Navigation|  | Positioning|  |        |  | Management |                 |
|  +-----------+  +-----------+  |        |  +-----------+                 |
|                               |        |                                |
|  +-----------+  +-----------+  |        |  +-----------+  +-----------+  |
|  |    Map    |  |    UI     |  |<------>|  | Analytics |  |    API    |  |
|  |  Renderer |  | Components |  |        |  |  Engine   |  |  Gateway  |  |
|  +-----------+  +-----------+  |        |  +-----------+  +-----------+  |
+-------------------------------+        +--------------------------------+
                    ^
                    |
                    v
+-------------------------------+
|   Infrastructure Components    |
|                               |
|  +-----------+  +-----------+  |
|  | Bluetooth |  |   Cloud   |  |
|  |  Beacons  |  |  Storage  |  |
|  +-----------+  +-----------+  |
|                               |
|  +-----------+  +-----------+  |
|  |    CDN    |  | Database  |  |
|  |           |  |  Systems  |  |
|  +-----------+  +-----------+  |
+-------------------------------+
```

9. Technical Components

9.1 Mobile Application Components

9.1.1 AR Development Platform
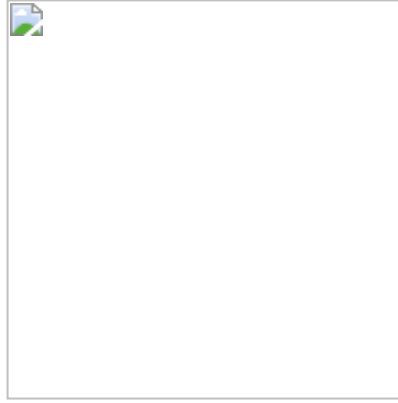
- **Unity AR Foundation (https://unity.com/solutions/xr/ar)**
  - Purpose: Provides a unified interface for building AR applications for both Android and iOS
  - Key Features:
    - Camera access and management
    - Motion tracking
    - Environmental understanding
    - Light estimation
    - Image recognition

9.1.2 Line-Based AR Library

- **Vectrosity**
  - Purpose: Enables the drawing of vector graphics in Unity
  - Key Features:
    - High-performance line rendering
    - Dynamic path updates
    - Customizable line appearance
    - Optimization for mobile devices

9.1.3 Bluetooth Beacon Integration

- **Beacon SDK (https://www.minew.com/product/mbm01-ultra-long-range-beacon/)**
  - Purpose: Detects and interacts with Bluetooth beacons
  - Supported SDK Protocols:
    - iBeacon for iOS
    - Eddystone for Android
    - AltBeacon for both iOS/Android
  - Key Features:
    - Background scanning
    - Distance estimation

9.1.4 Positioning Algorithm

- **Trilateration Engine**
  - Purpose: Calculates precise position based on beacon signals
  - Key Features:
    - Multi-beacon triangulation

- Floor detection

9.1.5 Map Rendering

- **3D Map Engine**
  - Purpose: Displays venue maps and integrates with AR components
  - Key Features:
    - Multi-floor visualization
    - POI (Point of Interest) rendering
    - Dynamic path calculation
    - Map rotation based on device orientation

9.2 Backend Components

9.2.1 User Management Service

- **Authentication System**
  - User registration and login
  - Profile management
  - Session management

9.2.2 Venue Data Management

- **CMS for Venue Information**
  - Floor plan management
  - POI management
  - Beacon configuration
  - Path network definition

9.2.3 API Gateway

- **RESTful API Services**
  - Authentication endpoints

9.3 Infrastructure Components

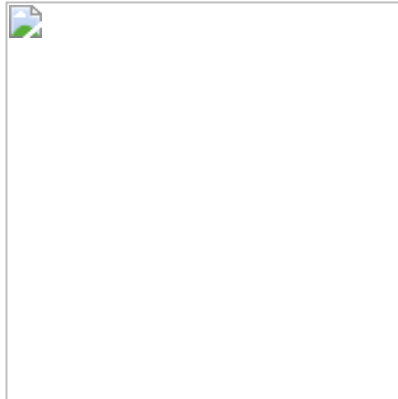- Bluetooth Beacon Specification (MBM01%20Ultra-Long%20Range%20Beacon.pdf)

10. User Interface Design

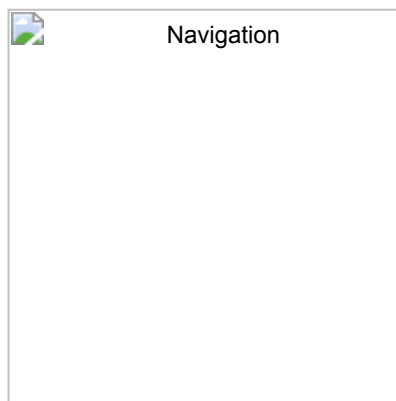## 10.1 Core Screens

10.1.1 Onboarding Screens

- Introduction to the application

- Login/Sign-In page.
- Permission requests (camera, location)
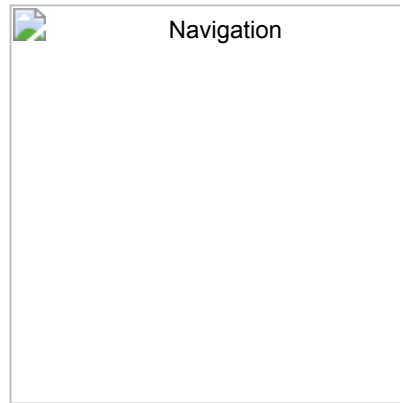- Basic tutorial on using AR navigation

10.1.2 Destination Selection Screen

- Searchable directory
- Category-based browsing
- Favorites and recents
- Destination details

Navigation

10.1.3 AR Navigation View

- Camera view with AR overlay
- Directional line on floor
- Distance and ETA indicators
- Floor indicators for multi-floor navigation

Navigation

10.2 UI Components

10.2.1 Information Displays

- Distance remaining
- Estimated time to arrival
- Current floor indicator
- Next direction indicator

10.2.2 Search and Filter Components

- Search bar with autocomplete
- Category filters
- Accessibility filters

10.3 Technology

- React will be used for the front-end developement

11. Integration Requirements

11.1 Map Integration

11.1.1 Floor Plan Format Requirements

- Coordinate system alignment with physical space
- POI annotation support

11.2 External System Integration

11.2.1 Venue Management Systems

- API integration with existing venue CMS
- Data synchronization protocols

- Event notification system

12. Performance Requirements

12.1 Positioning Accuracy

- Horizontal accuracy: ±0.7 meters in areas with proper beacon coverage
- Floor detection accuracy: 99% in areas with proper beacon coverage
- Position update rate: minimum 1 Hz, target 5 Hz

12.2 Response Time

- Initial route calculation: <3 seconds
- Route update after position change: <500ms
- AR rendering latency: <100ms
- UI responsiveness: <200ms for user interactions

12.3 Resource Utilization

- Memory usage: <200MB during active navigation
- CPU usage: <30% of device capability
- Battery impact: <15% per hour of active navigation on an Android phone version 11 and above
- Data usage: <10MB for initial venue download, <1MB per hour during navigation

12.4 Scalability

- Support for venues up to 200,000 square meters
- Support for up to 1,000 POIs per venue
- Support for up to 500 beacons per venue
- Concurrent users: up to 1,000 per venue

13. Security Considerations

13.1 Data Security

- End-to-end encryption for all network communications
- Secure storage of user credentials and preferences
- Compliance with GDPR and other relevant privacy regulations

13.2 Application Security

- Secure API authentication
- Input validation and sanitization

Glossary - Indoor Navigation System with AR Integration

A

AR (Augmented Reality): Technology that overlays digital information onto the real world viewed through a device's camera, used in this system to display directional lines on the floor.

AltBeacon: An open-source Bluetooth Low Energy beacon protocol alternative to proprietary protocols.

Accessibility Route: A navigation path that prioritizes elevator access, ramps, and avoids stairs for users with mobility impairments.

B

Beacon: A small Bluetooth Low Energy (BLE) transmitter that broadcasts signals used to determine a user's position within an indoor environment.

BLE (Bluetooth Low Energy): A wireless personal area network technology designed for applications in healthcare, fitness, beacons, security, and home entertainment industries that require devices to exchange small amounts of data periodically while maintaining long battery life.

C

CMS (Content Management System): Software used to manage the creation and modification of venue information, floor plans, and points of interest.

E

Eddystone: An open beacon protocol from Google that defines several different frame types that can be used individually or in combinations to create beacons that address a variety of different use cases.

F

Floor Plan: A scaled diagram of a venue showing walls, doors, and other physical features from an overhead view, used as the base map for the navigation system.

H

Heatmap: A graphical representation of data where values are represented as colors, used in this system to visualize user traffic patterns within venues.

I

iBeacon: Apple's protocol for Bluetooth Low Energy (BLE) proximity sensing that enables smartphones, tablets and other devices to perform actions when in close proximity to an iBeacon.

Indoor Positioning System (IPS): A network of devices used to locate people or objects where GPS is inadequate, such as inside buildings.

K

Kalman Filtering: A mathematical algorithm used to reduce noise and smooth position data from multiple beacon signals.

L

Line-Based Navigation: The system's core feature that displays a continuous directional line on the floor through AR, guiding users to their destination.

M

- **Multi-floor Navigation:** The ability of the system to guide users between different floors of a building using appropriate vertical transportation methods.
- **MBBS:** (Bachelor of Medicine, Bachelor of Surgery) is professional degree awarded in some countries, equivalent to the MD degree

N

Node-Edge Graph: A mathematical structure used to model the network of possible paths in a venue, where nodes represent intersections or points of interest and edges represent walkable paths.

P

- **POI (Point of Interest):** A specific location within a venue that may be a destination or landmark, such as a store, restaurant, restroom, or information desk.

- **Positioning Algorithm:** The software process that calculates a user's exact location based on signals received from multiple beacons.

R

- **Route Calculation:** The process of determining the optimal path between a user's current location and their desired destination.
- **ROI:** Return Of Investment.

S

Signal Strength: The measure of power present in a beacon's radio signal, used to estimate distance from the beacon to the user's device.

SVG (Scalable Vector Graphics): An XML-based vector image format used for floor plans that allows for high-quality scaling without loss of detail.

T

Trilateration: A method to determine position by measuring distances to multiple beacons at known locations.

U

UI (User Interface): The means by which users interact with the application, including screens, buttons, and visual elements.

UX (User Experience): The overall experience of a person using the application, especially in terms of how easy or pleasing it is to use.

V

Venue: A physical location where the navigation system is implemented, such as an airport, shopping mall, hospital, or convention center.

Vertical Transportation: Methods of moving between floors in a building, including elevators, escalators, and stairs, which are accounted for in the navigation system.

W

Wayfinding: The process of determining and following a route between an origin and a destination, which this system aims to simplify through AR guidance.

WCAG (Web Content Accessibility Guidelines): A set of recommendations for making content accessible to people with disabilities, which the system adheres to for its user interface.