AI Assisted Navigation Device

Software Requirements Specification (SRS)

Prepared by:
Documentation Team

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1. Introduction

1.1 Problem Definition

Navigating indoor spaces independently remains a significant challenge for individuals with visual impairments, mobility limitations, or cognitive differences. Environments such as university libraries often lack dynamic, context-aware guidance tools. Traditional solutions white canes, static signage, or reliance on guide dogs provide limited spatial context and can compromise user autonomy.

Some assistive technologies leverage computer vision or sensor arrays, but these are often costly, bulky, or raise ethical concerns due to continuous video capture. Such concerns are heightened in privacy-regulated spaces like university libraries, where camera-based systems may be restricted by ICT policies.

This project addresses these challenges by proposing a two-layer AI-assisted navigation system:

- A **smartphone-based vision system** for machine learning–driven obstacle detection.
- A **sensor-based prototype** using ultrasonic modules for real-time physical feedback.

The hybrid model provides reliable detection and navigation support while respecting privacy and avoiding cloud dependency.

1.2 Purpose of the System

The purpose of this system is to provide an ethical, accessible, and privacy-conscious indoor navigation tool for students with disabilities. It focuses on:

- **Obstacle detection** using on-device camera ML models.
- **Navigation feedback** through haptic and audio alerts.
- **Sensor-based redundancy** to ensure safety and reliability.

By discarding data after processing and avoiding persistent surveillance, the system ensures compliance with ethical standards. It also demonstrates a cost-effective and scalable approach suitable for academic environments.

1.3 Scope

Included in this phase:

- Camera-based obstacle detection indoors.
- Pre-trained ML models for common obstacles (chairs, shelves, signage).
- Real-time voice and haptic feedback.
- On-device processing without cloud reliance.
- Prototype testing within Deakin Library.

Excluded in this phase:

- Outdoor navigation or GPS integration.
- Multi-room dynamic mapping.
- Full sensor fusion (planned for later phases).

1.4 Stakeholders

The following groups are identified as key stakeholders:

- **End Users:** Students with accessibility needs at Deakin University.
- **Mekong Inclusive Ventures (MIV):** Innovation and accessibility partner.
- **Deakin University:** Pilot host and ethics review authority.
- **Software Team:** Responsible for ML model training and app development.
- **Hardware Team:** Responsible for prototyping and sensor integration.

2. General Description

2.1 Product Perspective

The proposed navigation system contributes to the broader category of assistive technologies aiming to improve indoor mobility and independence. While existing solutions rely on GPS, specialized headsets, or expensive wearables, our solution leverages common smartphone hardware and modular sensor components to reduce cost and complexity.

The project consists of two primary subsystems:

- **Mobile vision system**: A smartphone app running an on-device machine learning model (e.g., YOLOv8), capable of identifying indoor obstacles using the phone's camera. This provides semantic awareness e.g., recognizing a "chair" or "bookshelf."
- **Sensor-based subsystem**: An external prototype using ultrasonic sensors, powered by an Arduino microcontroller. This system detects obstacles and orientation changes, offering spatial awareness with audio or vibration alerts.

While these subsystems currently operate independently, they are designed for future integration, where sensor fusion will allow coordinated interpretation of physical and visual data.

2.2 User Characteristics

The target user base for this system includes students at Deakin University who require enhanced accessibility support for indoor navigation. These users represent a diverse range of accessibility needs and varying levels of familiarity with technology.

Primary user groups:

- **Visual impairments:** Users who are blind or have low vision and require **non-visual environmental feedback** to navigate spaces safely.
- **Mobility limitations:** Wheelchair users or individuals with restricted movement who require **real-time alerts** to avoid inaccessible routes, stairs, or narrow spaces.
- **Cognitive impairments:** Students with conditions such as ADHD, dyslexia, or short-term memory challenges who benefit from simplified, sequential directional cues and reduced cognitive load.

Common user traits and preferences:

- **Variable digital literacy:** Some users may be highly tech-savvy (e.g., familiar with screen readers and assistive apps), while others may have minimal technology experience.

- **Preference for discreet, hands-free interaction:** Feedback should be delivered in a way that maintains dignity and independence in public environments.
- **Need for low cognitive load:** Information must be concise, easy to interpret, and free from unnecessary complexity.
- **Offline capability:** The system must function without requiring internet connectivity, avoiding login barriers and cloud dependencies.

Accessibility design principles applied:

- **Inclusive UX principles:** Minimal setup, voice control integration, modular feedback strength, and intuitive interaction flow.
- **Compatibility with assistive technologies:** Seamless operation alongside screen readers.

2.3 User Personas

User Persona 1

Name: Anita Sharma
Age: 24
Background: Anita is a university student who has partial blindness. She spends most of her day moving between lecture halls, the library, and the cafeteria.
Needs: She needs a simple and reliable way to navigate indoors without depending on others.
Frustrations: Current solutions she has tried are either too costly, not designed for indoor use, or lack proper accessibility options.
Goals: Anita wants to be able to attend her classes and move around campus confidently and independently.

User Persona 2

Name: Raj Patel
Age: 55
Background: Raj works as an office manager. He has been dealing with deteriorating vision for the past few years.
Needs: He needs a tool that can help him safely move around busy office spaces and public buildings.
Frustrations: He often struggles with stairs, crowded hallways, and signs that are not accessible. Most navigation apps are focused on outdoor use, which doesn't help him indoors.

Goals: Raj wants to continue working confidently and be able to move around independently in his workplace without always asking for help.

User Persona 3

Name: Maria Lopez
Age: 68
Background: Maria is retired and enjoys visiting community centers and shopping malls. She has severe vision loss and sometimes uses a cane.
Needs: She needs support for navigating large indoor areas like malls or clinics where it's easy to get disoriented.
Frustrations: She finds existing solutions complicated to set up or not suited for older users who aren't very tech-savvy.
Goals: Maria wants something easy to use that gives her confidence when going out, so she can stay active and independent.

User Persona 4

Name: Chloe Edwards
Age: 27
Background: Chloe is a PhD candidate in architecture with limited mobility due to chronic joint pain. She uses crutches on some days and a mobility scooter on others.
Needs: She needs a system that helps her avoid physically demanding paths (e.g., stairs, steep ramps) and crowded hallways.
Frustrations: Most systems do not adapt to different modes of mobility or recognize physical fatigue as a factor in navigation.
Goals: Chloe wants a reliable system that adapts to her physical condition on the day and helps her conserve energy while moving between study zones.

User Persona 5

Name: Zoe Atkinson
Age: 22
Background: Zoe is a psychology student with ADHD and sensory sensitivity. She prefers calm environments and minimalist interfaces.
Needs: She needs clear, step-by-step instructions that don't overwhelm her and allow her to focus while navigating.
Frustrations: Overly complex voice prompts, sudden noises, and visual clutter in apps

distract and confuse her.
Goals: Zoe wants to confidently navigate the library and other buildings using a system that's calm, clear, and easy to follow.

2.4 Assumptions and Dependencies

The successful development, deployment, and testing of the system are based on the following operational and environmental assumptions:

User-related assumptions:

- Users will voluntarily opt in and provide informed consent for participation in trials.
- Participants will be briefed on system capabilities, limitations, and safety considerations before use.

Environmental assumptions:

- Indoor testing spaces, such as the Deakin Library, will maintain relatively stable layouts during the testing period, avoiding major furniture rearrangements or renovations.
- Adequate lighting and unobstructed beacon placement will be maintained to ensure consistent sensor performance.

Institutional and technical dependencies:

- The university will grant permissions for temporary camera use during trials in designated testing areas.
- The system will operate entirely offline, requiring no network or cloud services for navigation.
- All processing will occur on-device, and data will not be stored beyond the processing phase to ensure privacy compliance.
- Parallel hardware units (e.g., Arduino-based ultrasonic sensor prototypes) will be tested separately but follow a shared user-centered design framework for consistent experience.

Privacy and policy dependencies:

- Compliance with **Deakin University ICT policies**, **Privacy Act 1988**, and **Disability Discrimination Act 1992** will be maintained at all stages.

3. Functional Requirements

3.1 User Stories

US 1-Obstacle alerts:

As a visually impaired student, I want the device to give me a quick warning when something is in my way, so I don't bump into things indoors.

US 2-Directional guidance:

As a user, I want the feedback to tell me clearly whether to go left, right, or stop, so I can move around with confidence.

US 3-Hands-free control

As a user, I'd like to use voice commands to start or stop navigation, or repeat the last instruction, so I don't have to touch the phone all the time.

US 4-Location awareness

As a user, I want the system to tell me when I'm close to important spots like elevators or classrooms, so I know I'm in the right place.

US 5-Privacy mode

As a user, I want the option to turn off the camera and still get guidance, so I feel comfortable in places where privacy is important.

3.1 Location Detection

- The system will determine approximate user location indoors.

3.2 Obstacle Detection

- Ultrasonic sensors detect objects within a range in three directions
- Detection triggers immediate feedback via haptic vibration or audio cues.
- Capable of identifying static objects (e.g., furniture).

3.3 Navigation Feedback

- **Text-to-Speech (TTS)** engine delivers context-specific verbal instructions.
- **Voice command integration** allows destination selection without manual input.

3.4 User Input Options

- **Voice-based input** for hands-free operation.
- **Physical controls** for accessibility in noisy environments.

4. Interface Requirements

4.1 User Interface (Audio, Haptic)

- No reliance on visual UI elements, allowing accessibility for blind and low-vision users.
- **Audio feedback** delivered via earphones or bone conduction headphones.
- **Haptic feedback** provided through wearable devices or handheld controllers.
- User-adjustable audio volume and vibration intensity.

4.2 Hardware Interface

The hardware subsystem is designed around the integrated sensors and feedback mechanisms of modern smartphones, eliminating the need for external microcontrollers or additional modules. This approach ensures portability, cost efficiency, and accessibility, as it leverages devices already owned by end users.

Smartphone Sensors

The system makes use of the following embedded smartphone components:

- **Accelerometer** – Captures step count and motion patterns to support navigation.
- **Gyroscope –** Provides angular velocity and orientation tracking for accurate movement feedback.
- **Magnetometer (Compass)** – Enables directional calibration in indoor environments.
- **Barometer** – Tested on compatible devices to enhance altitude and floor-level detection.

- **Haptic Feedback Motor** – Delivers vibration-based alerts as an alternative or complement to audio announcements.

Current Implementation Status

The hardware team has developed a working mobile application prototype that demonstrates the following functionalities:

- **Step Detection**: The system can detect user steps. A feature to announce every ten steps has been defined for future iterations.
- **Orientation Awareness**: The application identifies device tilt and cardinal orientation (north, south, west) and communicates this through audio prompts.
- **Object Detection**: The system detects obstacles (e.g., furniture) and provides real-time spoken alerts indicating position (e.g., “object on the left”).
- **Text and Line Recognition**: The application supports basic detection of text or line structures and provides speech output.
- **Energy Efficiency**: Early testing has prioritised optimization for lower-specification smartphones to minimize power consumption.
- **Prototype User Interface**: A Figma model has been created to represent the application’s user interface; integration with the working prototype is ongoing.

4.3 Software and ui Interface

The software subsystem integrates machine learning models with sensor-based feedback, ensuring both intelligence and reliability.

Mobile Application:

- Android app provides camera-based obstacle detection using YOLOv8 trained on indoor datasets.
- Text-to-Speech (TTS) APIs deliver audio navigation cues.

4.4 Data Integration & Machine-Learning Stream

The machine learning subsystem forms a critical component of the navigation device, enabling real-time perception of obstacles and contextual information within indoor environments. The stream integrates object detection and text extraction, ensuring that users with visual or mobility impairments receive both spatial and semantic awareness during navigation.

The proposed system provides two complementary capabilities that work in tandem to support indoor navigation for users with visual or mobility impairments:

- **Obstacle-detection mode** – identifies objects in real time and issues haptic or audio warnings so users can avoid collisions.
- **Text-extraction mode** – reads printed information in the environment and converts it to speech, giving users rapid, hands-free access to contextual cues such as room numbers or directional signage.

By fusing physical-world perception (object recognition) with semantic awareness (OCR → TTS), the solution closes the gap between *knowing where things are* and *knowing what things say*, thereby enhancing safety, autonomy, and situational understanding.

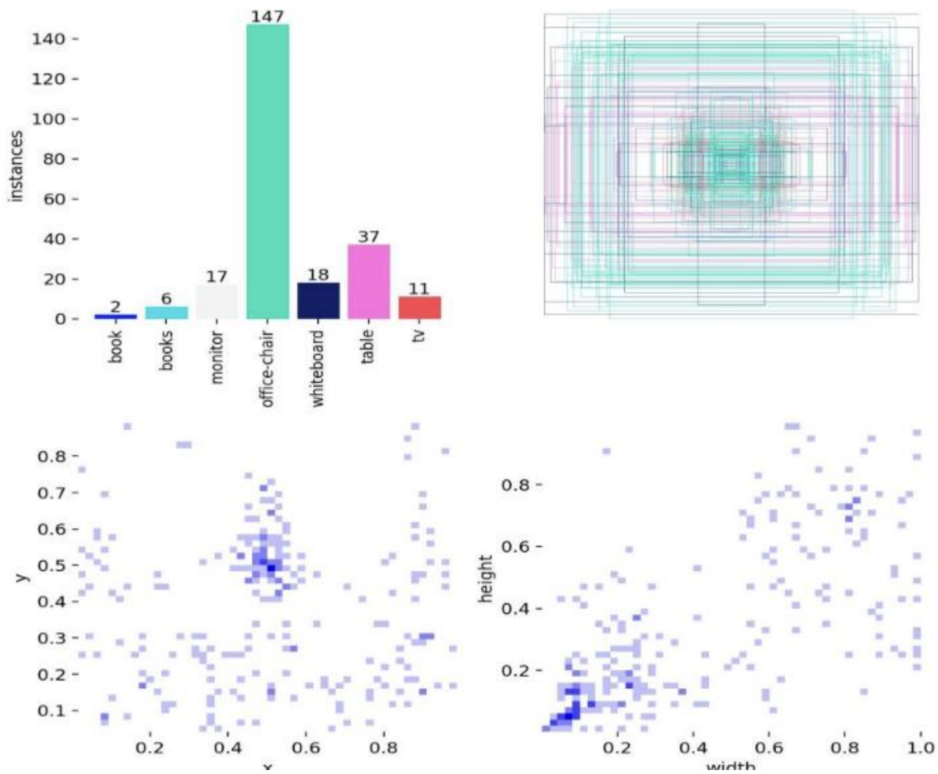
Technical Implementation

Dataset Characteristics

- **Custom dataset** developed by the Annotation Team, including indoor objects such as books, monitors, office chairs, whiteboards, tables, and televisions.
- **Bias challenges**:
  - *Severe class imbalance*: Office chair class dominated (147 instances), leaving minority classes under-represented.
  - *Centre bias*: Bounding-box centres clustered near the middle of images, reducing edge diversity.
- These biases favoured conservative models, which achieved high precision but missed minority classes, increasing the risk of undetected obstacles.

Model Selection and Evaluation

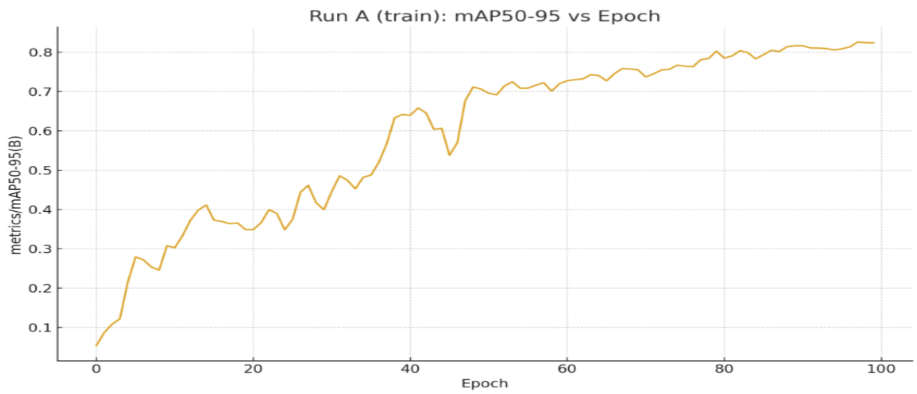
Several YOLO family models were benchmarked (YOLOv4-tiny, YOLOv5n, YOLOv8n, YOLOv8s, YOLOv11n). Among them, YOLOv8n was selected as the production baseline for its balance of speed, recall, and resource efficiency on smartphones.

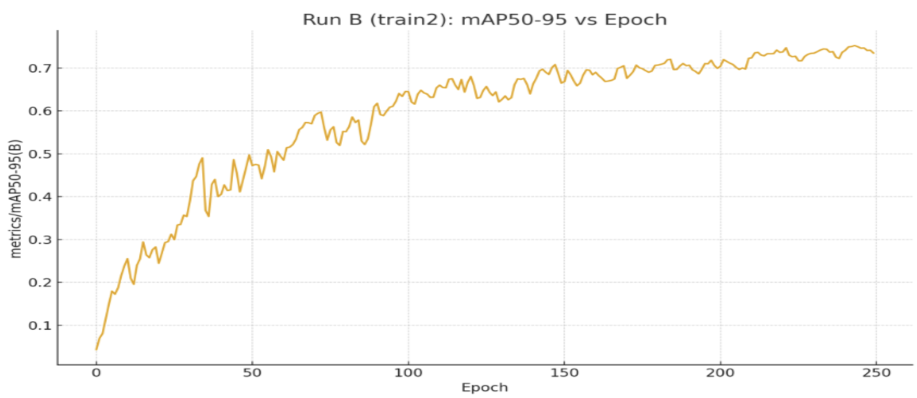


Object-Detection Sub-module

- **Model family:** YOLO (You Only Look Once), chosen for high accuracy at mobile-friendly frame rates.
- **Datasets:** Custom indoor dataset created by the Annotation Team (books, monitors, office chairs, whiteboards, tables, TVs).
- **Models evaluated:** YOLOv4-tiny, YOLOv5n, YOLOv8n, YOLOv8s, and experimental YOLOv11n.
- **Result:** YOLOv8n delivered the best balance of precision, recall, and latency for on-device inference and is locked in as the production baseline.

Appendix: mAP50-95 Curves





5. Performance Metrics Results:

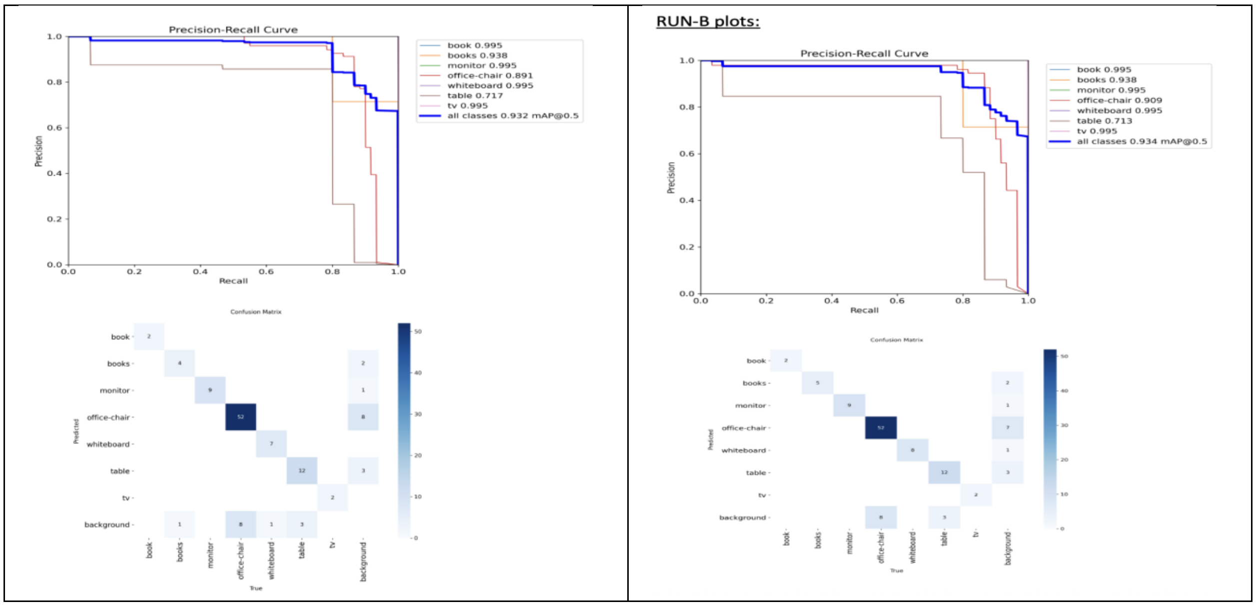
- Built and curated a custom Deakin-Library image set; all images are fully annotated with bounding boxes and class labels.
- Noted key dataset biases: heavy class imbalance (*office-chair* dominates) and centre-bias in bounding-box placement.
- Augmented the dataset (mosaic, mix-up, HSV, shear, perspective, flips/rotations) to counter imbalance and spatial skew.

Two training configurations were tested:

- **Run A (Baseline – Preferred)**
  - Epochs: 100 | Batch size: 32 | Image size: 640
  - Achieved **mAP50-95 ≈ 0.826**, with strong recall (0.917) and balanced generalisation.
  - Converged quickly (~90–100 epochs) and demonstrated better safety-critical performance.

- **Run B**
  - Epochs: 250 | Batch size: 16 | Image size: 768
  - Achieved **mAP50-95 ≈ 0.752**, with higher precision but significantly lower recall.
  - Conservative detection missed more minority cases, unsuitable for navigation.

Decision: Run A was adopted as the baseline due to its higher recall and better localisation at strict IoUs, ensuring obstacles are detected reliably in real time.



RUN A AND B

5. Performance Requirements

5.1 Response Time

- Obstacle detection and location updates must occur **within 1 second** to ensure timely navigation feedback.

5.2 Uptime and Reliability

- System should maintain **95% operational uptime** in the intended environment.
- Fail-safes must be in place to handle sensor malfunctions or signal loss.

5.3 Battery Efficiency

- Minimum **4 hours of continuous operation** on a full charge.
- Power-saving mode for idle periods to extend battery life.

6. Design Constraints

6.1 Environmental Limitations

- The system is indoor-only.
- Performance may degrade in environments with excessive noise, beacon interference, or rapid layout changes.

6.2 Platform Restrictions

- Initial release is Android-only.
- Camera use is restricted to trial environments with explicit consent, in compliance with privacy policies.

6.3 Resource Limits

- Development and deployment must stay within the allocated budget and available hardware inventory.
- Components must be low-cost, easy to source, and replaceable without full system redesign.

7. Non-Functional Attributes

7.1 Accessibility

The system is designed with a user-first, inclusive design philosophy to ensure equal access for individuals with diverse needs, including those who are blind, mobility-impaired, or cognitively impaired. Accessibility is embedded at every stage of development, from requirements gathering to testing.

Key features supporting accessibility include:

- **Non-visual guidance:** Audio prompts provide clear navigation feedback without requiring sight.

- **Mobility support:** Routes are optimized for wheelchair accessibility, avoiding stairs and narrow pathways.
- **Cognitive accessibility:** Step-by-step guidance, simplified instructions, and minimal cognitive load to accommodate users with processing or attention difficulties.
- **Assistive technology compatibility:** The app integrates seamlessly with screen readers and supports voice commands for hands-free use.
- **User customization:** Adjustable feedback intensity, speech rate, and haptic patterns allow personalization to match user preferences.

7.2 Privacy and Ethics Compliance

The system is designed to uphold the Privacy Act 1988 and Deakin University ICT Security Policy, ensuring user data protection, informed consent, and transparency in operations.

Key privacy safeguards include:

- No persistent storage of identifiable data. All image data is processed locally and discarded instantly after analysis.
- Minimal data collection: Only essential sensor readings and beacon signals are used.
- Informed consent: Participants in trials are provided with plain-language consent forms, detailing potential risks, data handling, and the right to withdraw.
- Privacy by design: Camera-based detection is used only in designated testing zones with university approval. In public-facing deployments, sensor-only mode is available to avoid camera use entirely.
- Anonymity in reporting: Trial results are anonymized; no personally identifying information is linked to performance data.

Ethical considerations include:

- Avoiding function creep by restricting technology use to approved navigation purposes.
- Implementing fail-safe modes where critical feedback (e.g., obstacle alerts) remains functional even if other modules fail.
- Continuous consultation with disability advocacy groups to align system design with user expectations.

7.3 Maintainability

The system's modular architecture is designed to simplify updates, repairs, and future enhancements. Each component whether software module or hardware unit can be upgraded or replaced without requiring a complete redesign.

Maintainability is supported through:

- **Component independence:** Hardware (e.g., ultrasonic sensors, microcontroller) and software modules (e.g., obstacle detection, location services) are decoupled for easy replacement.
- **Version control:** All code, design documents, and hardware schematics are stored in a central GitHub repository with clear version histories.
- **Documentation:** Comprehensive developer and maintenance documentation ensures future teams can troubleshoot and improve the system efficiently.

This approach enables the system to remain functional and relevant over time, even as user needs, hardware availability, or technology standards evolve.

7.4 Usability

Usability is prioritized to ensure that the system can be operated effectively by users with minimal training or technical background. The design is informed by iterative user testing with target personas.

Usability enhancements include:

- **Clear interaction flow:** Simple, predictable navigation steps with minimal branching paths.
- **Low cognitive load:** Information is presented in short, actionable messages rather than complex instructions.
- **Consistency:** Feedback patterns remain consistent across all navigation contexts, making them easy to learn and recognize.

7.5 Privacy & Ethics

- The system should always respect user privacy and only collect the data that is truly necessary. Personal or location information will never be stored without the user's clear consent.

- Wherever possible, information will be processed directly on the device rather than through cloud services, to keep user data secure.
- The design must follow recognized accessibility standards, making sure the device can support people with different levels of vision and mobility.
- The system should remain fair and inclusive, working well for users across different ages, genders, and backgrounds.
- Users should have easy controls to manage their own experience — for example, turning the camera on or off, adjusting the volume, or changing vibration feedback.
- The way the system works should be transparent and simple, so users always understand what is happening in the background.

8. Budget Estimate

8.1 Initial Estimate

- Beacons ×6: $90
- Ultrasonic sensors ×3: $15
- ESP32: $15
- IMU: $8
- Haptic & buzzer: $12
- Battery: $20
- Enclosure: $30
  Total: ~$190

8.2 Expanded Budget Estimate

The project budget combines **hardware**, **software**, and **operational costs** to provide a realistic estimate.

Category	Items	Estimated Cost (AUD)
Hardware	Beacons ×6, Ultrasonic sensors ×3, ESP32, IMU, Haptic & buzzer, Battery, Enclosure	$190
Software Development	Android app development (YOLOv8 integration, TTS, voice commands), Arduino firmware	$500

Category	Items	Estimated Cost (AUD)
Testing & Validation	User trials, beacon calibration, lab setup	$200
Maintenance & Support	Battery replacements, software updates, bug fixes	$150
Contingency (10%)	Buffer for unexpected costs	$100

Total Estimated Cost: ~$1,140 AUD

This budget reflects a prototype and early user trial stage. Scaling to campus-wide deployment would increase hardware and testing costs proportionally.

9. Appendices

9.1 Policy Documents

- Deakin University Privacy Policy.
- Disability Standards for Education 2005.
- Australian Human Rights Commission – *Guidelines on the rights of people with disability in the digital age*.

9.2 Survey or Interview Notes

Preliminary Interviews:
- Students with vision impairments highlighted the need for *instant* obstacle alerts and reduced reliance on internet connectivity.
- Mobility-impaired users emphasized the importance of elevator routing and avoidance of narrow passageways.
- Students with ADHD preferred simplified instructions and minimal multi-step commands.

10. Uses of SRS Document

This document serves three primary audiences:

1. **For Developers:**
   Acts as a technical blueprint for implementing core features, integrating hardware, and ensuring performance benchmarks.
2. **For Project Sponsors:**
   Provides clear evidence of how the system meets user requirements and delivers on accessibility, privacy, and ethical standards.
3. **For Ethical Review Committees:**
   Details how the project complies with privacy regulations, informed consent principles, and institutional policies.

11. FAQs on SRS Format

Q1: Why is camera use restricted?
A: Cameras introduce privacy risks in public spaces. Their use is limited to controlled trials in approved areas with explicit consent.

Q2: What sensors are considered safe?
A: Ultrasonic sensors are non-intrusive, do not record images, and operate on low-frequency sound waves that pose no health risks.

Q3: Can this system be adapted for other buildings?
A: Yes. With beacon placement and calibration, the system can be deployed in other indoor environments without hardware redesign.

12. Prototypes

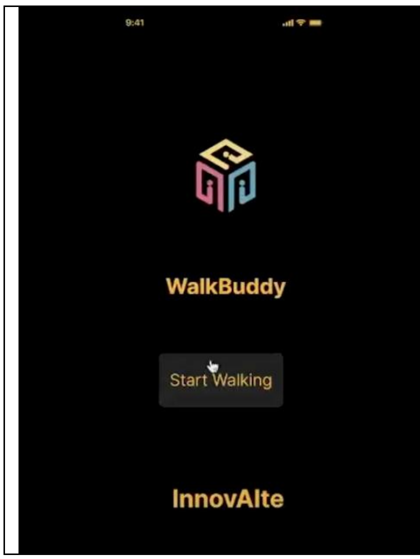
12.1 High-Fidelity Prototype Flow

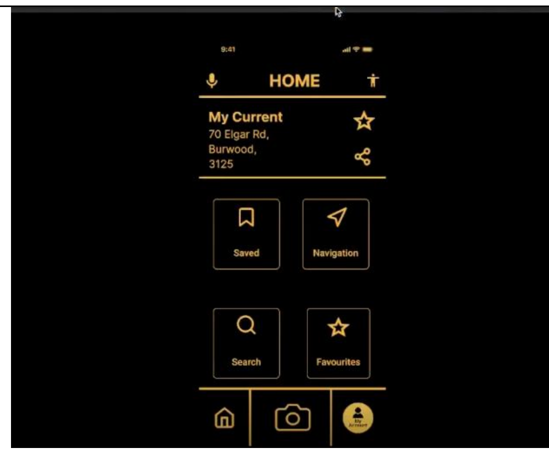
The high-fidelity prototype (Figure 12.1) represents the near-final user interface design of the AI Assisted Navigation App. Unlike low-fidelity wireframes, which focus on layout and functionality, this prototype incorporates actual color schemes, iconography, and interaction elements to simulate the real user experience.

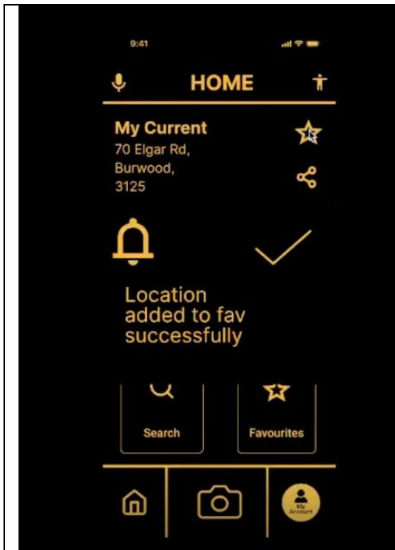
The prototype flow begins with the Home screen, which provides quick access to essential features such as Saved Places, Navigation, and Accessibility Settings. From here, users can:

- **Manage Saved Places –** store frequently visited locations for faster navigation.
- **Initiate Navigation –** receive real-time indoor guidance with obstacle alerts.
- **Use Quick Actions –** access tools like "Explore" or "Scan" for contextual support.
- **Adjust Account & Preferences –** personalize accessibility settings (e.g., audio feedback).

By mapping out these screens in a high-fidelity prototype, the design ensures usability and accessibility testing before implementation. This allows stakeholders to validate both the visual style and user experience while ensuring the application meets the needs of visually impaired and low-vision users.



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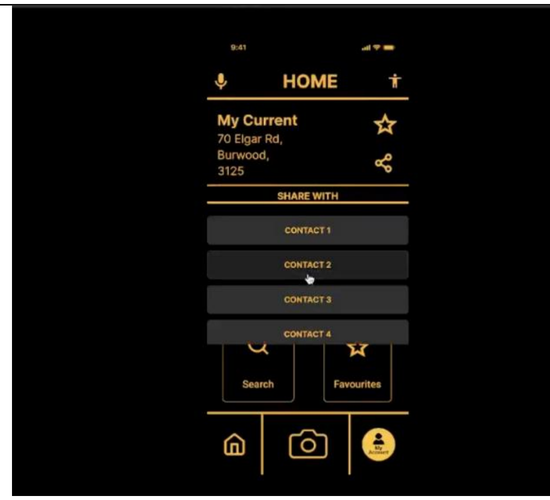
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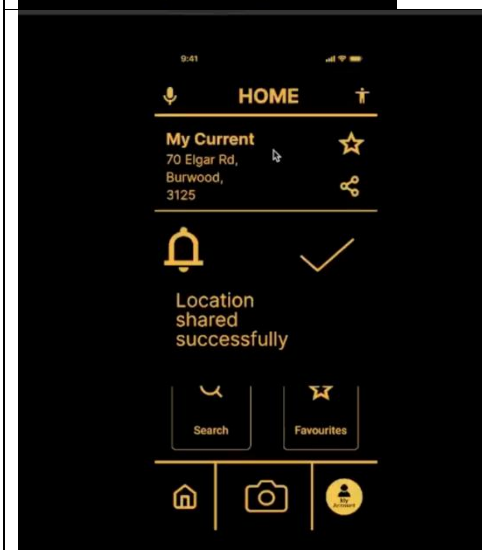
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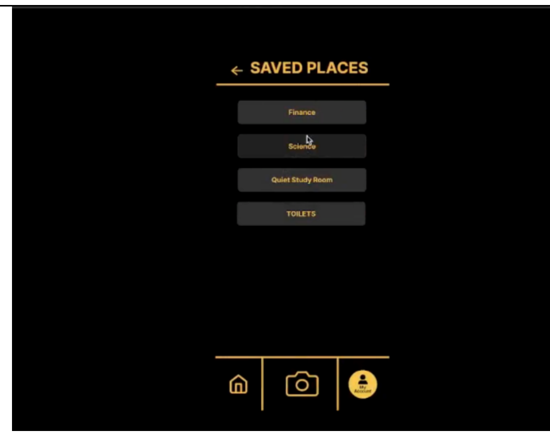
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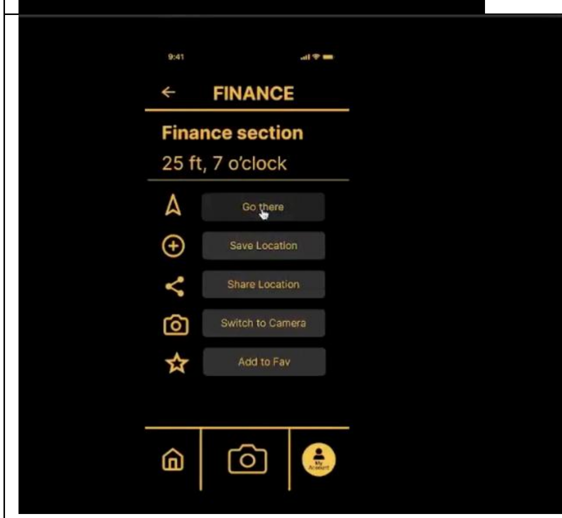
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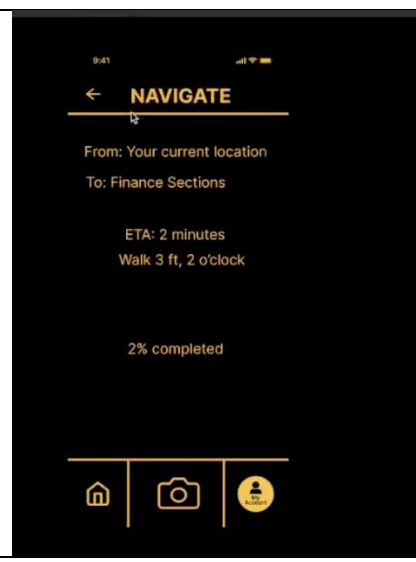
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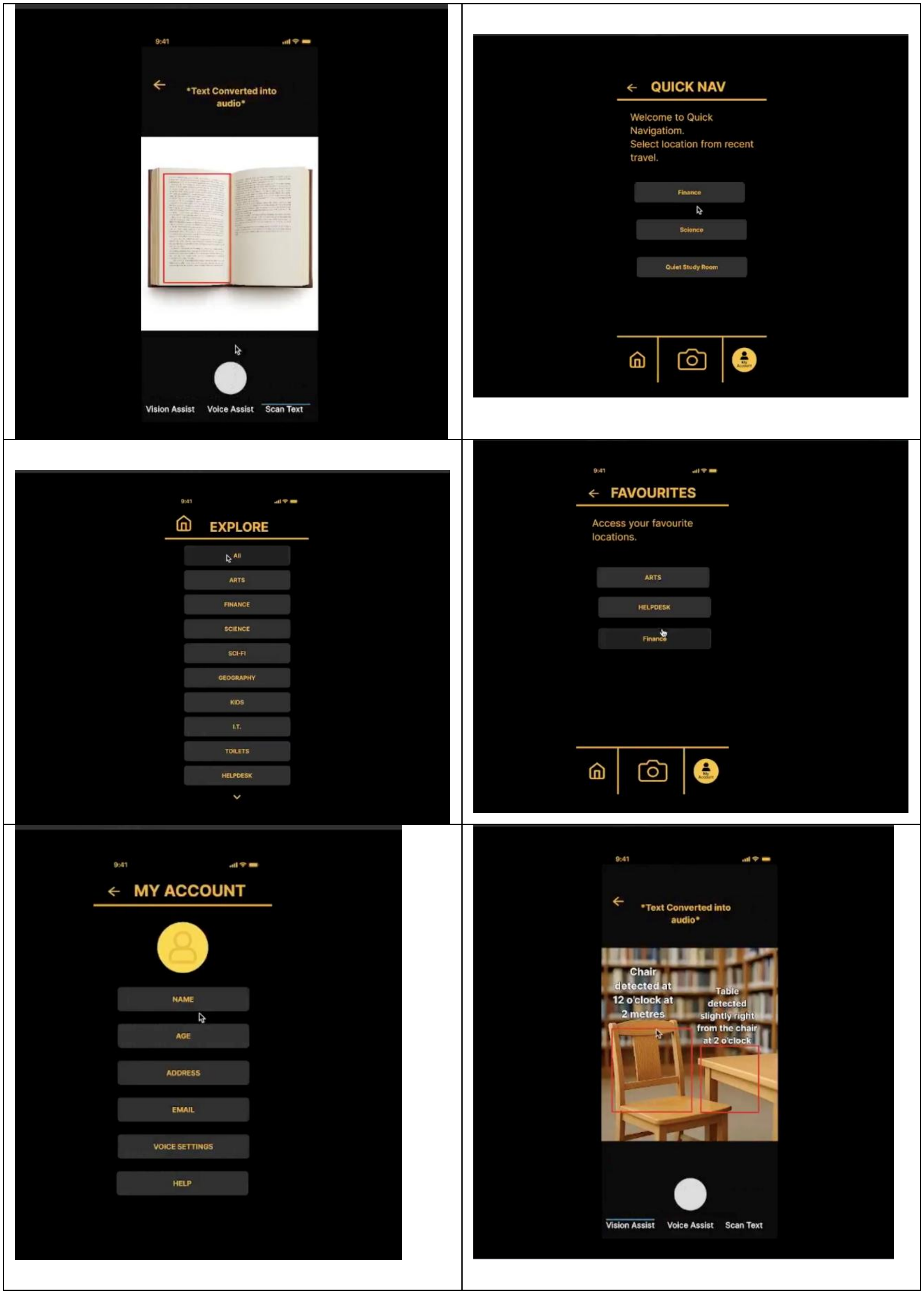

Figure 12.1: Wireframe flow of the AI Assisted Navigation App showing key screens (Home, Saved Places, Navigation, and Account).

13. Research of Similar Solutions

WeWALK Smart Cane

- **Tech:** Ultrasonic sensors + smartphone integration.
- **Pros:** Easy to use, widely available.
- **Cons:** Limited semantic object detection, expensive (~$600).

Microsoft Soundscape

- **Tech:** 3D audio cues via GPS and beacons.
- **Pros:** Strong spatial audio navigation.
- **Cons:** Outdoor-focused, lacks object-level awareness indoors.

NavCog (Carnegie Mellon)

- **Tech:** Indoor BLE beacons + AI navigation.
- **Pros:** Accurate location tracking indoors.
- **Cons:** Requires dense beacon installation.

14. Problem Statement

Current indoor navigation aids for individuals with disabilities are often constrained by high costs, dependency on continuous internet connectivity, and significant privacy concerns in shared public spaces. These limitations make many existing solutions unsuitable for environments such as university campuses, where data privacy, accessibility, and affordability are critical.

To meet the needs of students navigating complex indoor settings like libraries, there is a growing demand for systems that function offline, respect user privacy, and adapt to changing layouts while still providing accurate, real-time obstacle detection.

This project addresses these challenges by developing a modular, ethical, and cost-effective indoor navigation system specifically designed for students at Deakin University. It integrates on-device machine learning and sensor-based feedback to deliver a reliable and inclusive navigation experience without compromising user autonomy or institutional privacy standards.

15. Conclusion

The AI-Assisted Indoor Navigation Device offers a privacy-compliant, accessibility-focused, and cost-effective alternative to commercial navigation systems. By combining on-device camera-based object detection with optional ultrasonic sensing, it provides reliable, real-time feedback to support independent navigation.

Its modular architecture ensures scalability to other environments, while its privacy-by-design approach aligns with legal and institutional requirements. This project not only meets immediate accessibility needs within the Deakin Library but also sets the foundation for broader deployment across campus and similar indoor environments.

16. Testing & Validation

Testing and validation are critical to ensure the system performs reliably and meets user needs. The approach includes both **technical testing** and **user validation**:

16.1 Unit Testing

- Each hardware component (ultrasonic sensors, vibration motor, BLE beacons) will be tested individually to confirm accuracy and response time.
- Mobile app modules (object detection, text-to-speech, voice commands) will undergo isolated testing in controlled conditions.

16.2 Integration Testing

- Hardware and software subsystems will be combined and tested to ensure smooth data flow (e.g., sensor input triggering correct feedback).
- Focus will be placed on response times (<1 second) and consistent performance across different indoor environments.

16.3 User Acceptance Testing (UAT)

- A group of students with diverse accessibility needs will trial the device in the Deakin Library.
- Feedback will be collected on usability, comfort, and clarity of navigation cues (haptic/audio).
- Success will be measured by task completion rates (e.g., navigating to a study desk or elevator without assistance).

16.4 Performance Validation

- Reliability: The system should operate with at least 95% uptime in real testing.
- Accuracy: Obstacle detection should identify hazards within 30 cm consistently.
- Battery life: Device should last a minimum of 4 hours in continuous use.

16.5 Ethical & Safety Validation

- All testing will be conducted under Deakin's ethics approval process.
- Plain-language consent forms will be provided, and participants may withdraw at any time.
- Privacy settings (e.g., disabling camera mode) will be tested to ensure they function as described.

17. Risks & Mitigation

Even with careful planning, risks can affect the success of the AI Assisted Navigation Device. The following table identifies major risks and the strategies to reduce them:

Risk	**Impact**	**Likelihood**	**Mitigation Strategy**
Sensor failure (ultrasonic or TOF sensor stops working)	Loss of obstacle detection, reduced safety	Medium	Include redundant sensors; test each unit before deployment; provide fail-safe vibration alerts.
Beacon misplacement or interference	Reduced location accuracy indoors	High	Calibrate beacon placement; test signal strength before trials; allow manual override mode.
Battery drains too quickly	Device shuts down during navigation	Medium	Use power-saving modes; test runtime under real conditions; include battery status alerts.
Privacy concerns from camera use	User rejection or trial delays	High	Default to sensor-only mode; provide clear consent forms; ensure camera processing is on-device only.

Risk	Impact	Likelihood	Mitigation Strategy
User finds device confusing or hard to use	Poor adoption, negative feedback	Medium	Conduct user testing with different personas; simplify interface; provide onboarding tutorials.
Budget overrun	Limits hardware/software quality	Low	Track costs carefully; prioritise essential features; source low-cost modular components.
Technical integration issues between hardware and app	Delays in development	Medium	Use modular architecture; conduct early integration testing; maintain clear documentation.

18. References

- Shanley, L., Johnstone, M.N., Crowley, M. and Szewczyk, P. (2020) 'Australian Attitudes Towards Privacy', *Human Aspects of Information Security and Assurance: 14th IFIP WG 11.12 International Symposium, HAISA 2020, Mytilene, Lesbos, Greece, July 8–10, 2020, Proceedings*, Vol. 593, p. 3. Springer Nature.
- Nuske, A., Brett, M. and Knight, E. (2023) 'Disability services in higher education: An Australian perspective', in *Handbook of Higher Education and Disability*. Cheltenham: Edward Elgar Publishing, pp. 101–114.
- De Bruin, K., Poed, S. and Jackson, R. (2024) 'Performance of Australia's Disability Standards for Education 2005: a policy analysis and evaluation', *International Journal of Inclusive Education*, 28(14), pp. 3533–3553.
- Goggin, G., Hawkins, W. and Schokman, A. (2024) *Disability & Digital Citizenship*. [Book reference – publisher details to be added if available].
- Bochkovskiy, A., Wang, C.Y. and Liao, H.Y.M. (2020) 'YOLOv4: Optimal speed and accuracy of object detection', *arXiv preprint*, arXiv:2004.10934.

- Akwiwu, Q. (2025) ‘Object detection, segmentation, and distance estimation using YOLOv8’. [Preprint/Journal – details to be added when published].
- Galabov, M., Stefanov, T., Stefanova, M. and Varbanova, S. (2025) ‘Smart Canes for the Visually Impaired: Technological Support for Independence and Mobility’, *BRAIN. Broad Research in Artificial Intelligence and Neuroscience*, 16(3), pp. 18–30.
- Schwartz, B.S., King, S. and Bell, T. (2024) ‘EchoSee: An Assistive Mobile Application for Real-Time 3D Environment Reconstruction and Sonification Supporting Enhanced Navigation for People with Vision Impairments’, *Bioengineering*, 11(8), p. 831.
- Sabab, S.A. and Ashmafee, M.H. (2016) ‘Blind reader: An intelligent assistant for blind’, *2016 19th International Conference on Computer and Information Technology (ICCIT)*, pp. 229–234. IEEE.