MEDnav

CAS 757 - Group Project Final Report

Revision 6.1

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Group 1-MEDnav

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Executive Summary

Over 60% of hospital visitors report being lost and not being able to find their way which leads to staff wasting their time giving directions and patients late or even missing crucial appointments. At MEDnav, we strive to implement a new gold standard for hospital wayfinding where we replace typical hospital signs and maps with our new augmented reality (AR) navigation app. But MEDnav is more than just a wayfinding app, it is a platform that provides mapping, connections to other users, and security to improve the entire hospital experience for patients, visitors, and hospital staff.

The wayfinding industry is one of the fastest growing markets with multiple research firms forecasting global market revenues of double-digit billions. The industry is increasingly lucrative because solutions need to satisfy both users and hosts, in this case visitors and hospitals. Users or hospital visitors benefit from the MEDnav platform as they receive a more accurate hospital navigation experience with our AR navigation app that uses existing hospital floor maps and on-device phone sensors. Users further utilize our application to connect with friends/family, share their location within the hospital, and notify their loved ones of when they are available for guests/visitors. Hosts or hospital administrators benefit from the MEDnav platform with our security features which identify potential closures and restrict specific areas.

As the competitive landscape fills with prospective solutions, MEDnav provides a complete and comprehensive platform to improve the entire hospital experience and increase efficiency for hospitals and their staff.

Project Objectives and Scope

The primary objective of the MEDnav project is to create a wayfinding software platform which leverages a combination of navigation, user connections, and security features to deliver an enjoyable hospital experience for all. The platform will be supported for mobile (Android and iOS) and desktop (Mac and PC) use to enable hospital patients, visitors, and staff access to this game-changing technology. The platform will mainly use the app interface to interact with patients and visitors in the context of navigation and user connections/alerts, whereas the desktop version will help hospital staff and administrators implement the navigation product. The objectives are achieved using the following features in the application:

- Registration
- Connecting users
- Availability status
- Reporting and notifications
- Navigation and browsing

The *Registration, Connecting users, and Availability status* features help users such as visitors, patients, and staff create and connect accounts and display their status such as “busy” or “available". Whereas the *Reporting and notifications*, and *Navigation and browsing* features provide all users with accurate and appropriate wayfinding in the complex hospital structures. These listed features satisfy MEDnav’s objective and will be described in-depth as functional requirements of the software in the following report.

In order to ensure that the objectives and requirements are met, the Scrum methodology was implemented and documented in the Meeting Logs section of this document. Roles and responsibilities of each team member were also outlined in the Revision Log and Work Breakdown sections, to ensure the project stays on track and that the work is transparent. The Motivation and Background of the project is found in their respective sections and the implementation and design of MEDnav is detailed in the Business Logic, Functional Requirements, Non-functional Requirements, Requirement Elicitation, Strategy for Testing Each Requirement, Description of Underlying Structure, Description of how MEDnav Functions, and Standards Compliance sections.

For this prototyping project, it is also important to define what lies within and outside of our scope. As the project is intended for multiple users, visitors, patients, and staff specific staff such as doctors, hospital nurses, and administrators lie within the target scope. Comparatively, volunteers, and custodian staff are not included within the scope of this project. In addition, although there are multiple potential features to include for navigation purposes, in the context of the MEDnav app, parking/roadway navigation and weather features were not included within the scope as this information can be acquired using other on-device phone apps. Finally, an aesthetic design is required for a favourable navigation experience and although it is an important feature, it has not been detailed here as it will be outsourced to a consulting visual design company.

Motivation

When visiting a hospital, it's often a very stressful time. You could be undergoing a major surgery, visiting a loved one that is very ill, or have entered the emergency ward for something unexpected and troubling. In this high stress environment, it's hard to keep your head clear and maintain focus. A recent study by [1] even identified that 87% of hospital visitors report being lost and not being able to find their way. The same study in [1] details that hospital staff can waste up to 4,500 hours giving out directions to lost visitors. More importantly, lost patients can be late or even miss crucial appointments. For example, a study by [2] in the UK identified that in 2016-2017, there were over 8 million missed medical appointments which led to over $864 million dollars in lost costs to hospitals. That is why the MEDnav product is needed to properly navigate hospital goers and improve their overall experience without being a burden on the hectic hospital system. In addition, MEDnav can help hospital administrators and staff improve overall workflow and reduce costs.

Background and Literature Review

Hospitals and healthcare workers are increasingly aware of the value in optimizing the patient and visitor experience as it helps reduce costs and establishes a more efficient workflow. Oftentimes, especially for first time visitors, the hospital experience initiates a state of anxiety which leads to visitors having a poor sense of direction and poor estimation on the time it takes to get to their preferred location, as per [3]. The article in [3] further states that Wayfinding "the craft of guiding people from one place to another in a safe and orderly manner" is an essential tool that improves behaviour, mood, and experience for hospital visitors. The current wayfinding standards are mainly manifested in aesthetic visual graphics such as signs, arrows, and even digital maps. Proper wayfinding also inherits many other benefits, says [4] such as stress and frustration reduction, functional efficiency, visitor accessibility, safety, and an improved bottom line. That is why builders and hospital administrators realize economic benefits and improvements to their workflow with well designed wayfinding solutions, as per [5]. However, there exists certain obstacles with current indoor wayfinding. Since apps such as GoogleMaps provide such reliable digital navigation outdoors, people expect a similar experience indoors which is difficult to attain explains [6]. However, some companies have found success in creating indoor navigation apps such as VMA Nordic in [7] and Inpixon Indoor Intelligence in [8]. VMA Nordic has created an app that helps passengers navigate their way through Gatwick airport in London, and the results are very promising. VMA Nordic has been able to streamline passenger flow, reduce congestion, and reduce the amount of passengers missing their flights by a significant amount. Additionally, Inpixon Indoor Intelligence has implemented their comprehensive indoor wayfinding solutions in shopping malls and elaborate workplace centers. As these wayfinding options become more readily available, there is a need to bring these technologies and their concepts to the healthcare industry. Although some companies such as Inpixon Indoor Intelligence have attempted to enter the healthcare market, there is a requirement for this technology to perform more than simply wayfinding, which our MEDnav product is ready to offer, as explained in the following document.

Business Logic

In software, a business logic diagram demonstrates the specific features of the product that generates economic benefits for the customer; the business logic for the MEDnav product is described below in *Figure 1*. Each item or bubble listed in *Figure 1* identifies a feature of the MEDnav product that can create an economic benefit for hospitals and their administration

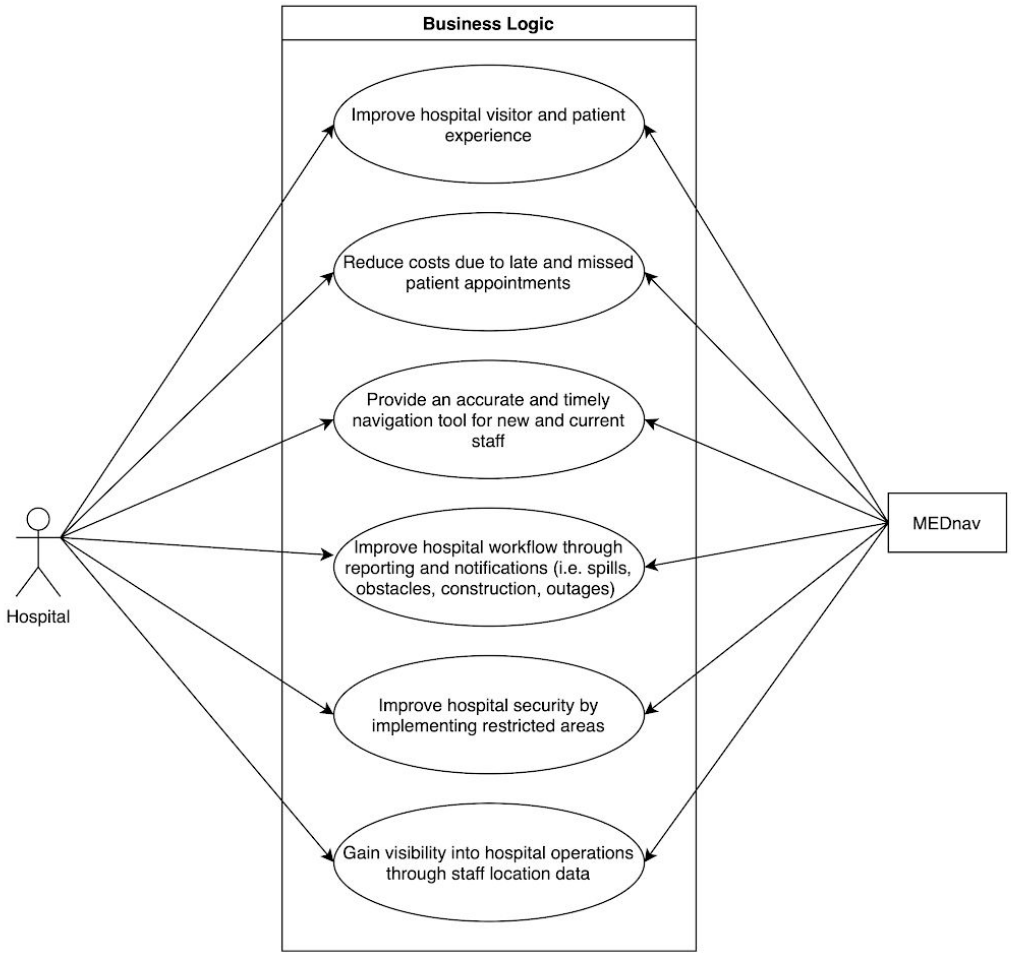

Figure 1: *Use Case Diagram for Business Logic*

Requirement Elicitation

In order to create a product that satisfies customer needs, it is important to identify the resources needed to accomplish each activity and task, verify that the tools are available, and schedule the execution of these efforts. Functional requirements are therefore generated to achieve these benchmarks and deliver a product that fits the customer. The key to establishing appropriate functional requirements is to understand the stakeholders that buy and use the product. Therefore, it is important to plan how the requirements will be elicited for each stakeholder. Requirement elicitation is determined for each stakeholder by understanding how they benefit the most from the product (i.e. reduces costs, generates revenues, satisfies a market need, improves safety, solves a specific problem). The following table identifies the stakeholders and groups that have a significant interest in the product over its life cycle and the specific interest in the product and its execution:

Table 2: Requirement Elicitation for Stakeholder Interest

Stakeholder	**Interest**
Visitors	Interested in a product that helps them navigate through complex hospitals. The product should be affordable and easy to use
Patients	Interested in a product that helps them navigate through complex hospitals and that can share pertinent information with their loved ones and/or visitors. The product should be affordable, easy to use, and secure
Doctors	Interested in a product that ensures patients arrive at their appointments on time. The product should be easy to use and efficient
Nurses	Interested in a product that can be easily operated in order to input pertinent patient information. The product should be easy to use, secure, and intuitive
Reception Staff	Interested in a product that reduces time spent on navigating patients, and improves the hospital experience by documenting each visit. The product should be easy to use, secure, and intuitive
Hospital Executives	Interested in a product that can improve hospital workflows, reduce costs, and improve the hospital experience in order to generate revenues. The product should be secure, easy to use, provide data insights, and is easy to update

Given the insight from the Stakeholder Interest, appropriate functional requirements can be generated to carry out the design of the MEDnav product. It's important to reach these goals for each stakeholder in order to create a product where everyone benefits. Although there may be some conflicting information regarding interest, the aim is to create a product that satisfies the optimal amount of stakeholders and their interests. It is also unlikely that all functional requirements will be identified in a single meeting, therefore elicitation recursion was implemented for this project at each testing stage.

For each stakeholder identified, requirement elicitation must also be performed through a recursive approach to ensure all of the requirements based on the different interests have been met. The following table identifies each stakeholder and the requirement elicitation procedure:

Table 3: Individual Approach Requirement Elicitation

Stakeholder	**Elicitation Approach**
Visitors	Requirements will be elicited through case stories, literature reviews, questionnaires, product reviews, and interviews. Members on the software team also perform research in hospitals, therefore gathering information from them will be crucial to identify how to meet these stakeholder needs.
Patients	Requirements will be elicited through case stories, literature reviews, questionnaires, product reviews, and interviews. Data will also be collected by reaching out to patients at nearby hospitals in order to gather information on their most recent hospital experience and determine what can be improved.
Doctors	Requirements will be elicited through interviews, case stories, and questionnaires. Gathering information from doctors can identify how to make the product efficient and user friendly as doctors have limited time to train for hospital IT systems.
Nurses	Requirements will be elicited through interviews, case stories, workshops, and questionnaires. Gathering information from nurses can identify how the product must be user-friendly and connect patients/visitors with hospital staff seamlessly. The team also reached out to registered nurse Krista Campbell (Juravinski Hospital Hamilton) for additional insight on the nurse-patient experience.
Reception Staff	Requirements will be elicited by meeting with reception staff to establish current standards, gather potential user stories and cases, and set up workshops to train other staff members.
Hospital Executives	Requirements will be elicited by meeting with the Chief Executive Officers and Directors of the Hospital to describe the specific expectations to be generated from the product. This will include expected revenues and/or cost reductions, questionnaires on the effectiveness of the product, and data on the amount of users.

There are many methods and techniques to elicit requirements, however, it must be noted that not all work well for each stakeholder. For example, for visitors/patients many objective interviews will be conducted to gather information on the current status on the overall hospital experience; whereas for Hospital Executives, a targeted approach must be used in order to gather information on the specific business approach and how to profit from using the product.

Functional requirements

In software, functional requirements help establish specific functions, deliverables, and implementation steps for the project. The following items identify each functional requirement in order to properly carry out the MEDnav product.

1. Registration

1.1. Non-Registered User (for all non-registered users)
- 1.1.1. Initial class assigned when application is downloaded
- 1.1.2. Access to public hospital information
- 1.1.3. Access to public floor plans
- 1.1.4. Able to search for public locations within hospital
- 1.1.5. Able to navigate within hospital
- 1.1.6. Able to get location within hospital

1.2. Registered User
- 1.2.1. Assigned after registration information inputted
- 1.2.2. Extends public user
- 1.2.3. Has hidden registration information:
  - 1.2.3.1. Name, Phone #, Address
- 1.2.4. Able to accept visitor invitations
- 1.2.5. Able to accept patient invitation from staff
- 1.2.6. Able to register as staff

1.3. Patient User
- 1.3.1. Assigned after staff invitation accepted
- 1.3.2. Returns to a registered user when hospital visits complete as updated by the staff member who originally invited them
- 1.3.3. Extends registered user
- 1.3.4. Connected to staff who sent invitation
- 1.3.5. Has hidden patient information:
  - 1.3.5.1. Hospital ID Number
  - 1.3.5.2. Room ID
  - 1.3.5.3. Visitors
- 1.3.6. Able to send visitor invitations

1.4. Visitor User
- 1.4.1. Assigned after patient invitation accepted
- 1.4.2. Returns to a registered user when all hospital stays of connected patients are complete
- 1.4.3. Extends registered user
- 1.4.4. Linked to patient who sent visitor invitation

1.5. Staff User
    1.5.1. Selected role verified through hospital computer login (existing username and password single sign-on)
    1.5.2. Returns to registered user when no longer employed by hospital
    1.5.3. Application requires single sign on password before each use
    1.5.4. Extends registered user
    1.5.5. Connected to patient who accepted invitation
    1.5.6. Has staff information
        1.5.6.1. Input staff specific info
        1.5.6.2. Staff ID Number
        1.5.6.3. Job title
        1.5.6.4. Office
        1.5.6.5. Extension
    1.5.7. Able to update floor plans with route conditions from reports
    1.5.8. Able to return patients to registered users when their hospital visits are complete

1.6. System Administrator (for updating and correcting errors within a hospital)
    1.6.1. Assigned through system initialization
    1.6.2. Application requires two factor authentication before each use
    1.6.3. Extends staff user
    1.6.4. Able to upload and modify floor plans
    1.6.5. Able to update floor plans with route conditions from reports
    1.6.6. Able to update/modify any information stored in the database
    1.6.7. Able to return staff to registered users when they are no longer employed

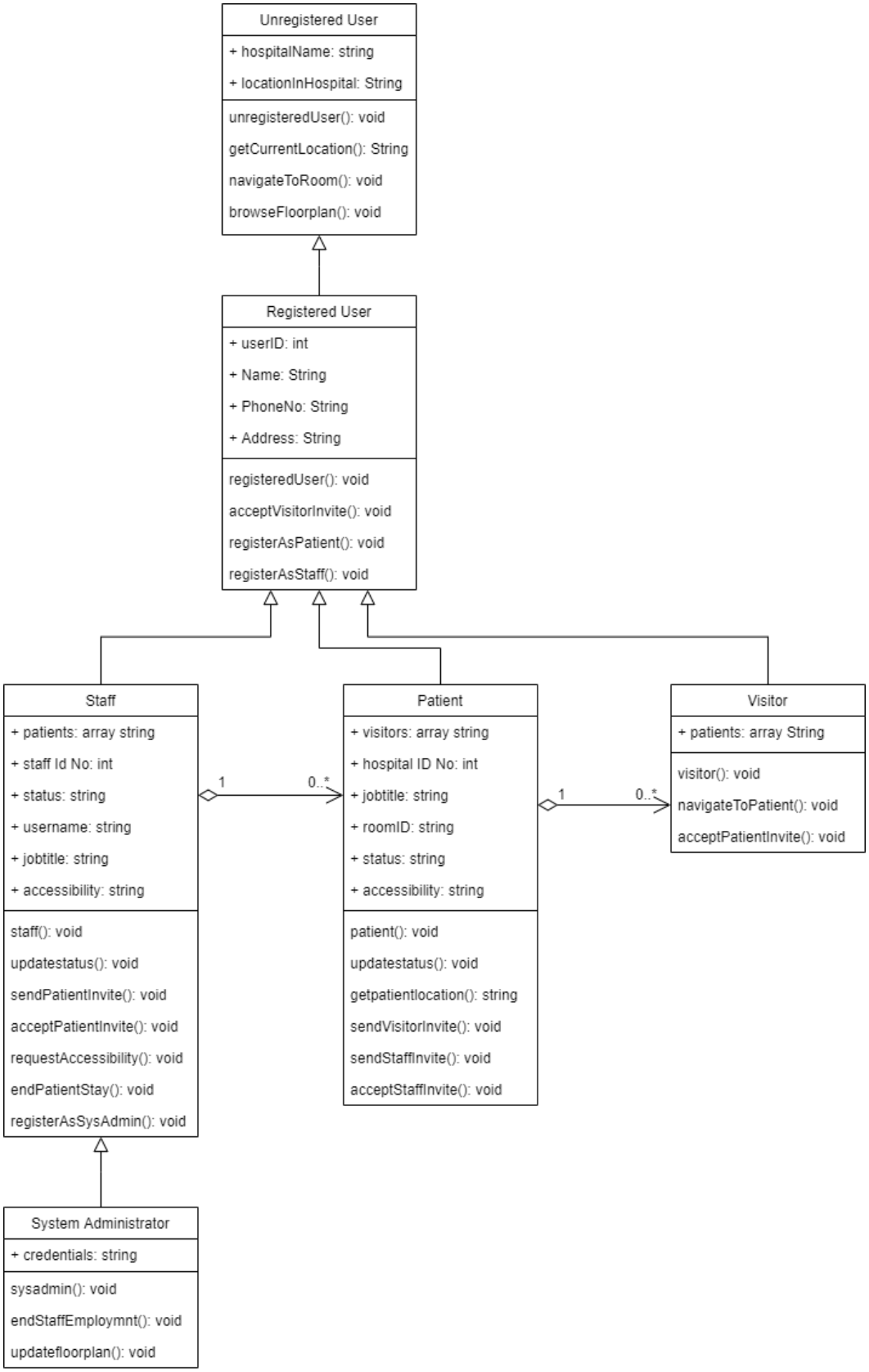

Figure 2: *Class Diagram for User Types*

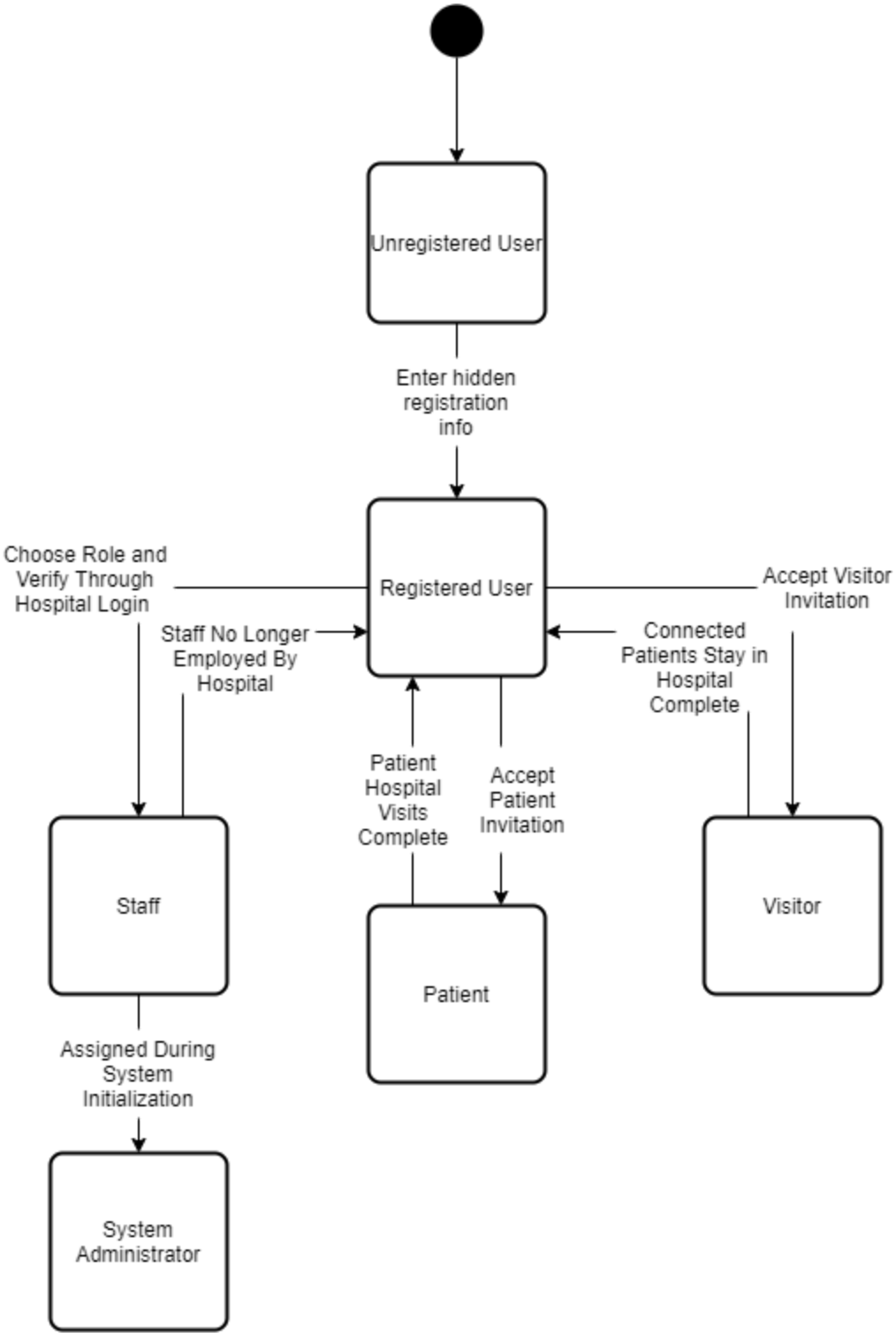

Figure 3: *State Diagram for Users Roles and Transitions*

The registration functional requirements lay out the structure of the program and how users of the applications are classified under different roles. The class diagram in *Figure 2* demonstrates the underlying structure of the different roles of the programs. The state diagram in *Figure 3* demonstrates that the users role which is the state in the diagram transitions based upon the users actions in the application. The unregistered user is the default role given to a user when the application is first downloaded. This class allows users to see their location, browse floor plans, and navigate to locations within the specific hospital they downloaded the application for. The user is then prompted to add registration info into the program so that the identity of the individual can be stored in the system. When this name, phone number and address are entered the user becomes a registered user. From this class the user is able to transition into their specific role in the hospital whether that be staff, patient or visitor.

Staff are able to select their role as per functional requirement 1.5.1. Their role is verified using the hospital's existing computer login system. As per functional requirement 1.5.3 staff are also required to use their computer login password each time before entering the app since they have sensitive privileges that need to be protected. Staff have specific information tied to their account and are bestowed specific privileges.

Furthermore, registered users can transition into patients by connecting with staff members as mentioned in functional requirement 2.3. Patient's have patient specific information stored and special functions associated with their role. Patients return to their original role as a registered user when all of their hospital visits are complete as updated by the connected staff member who originally invited them to become a patient as per functional requirement 1.3.2.

Additionally, registered users can transition into visitors by establishing a connection with a patient as outlined in functional requirement 2.2. In this role they are able to navigate to their connected patients. When all the patients connected to a visitor return to registered users the visitor is also returned to a registered user as per 1.4.2.

Staff also extends to the system administrator these administrators are created during system initialization since they are integral to the smooth functioning of the system. Their login requires two factor authentication as per 1.6.2 as they have powerful system level privileges. System administrators are able to view and modify information stored in the databases to fix any issues that could arise; they are also able to change the overall floor plan and have the authority to approve traffic closures on the floor plan. If system administrators need to be updated the system requires re-initialization since they are so crucial to its function.

2. Connecting Users

2.1. Connection definition

2.1.1. Connection is a link stored in the database between users accounts

2.1.2. Connections allow sharing of information and shared functionality between accounts

2.2. Patients and visitor able to connect

2.2.1. Connection details

2.2.1.1. Connected visitor is able to see a patient's location

2.2.2. Connection establishment

2.2.2.1. Patient able to create a visitor invitation link

2.2.2.2. Patient is able to send link to visitor/registered user

2.2.2.3. Visitor must enter a password to connect

2.3. Staff and patient are able to connect

2.3.1. Connection details

2.3.1.1. Connected staff are able to view and update a patient’s availability status

2.3.1.2. Connected staff are able to view a patient’s location

2.3.1.3. Connected staff are able to use patient account when accessibility permission is granted (see FR 3.5)

2.3.2. Connection establishment

2.3.2.1. Staff is able to send patient connection request

2.3.2.2. Patient is able to send staff connection request

2.3.2.3. Patient and Staff able to accept connection request

2.3.2.4. Staff able to request accessibility permissions, which must be approved by patient

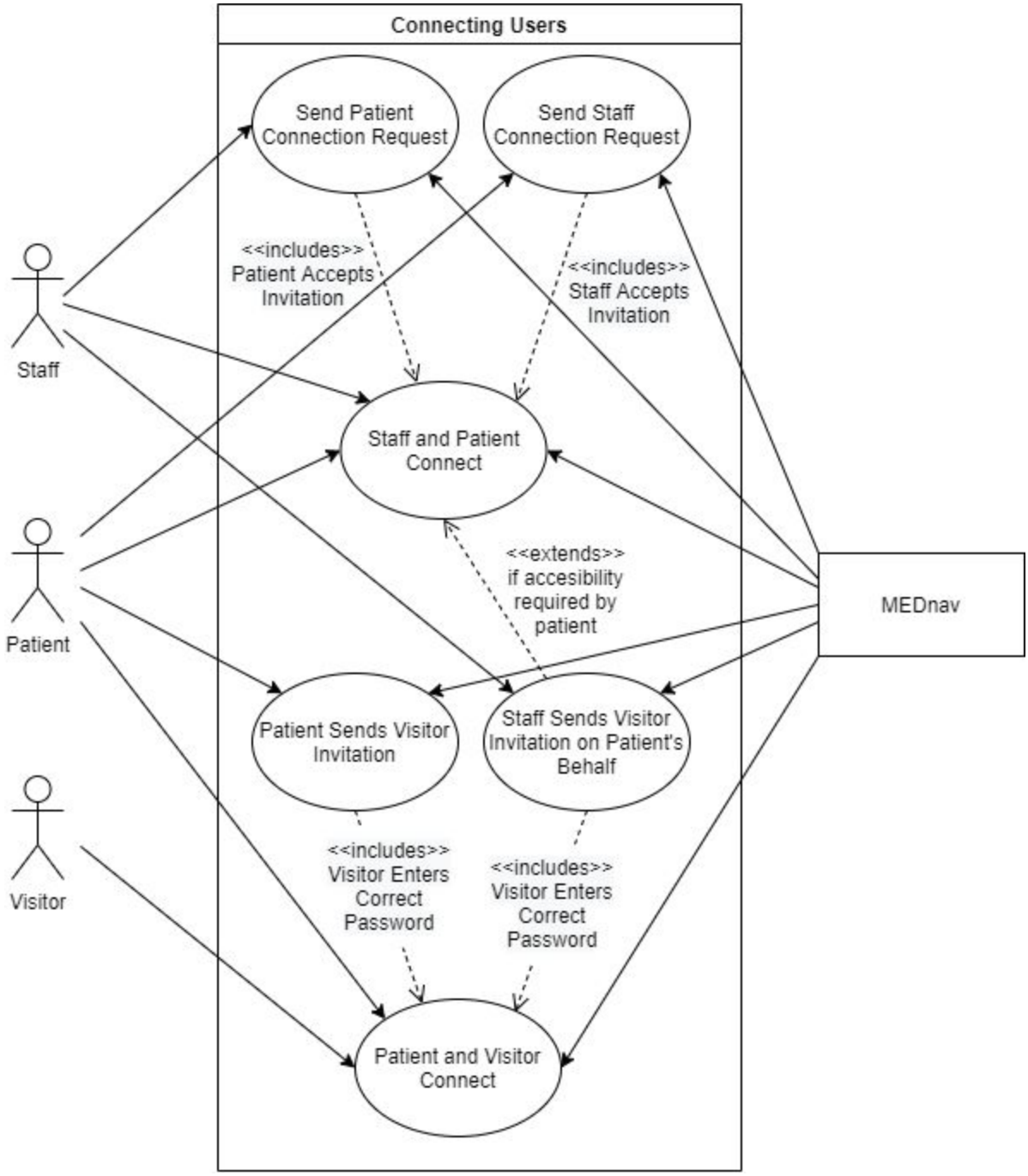

Figure 4: *Use Case Diagram for User Connections*

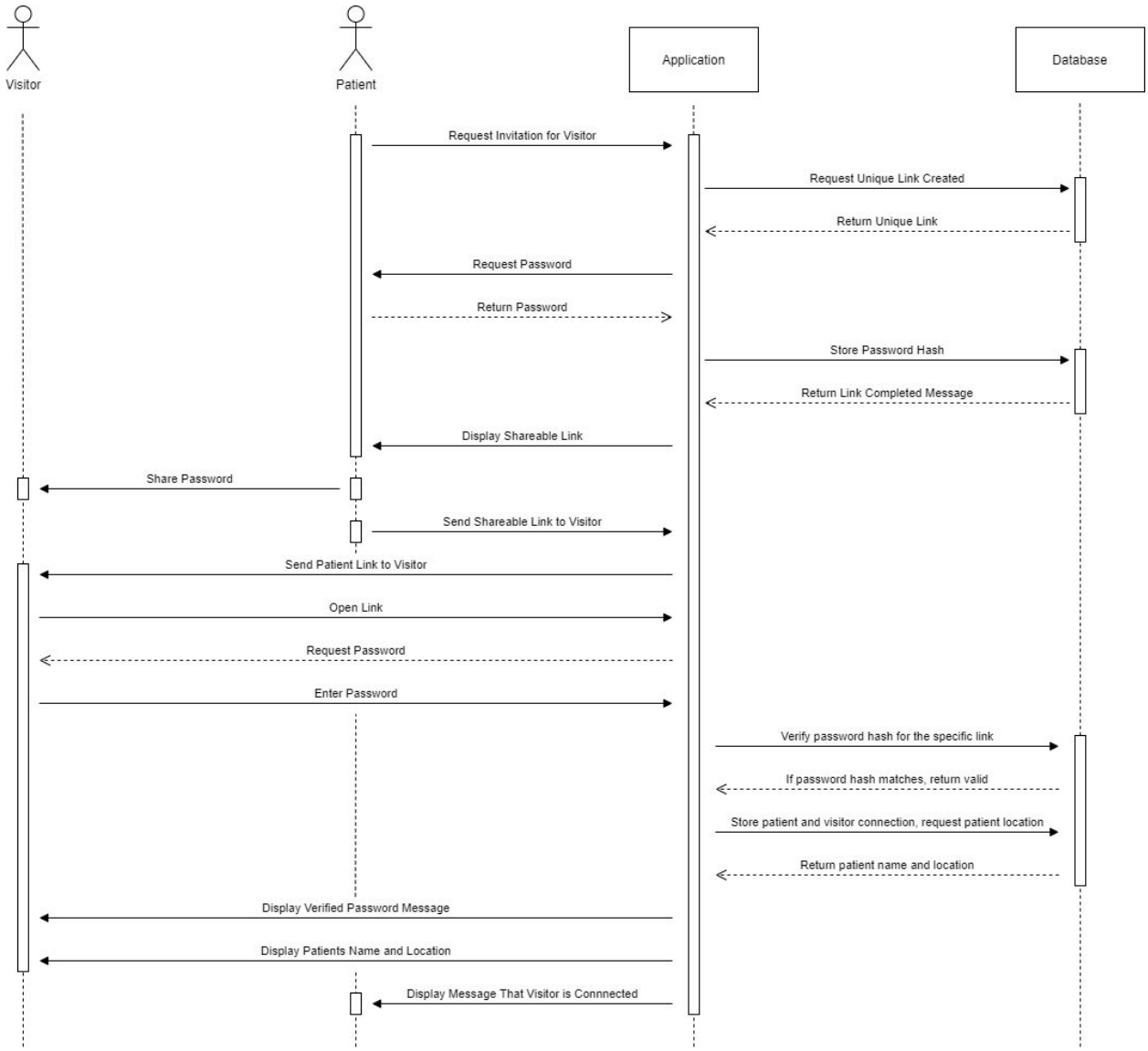

Figure 5: *Sequence Diagram of Visitor and Patient Connecting*

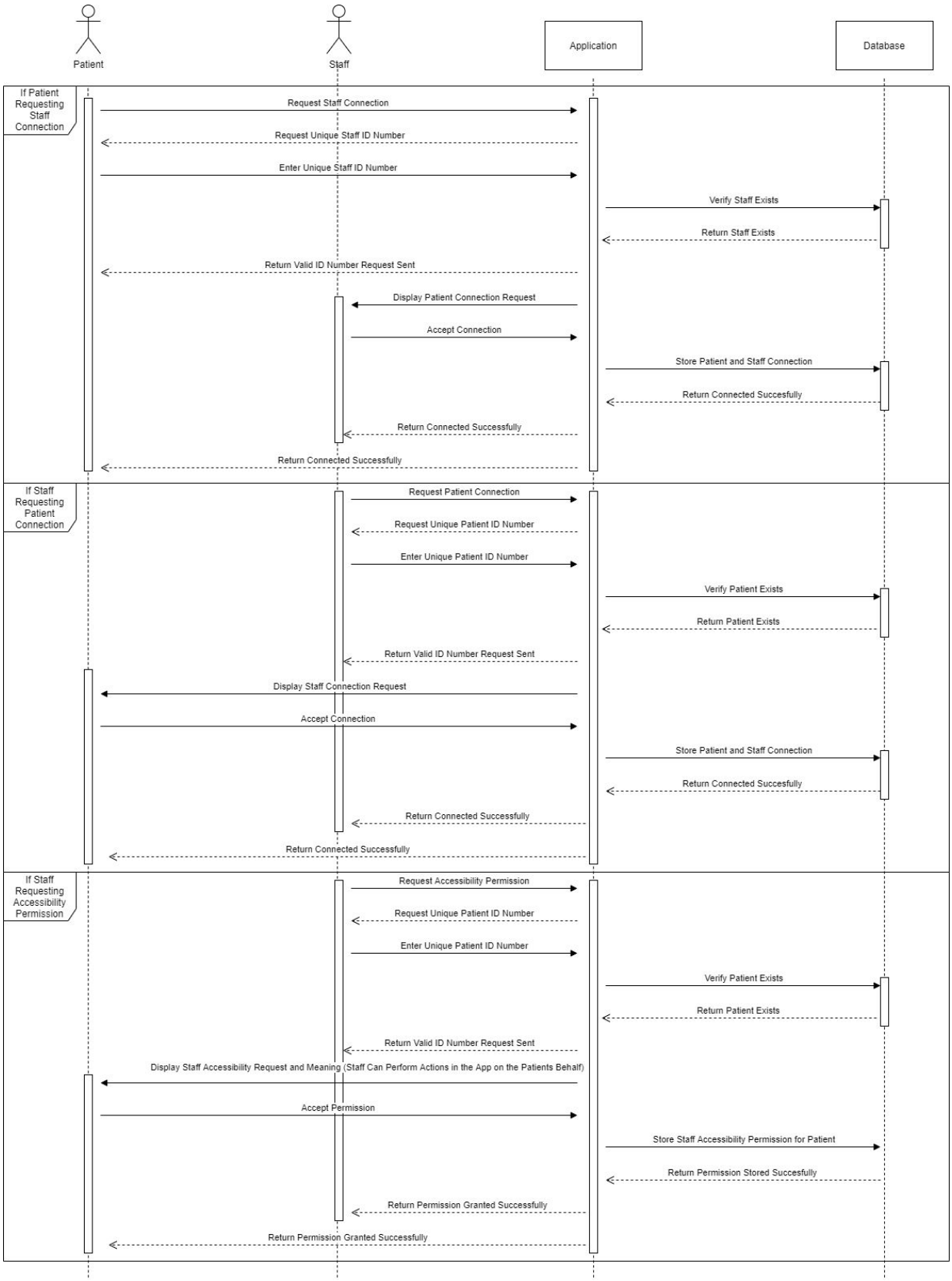

Figure 6: *Sequence Diagram of Staff and Patient Connection*

Connecting users of different roles is core to the functionality of MEDnav. Connections are stored in the database for the system and allow these connected users to share information and carry out important functions within the application. The first type of connection is between a staff member and a patient as outlined in FR 2.3 this is important for upgrading a registered user into a patient as per FR 1.3.1. Patients are also able to send connection requests to staff which is useful for patients requiring multiple care providers. These connection requests are not password protected since it is expected that staff members will be trusted to not send/accept unsolicited links to/from patients. The process of making these connections and bestowing accessibility privileges is outlined in *Figure 6*. Patient and staff connections are useful as they allow staff to see a patient's location which could be really useful for example if a patient is late to an appointment. They are also able to update a patient's status to avoid unwanted visitors during important points in their care. Furthermore staff have the ability if accessibility is granted to carry out the functions of a patient within the application.

The other type of connection is between a patient and visitor. Which is carried out by the patient sending a password protected link to a visitor within the application. This process is outlined in the sequence diagram in *Figure 5*. This is a useful connection as it allows visitors to navigate to patients' locations. It also provides visitors the ability to see patients availability status so they can determine the best time to visit. Connections provide key utility to MEDnav and as such their functionality is outlined by the functional requirements in this section. The use case diagram in *Figure 4* provides a good overall summary of the different connections and the different actors involved in each step.

3. Availability Status

3.1. The system allows for multiple statuses per user type:

3.1.1. Patient Statuses:

3.1.1.1. Available: Patient has an open schedule and is available in their room

3.1.1.2. Away: Patient has an open schedule but is not currently available in their room

3.1.1.3. Busy: Patient currently has an event scheduled (e.g. procedure or test)

3.1.2. Staff Statuses:

3.1.2.1. Available: Staff member has an open schedule and is available to see patient

3.1.2.2. Busy: Staff member is not currently available

3.2. The system allows for status to be updated in real-time or according to scheduler

3.2.1. Real-time status change overwrites current status

3.2.2. Ability to select future availability through hourly scheduler

3.3. The system allows for statuses to be viewed by connected users

3.3.1. Patient status can be viewed by staff and visitors

3.3.2. Staff status can be viewed by patients and other staff

3.4. The system allows for users to receive notifications of status changes

3.4.1. If user is unavailable, one can see when the user is next available

3.4.2. User can opt-in for notifications of another users' availability status changes

3.5. The system allows for staff to modify the status of patients

3.5.1. If user can not change their own status, they can allow staff privileges to modify their status

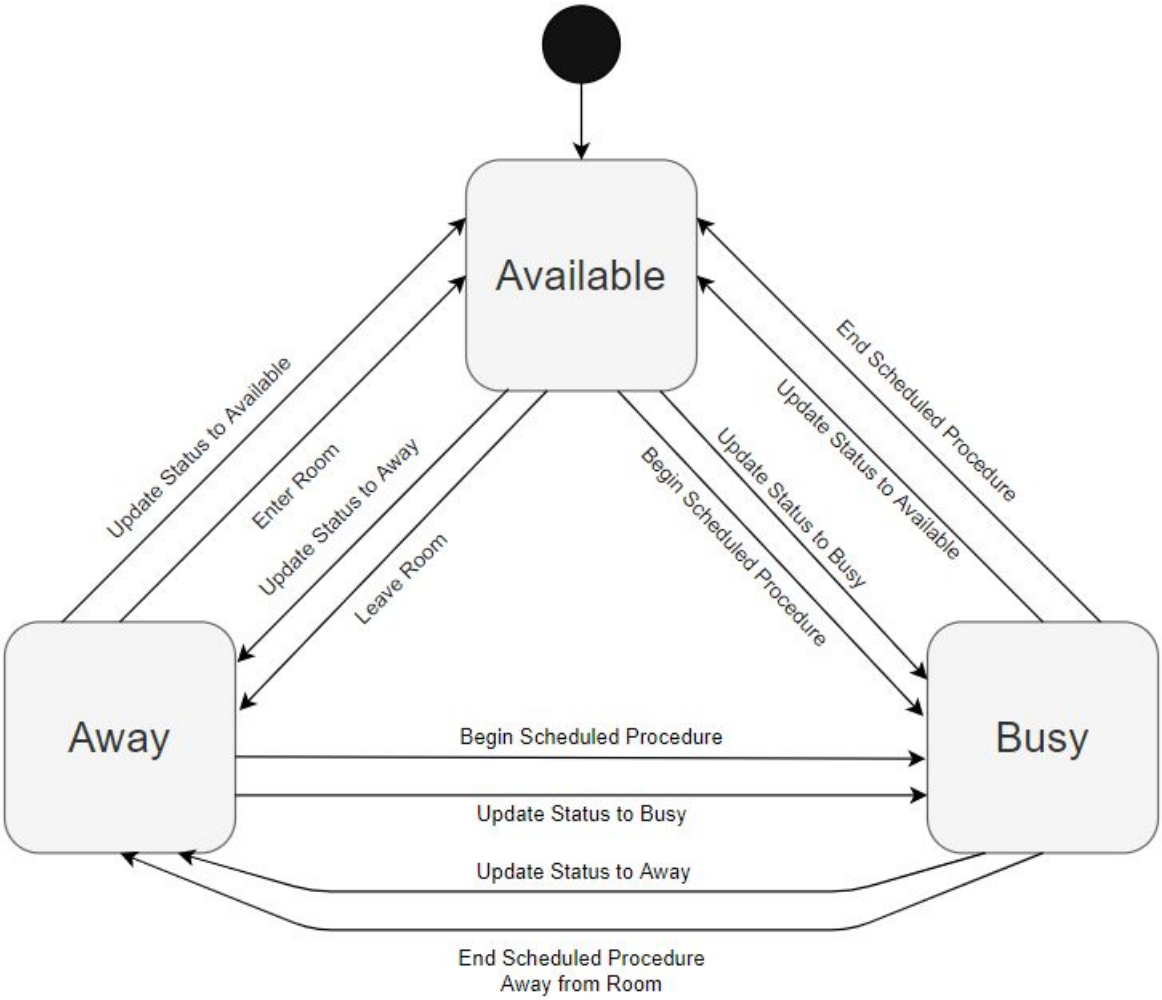

Figure 7: *State Diagram for Patient Availability Status*

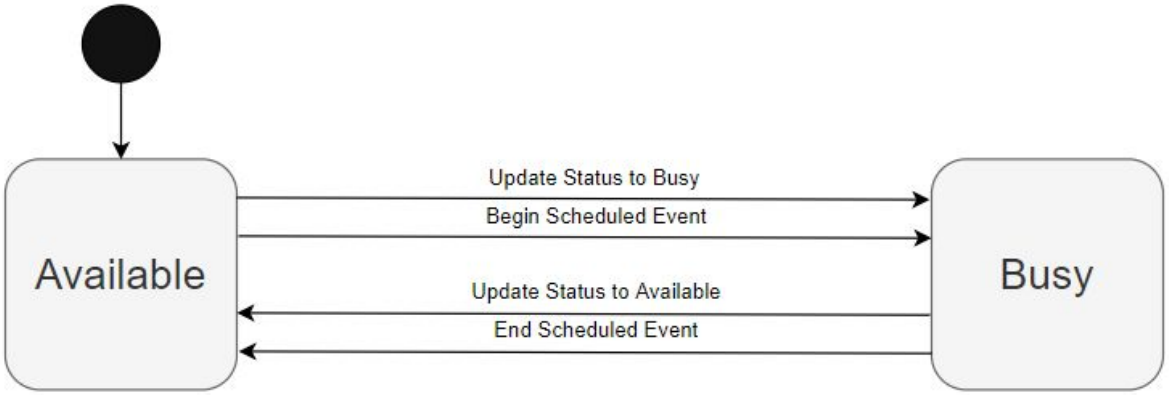

Figure 8: *State Diagram for Staff Availability Status*

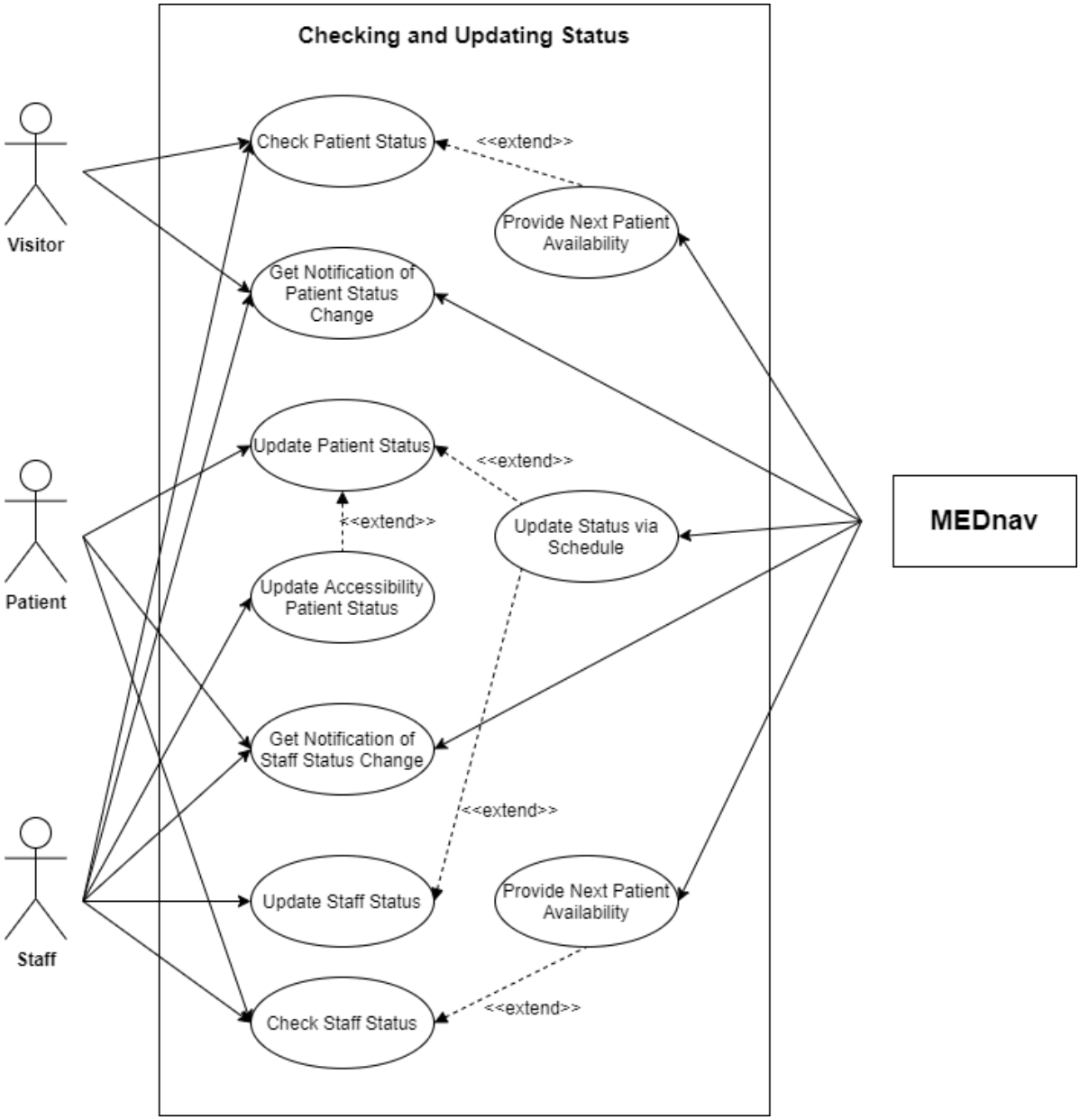

Figure 9: *Use Case Diagram for User Availability Status*

The functional requirement for availability status (FR 3) covers the ability for users of the app to update and display their status of availability. Availability statuses will be shown to other connected users including visitors, patients. and staff. Patients can have three possible statuses which are: available, away, or busy. These statuses are described in FR 3.1.1 and the transitions between patient statuses can be seen in *Figure 7*. In addition staff can also have statuses, of two varieties: Available and busy. These statuses are described in FR 3.1.2 and the transition between staff statuses can be seen in *Figure 8*. Patients and staff have the option to either update their status manually through the MEDnav application, as per FR 3.2.1, or to synchronise their status with a schedule or a calendar as per FR 3.2.2. Statuses can be viewed by connected users, either staff, patients, or visitors. Staff and visitors can view the status of

patients they are connected to according to FR 3.3.1. Similarly, by FR 3.3.2, patients can view the statuses of staff they are connected to. When viewing a user's status, if they are unavailable then the user who is viewing can see when the next available time in the schedule would be, according to FR 3.4.1. If they choose, a user could also opt-in to receive notifications about changes in another connected user's status as per FR 3.4.2. Not all patients may be able to use their phones in order to change their statuses, this could be due to accessibility issues due to medical conditions or other reasons. In this case, staff may be permitted to make changes to user statuses of users they are connected to, as per FR 3.5. This is also shown as an extension of the status updating in *Figure 9*.

4. Reporting and Notifications:

- 4.1. System allows for user to report the following categories:
  - 4.1.1. Route Conditions (Spills, Obstacles)
  - 4.1.2. Route Closures (Construction, Outages)
  - 4.1.3. Busy or Heavily Trafficked Areas
- 4.2. Staff users can verify reports before they are published and viewable by others users
  - 4.2.1. Staff can verify reports to be made visible to other users
  - 4.2.2. Staff can resolve reports to remove visibility from all users
- 4.3. User can see and receive notifications for reports that would affect them
  - 4.3.1. Verified reports are visible to all users
  - 4.3.2. Notifications based on events along generated route by FR 5.4.2.2
  - 4.3.3. Notify users of Hospital Color Codes to avoid putting users in dangerous situations
    - 4.3.3.1. Automatically updates via integration with hospital code system
    - 4.3.3.2. Provides clear explanation of color code to user
      - 4.3.3.2.1. Defines meaning of code
      - 4.3.3.2.2. Provides location of affected region and notification if within close proximity to user

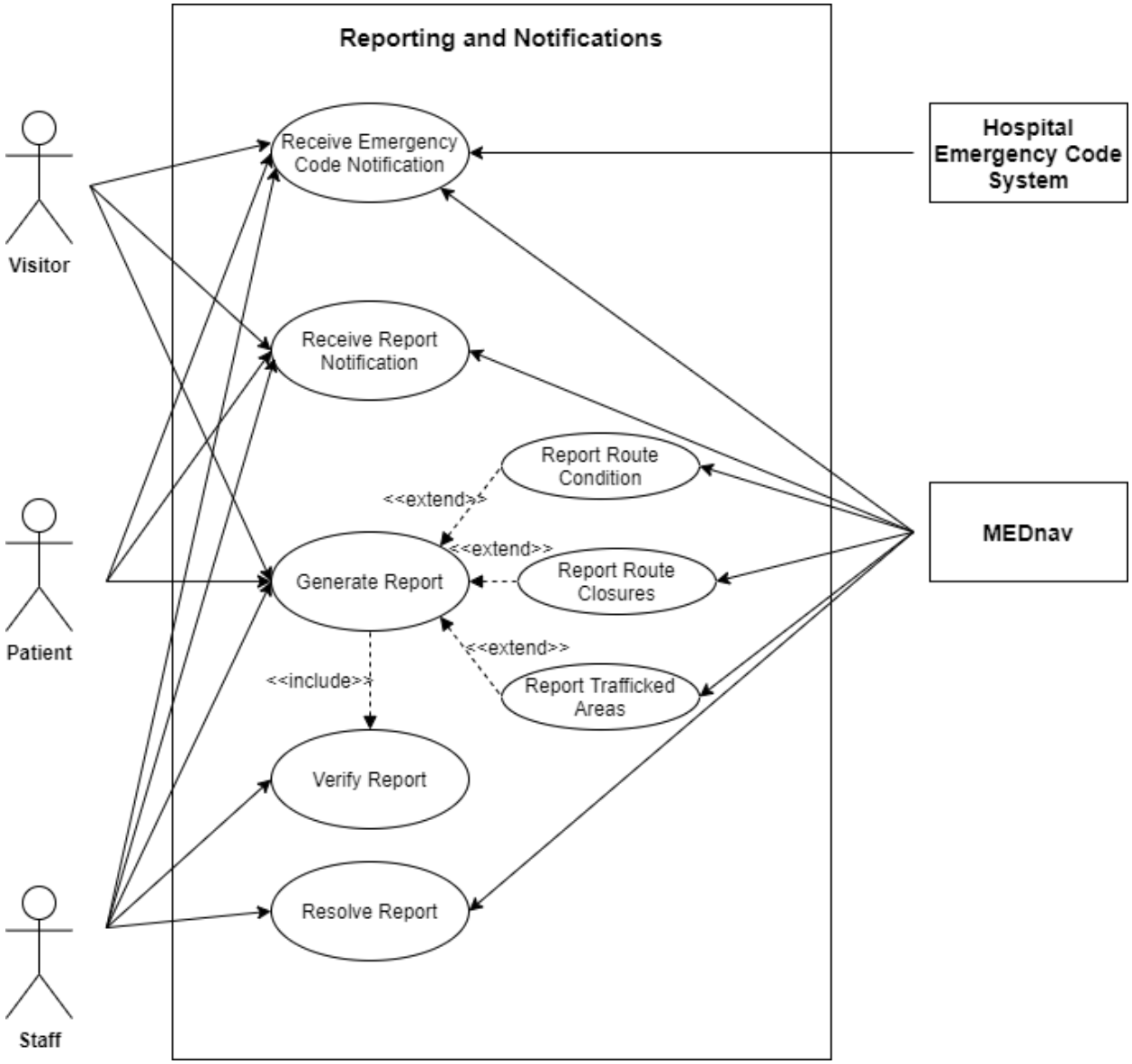

Figure 10: *Use Case Diagram for Reporting and Notifications*

The functional requirement for reporting and notification (FR 4) covers the ability for users of the app to create reports of events in the hospital that will be shown to other applicable users. These events include three main categories as detailed in FR 4.1, which are: Route conditions, route closures, and busy or heavily trafficked areas. Route conditions, as detailed in FR 4.1.1, include such things as spills, obstacles, and any other form of minor blockages. Busy or heavily trafficked areas, according to FR 4.1.3, include any areas in which there is more foot traffic than expected, that would cause delays to visitors, patients or staff that want to pass through the area. Route closures and trafficked areas can be reported by any users and can be verified by staff users, as per FR 4.2.1. Verifying a report makes it a legitimate report that can be visible to all other users, preventing an abundance of meaningless or inaccurate user-generated reports.

These reports can also be resolved by a staff member once the issue has been fixed or removed, as per FR 4.2.2. Route closures operate by a similar logic, however when they are verified by staff, they must be put into effect in the hospital floor plan and database by a system administrator, as per FR 5.3.2. After a report has been verified by staff, it becomes visible to other users as per FR 4.3.1. In addition, users will receive notifications if they are nearing the area of a report or if their generated route for navigation will route them through the area of a report according to FR 4.3.2. In addition, MEDnav will integrate with the hospital's emergency code system to notify users of codes that would be relevant to them as stated in FR 4.3.3. The use cases for this functional requirement can be seen in *Figure 10.*

5. Navigation and Browsing

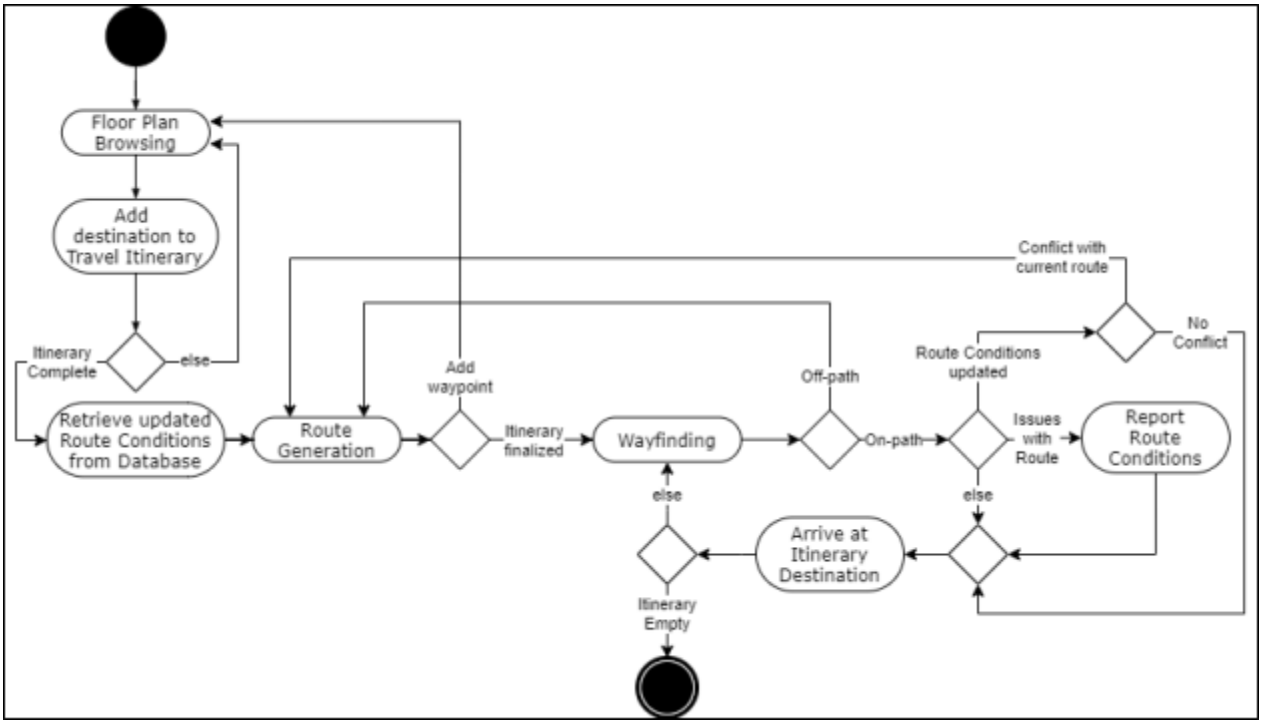

Figure 11: *Navigation Activity Diagram*

MEDnav's navigation feature encapsulates the ability to create a travel itinerary of locations in the hospital, generate a route that a user can follow, and intuitive turn-by-turn instructions to guide users to all the locations on their itinerary. These features are available to all users (registered and non-registered) as per Functional Requirements (FR) 1.1.

The navigation activity diagram in *Figure 11* illustrates a high-level overview of the navigation functionality. Users can browse the hospital floor plan and create a list of locations they may want guidance to or a travel itinerary. Then, MEDnav will generate a customized route that accounts for their current location, travel itinerary, and the most updated hospital route conditions from the MEDnav database. This ensures that the generated route is free of any obstacles. The user may modify the generated route by adding waypoints to their itinerary until they are satisfied, as per FR 5.4.3.1. Lastly, the user will begin the wayfinding step, where they are provided turn-by-turn prompts to help them navigate in real-time, as per FR 5.5.2. These prompts will guide users in real-time to the locations on their travel itinerary. While en route, the users may report issues with the route (as per FR 5.5.7). Reports will then be verified and used to update the route conditions for other users navigating the hospital. Users may be re-routed if an updated route condition conflicts with their current route or if they deviate off the generated path, as per FR 5.4.3.2 and 5.4.3.3.

5.1. Floor Plan Browsing

5.1.1. Users can search for locations in the hospital by name

5.1.2. Users can browse a labelled floor plan map of the hospital

5.1.2.1. User is able to toggle label groups to be viewed

5.1.3. Users can view a list of locations near them

5.1.3.1. The application must have access to the device location

5.1.4. User may request help if the destination is unknown

5.1.4.1. The help option will show the hospital help desk location

5.2. Travel Itinerary

5.2.1. Users can generate a travel itinerary by selecting locations they need guidance to

5.2.2. Users can modify the sequence of destinations in their itinerary

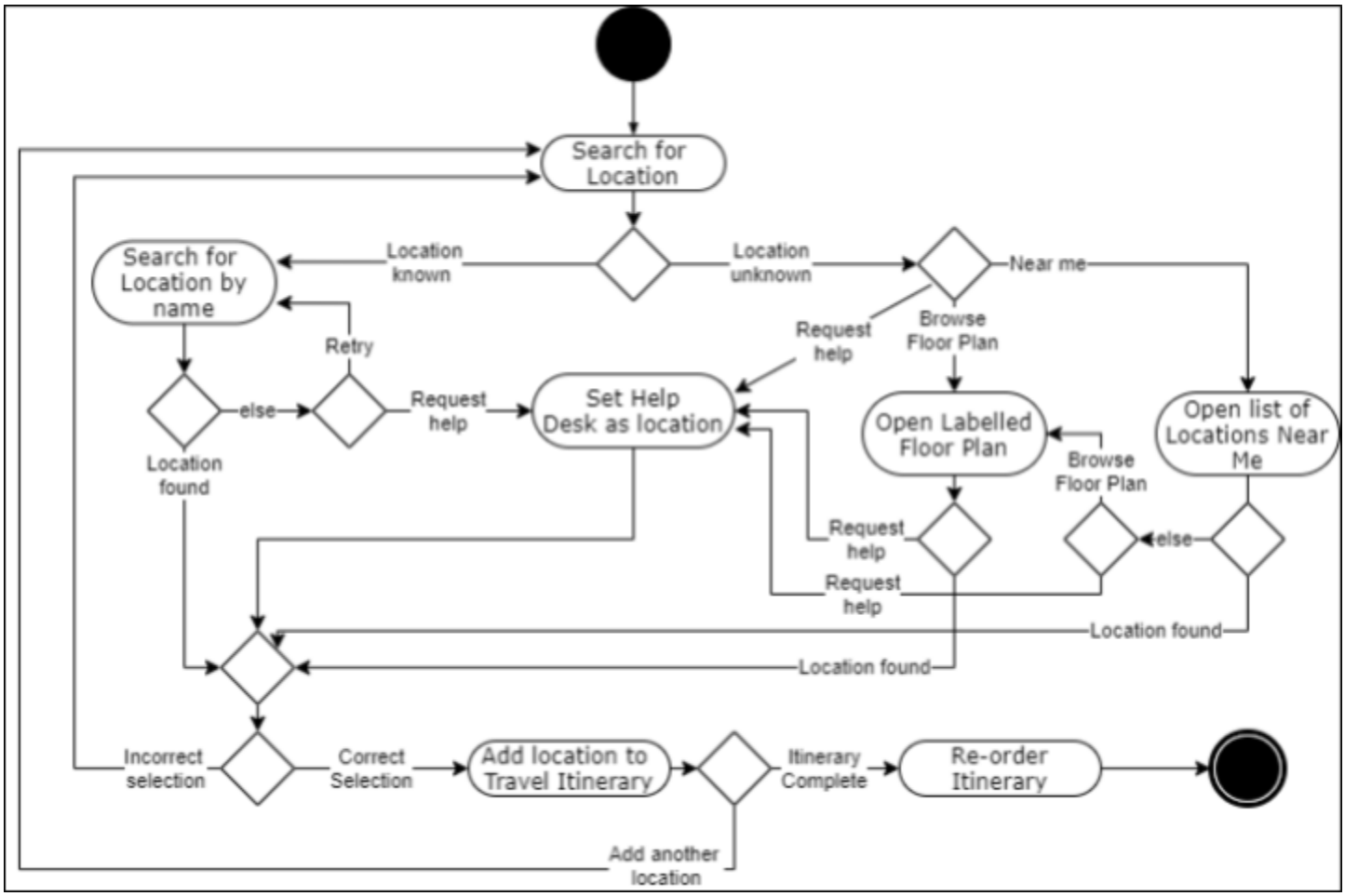

Figure 12: *Floor Plan Browsing and Travel Itinerary Activity Diagram*

Figure 12 provides details on the options available to the user in how they can find the location they want to navigate to and how they can generate their travel itinerary. If the user knows the location they want to navigate to, then they can opt for searching for the location by name and retry any number of times, as per FR 5.1.1. If the user does not know the location, then they may opt for browsing a labelled floor plan of the hospital or a list of locations near them, as per FR 5.1.2 and FR 5.1.3. If the three methods of floor plan browsing (searching, labelled map, and Near Me) do not help find their desired location, then they can request help, as per FR 5.1.4. Requesting help will automatically set the destination for the hospital help desk, where the user can receive one-on-one support from a hospital staff.

Once the user has identified a location, they can add it to their travel itinerary, they can continue to add more locations, and modify the sequence of destinations in their itinerary to match the order in which they would like to arrive at each destination, as per FR 5.2. At this stage, the user has completed their itinerary and can proceed to generate a route specific to their travel itinerary.

5.3. Route Conditions

5.3.1. The application must have access to the most updated route conditions.

5.3.2. System Administrator must update the floor plan based on the verified reports by the staff, as per FR 4.2.

5.4. Route Generation

5.4.1. The application must generate a route for the user to follow based on the user's current location

5.4.2. The generated route must prioritize:

5.4.2.1. The user's travel itinerary

5.4.2.2. The most up-to-date route conditions

5.4.2.3. Minimizing travel distance

5.4.3. The application will re-route users if:

5.4.3.1. They add waypoints to their itinerary

5.4.3.2. The deviate from the defined path during wayfinding

5.4.3.3. Updated route conditions conflict with the defined path

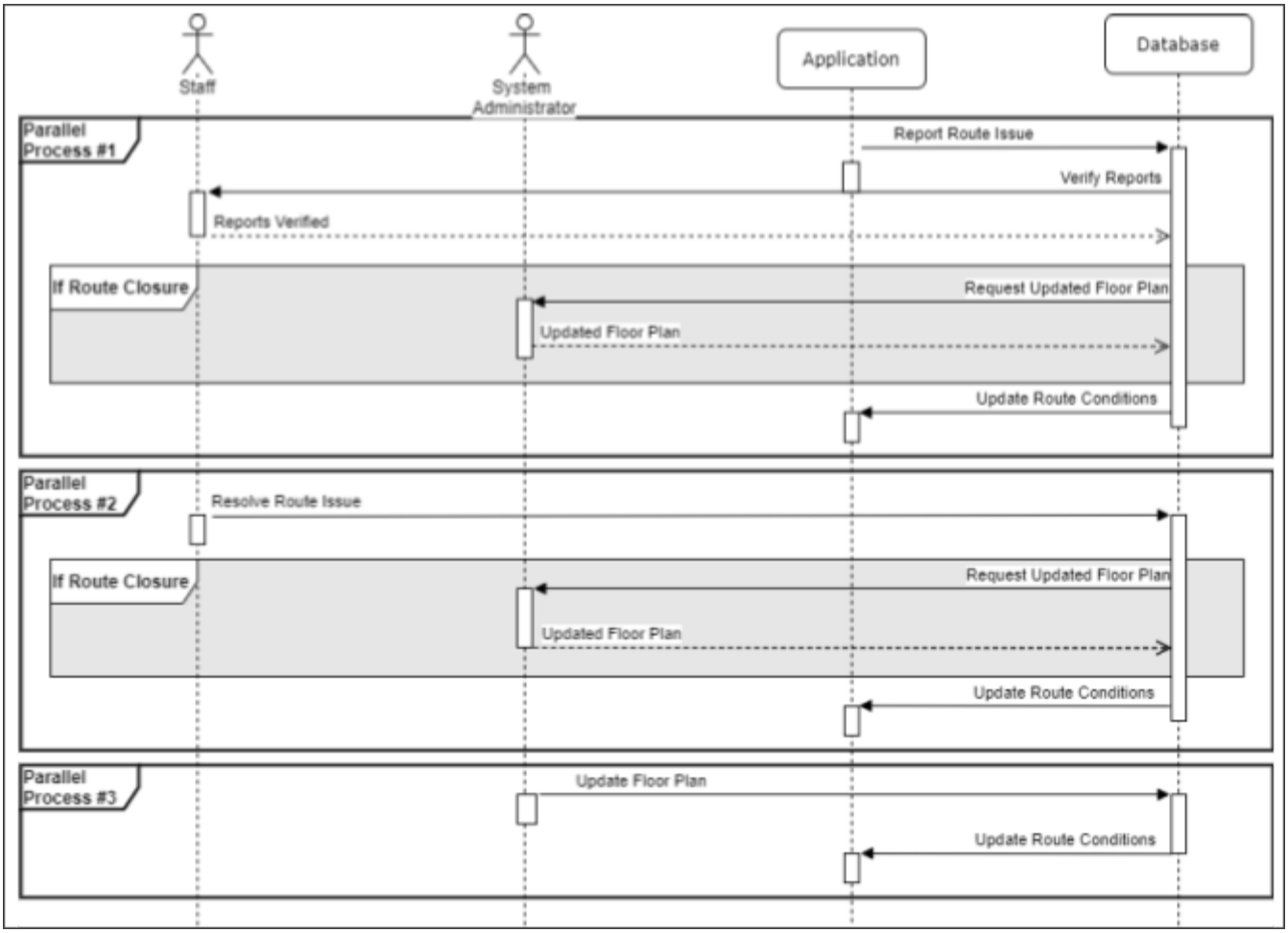

Figure 13: *Sequence Diagram for Updating Route Conditions*

Generating a route is a straightforward task. The application needs to know the user's current location, travel itinerary, and the most updated route conditions of the hospital, as per FR 5.4.1 and 5.4.2. Accessing the user's current location is a trivial task of pinging the device's location information which MEDnav is installed on. The travel itinerary was completed in the last stage. Therefore, the only remaining step is retrieving the most updated route conditions of the hospital.

Figure 13 illustrates the sequence of steps by which the hospital route conditions are updated, stored in the database, and shared with the users via the application. As seen in *Figure 13*, three parallel processes can update the route conditions: user-generated route reports, route issue resolution by the staff, and route modifications by the System Administrator.

In the first two scenarios, the System Administrator is involved if there is a report which involves Route Closures or any other major change which would require the modification of the hospital floor plan, as per FR 5.3.2. In the case of minor issues (spills, obstacles, traffic, etc.) that are verified by the staff, the database will update the route conditions accordingly. The update will be shared with all the users in the hospital via the MEDnav application. The updated route conditions can be used by users looking to generate a route or those who are currently en route to a destination and encounter a conflict (refer to *Figure 11*) and need to be re-routed, as per FR 5.4.3.3.

Once the most updated route conditions are retrieved from the database, the application will go ahead and generate a route that first prioritizes the user's current location, their travel itinerary, the route conditions, and then finally minimizing the route distance. It's crucial to prioritize the route conditions over minimizing travel distance to ensure the application generates a route that the user can physically follow. And prioritizing the current location and itinerary above all else will ensure that the generated route will account for the user's travel requirements. Conditions for re-routing are illustrated in *Figure 11* and explained in detail on page 27.

5.5. Wayfinding

5.5.1. The application must have access to the device location

5.5.2. The application must provide turn-by-turn prompts to guide users in real-time

5.5.3. The prompts must be available in two variants: Augmented Reality (AR) and Floor Plan Navigation

5.5.4. AR Navigation

5.5.4.1. Navigation prompts must be superimposed onto the user's real-world settings using the smartphone's camera

5.5.4.2. A Mini-Map must be visible to highlight the trip progress

5.5.4.3. The Mini-Map must be located off-center on the device screen

5.5.5. Floor Plan Navigation

5.5.5.1. A top-down view of the user's route

5.5.5.2. User is able to zoom in and out and move around on the map

5.5.6. The application must provide an easy method to switch between AR and floor plan navigation modes

5.5.6.1. When user is in motion the application automatically switches back to AR mode

5.5.7. Users have the ability to report route conditions while en route and not moving

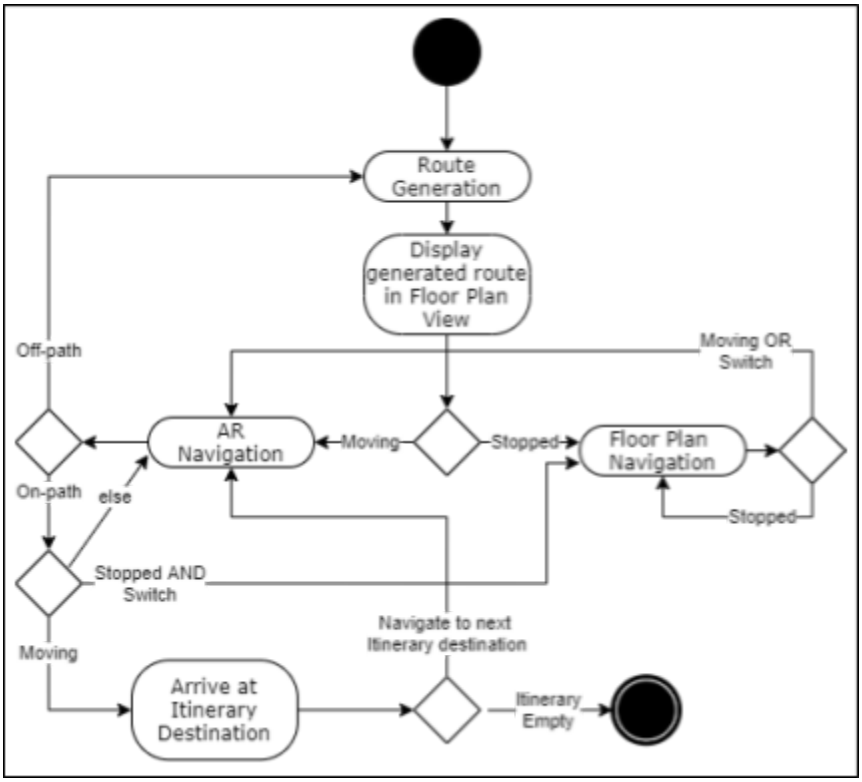

Figure 14: *Wayfinding Activity Diagram*

Now that a route has been generated for the specific travel itinerary, the application will proceed to the wayfinding stage. The wayfinding stage provides the user with real-time turn-by-turn prompts to help navigate them to the locations in their itinerary. Real-time prompts are possible if the application has access to the device's location information, as per FR 5.5.1. and 5.5.2. The prompts are available in two modes: Augmented-Reality (AR) Navigation and Floor Plan Navigation, as per FR 5.5.3.

In AR Navigation mode, the navigation prompts are displayed as graphics overlaid on top of the real-world settings captured by the smartphone camera to give them a sense of their surroundings. While in AR Navigation, the user has a mini-map located off-center on the phone screen to allow the user to focus on their surroundings, as per FR 5.5.4. The mini-map displays the next few turns the user will have to make to prepare them.

Floor Plan Navigation mode is a top-down view of the floor plan highlighting the user's full journey. Zooming and Panning features are available to the user to better understand the progress of their journey as per FR 5.5.5.

The Floor Plan Navigation mode is the default method of displaying the route when leaving the route generation stage, as can be seen in the wayfinding activity diagram in *Figure 14* above. Then as soon as the user begins walking, the application switches to AR Navigation mode to prevent users from roaming the hospital unaware of their surroundings. Users can also switch into the Floor Plan Navigation mode while in AR Navigation mode by coming to a complete stop and double-tapping the on-screen mini-map, as per FR 5.5.6. Following the prompts in the AR Navigation mode should guide the user to all the locations on their itinerary and complete the navigation stage.

Non-functional requirements

Table 4: Non-functional requirements

Requirement	Description	Implementation
Usability	The navigation must be simple and intuitive	The navigation interface will use dynamic frontends and layouts to ensure that all screen sizes are compliant on all screen sizes. Typical app icon conventions will also be followed to ensure users have familiar and attractive options.
Availability	The system must have limited downtime	As MEDnav will need to be updated, legacy software must therefore ensure that a version is always working natively on the device to reduce downtime.
Scalability	The system must be responsive to updates and new features	As MEDnav has enormous potential, the ability for the app to grow is important. Implementing new features must be fast and easy to achieve as it can improve or enable new services for hospitals and/or users.
Performance	The system must be fast and robust	As MEDnav is a navigation tool, it must be fast to ensure that users arrive at their destination quickly and appropriately.
Security & Privacy	The system must be secure and maintain the privacy of its users	As MEDnav is mainly a phone app, it must restrict access to users' personal information. Although location services must be enabled, public key cryptography will ensure privacy of information from other applications on the phone. Also, when sharing your location with friends/family, a password authentication step will be implemented (i.e. the bank e-transfer model).
Integration	The system must facilitate multiple operating systems and sharing	MEDnav must be able to integrate on multiple operating systems (mainly iOS and Android), many devices (tablets, phones, and laptops), and must be able to share data with other users (location sharing with family/friends).
Reliability	The system must be consistent	As MEDnav is a navigation tool, repeatable and reliable measurements are required to ensure appropriate delivery and proper user experience
Safety	The system must ensure safety of its users	As MEDnav is a navigation tool, it must always ensure the safety of users while navigating, therefore the Augmented Reality (AR) mode must be immediately initiated when the user is in motion (i.e. walking).

Strategy for Testing Each Requirement

1. Registration

It is important to test the registration functional requirement as it is crucial to the structure of the program and thus integral to the systems functioning. In order to test this it would be useful to assign oneself as the system administrator allowing for deeper insights into the information stored in the database and the functioning of the system. It is important to test the transition of users into the different roles within the system. Multiple instances of unregistered users should be created using multiple different devices with the application. It would be important to test the error handling of the system when transitioning to a registered user. Using these new registered users the transitions into the three different roles staff, patient and visitor could be tested. In all three of these cases it would be important to test the error handling functionalities of the transitions. Specifically since the transitions require the inputting of text based information it is crucial to test for vulnerabilities to overflow or injection attacks. For staff it would be specifically important to test the systems integration with the hospital login system and ensure this didn't present any potential vulnerabilities. It would also be important to test the transitions back to registered users from all three of the roles. Also it should be ensured that a registered user could successfully transition into and out of all three of the different roles without presenting any issues.

2. Connecting Users

It is important to test the connection of users as this is also another point of potential vulnerability. The testing of the connections is also closely tied to the testing of the registering functional requirement as connections are responsible for transitions between different roles. In connecting patients and visitors it is crucial that the password verification system is thoroughly tested ensuring it isn't vulnerable to any known attacks. It is also crucial to verify when selecting a visitor/registered user to send an invitation to that no visitor information is accidentally available. It is also important to test how the system handles an incorrect invitation sent as this could present issues for the system. The sending of multiple identical invitations or unwanted spamming of invitations should be tested to ensure it is mitigated or avoided by the system.

The patient and staff connection is easier to test since it doesn't require a password. Again the spamming of requests and invitations sent to unwanted users should be tested. Since both staff and patients can send requests it may be useful to see how the system handles coincident requests by both parties. Furthermore, testing how errors in patient or staff ID number requests for connection are handled should be tested. It should also be tested that this numerical input is handled appropriately to avoid attack.

3. Availability Status

In order to test the availability status functionality, one could ensure that only the proper statuses are displayed for each type of user. For patients, this would be: Available, Away, Busy. However for staff, the statuses would be: Available and Busy. This can be done by creating users of these types and ensuring that only the listed states are available for each status. The tester can also make sure that the users can manually change their status at any time as well as seeing if MEDnav successfully changes the status based on a schedule. In this case, a manual update of the status should always overwrite the scheduled change. Finally, one can test that a user can correctly see the status of a connected user, and is able to view the next availability according to a schedule if that user is not available. Additionally all users should be able to opt-in to receive notifications regarding the changes in status to connected users. These can all be tested by generating multiple users of different types and simulating a small connected group of users, making sure all the statuses and notifications are consistent and expected.

4. Reporting and Notifications

In order to test the reporting and notification functionality, one could generate mock reports and view these reports as different users. The user should be able to separately generate the three types of reports as described in FR 4.1. Furthermore, other non-staff users should test that they will not be able to view these reports, as they have not yet been verified by staff users. Following this, one should test staff user functionality, in that they can successfully verify reports submitted by users, and subsequently resolve reports that are no longer needed. Finally one must test integration with the hospital emergency code system to ensure that when a code is called in the hospital, it will be relayed through the app to relevant users. This can be done by testing this feature of the app at the same time as testing the emergency system.

5. Navigation and Browsing

The backbone of the entire navigation and browsing stage is the hospital floor plan. The tester must ensure that there are no discrepancies between the hospital floor plan MEDnav uses to generate its routes and the blueprints of the physical hospital. It is also important to reliably and accurately track the movements of users within the hospital, this needs to be tested in an array of different locations in the hospital. Given that the floor plans are consistent and the system can localize the position of all the users, then it will be straightforward verifying the remaining navigation functionalities.

Floor Plan Browsing and Travel Itinerary testing must verify that a trip with an arbitrary number of stops located throughout the hospital should be able to be generated. This can be tested by generating random travel itineraries of varying lengths and making sure to cover all zones of the hospital. It should also be tested that unavailable locations can’t be added to the itinerary.

Then Route Generation should be able to provide a route for the user that they can physically follow. To make sure of this, the most updated version of the route conditions must be available on the MEDnav database. Then the tester, alongside the System Administrator, can generate routes with and without the influence of certain route conditions to see the effects on how users are navigated throughout the hospital.

Finally, the wayfinding functionality can be verified by following the route that has been generated by MEDnav. During the navigation mode, it’s crucial to measure the user's awareness of their surroundings. It's also imperative that the users will not cause or become more prone to accidents as they roam the corridors of the hospital with their faces in their phones. To verify this condition, AR Navigation mode must be engaged whenever the user is on the move to give them a sense of their real-world settings with the AR capabilities.

Description of Underlying Structure

The underlying structure of the MEDnav system contains two key components: the application and the database, as seen in the sequence diagrams in *Figure 5, 6 and 13*. The application is the instance of the program operating on each individual's device; it allows users to carry out the core functionality of the app. The application directly interacts with the user displaying necessary information and allowing the user to interact with the system.

The other key component, the database is the sole player that allows the application to function. The database allows the system to store information and interact directly with the different instances of the application. The information stored is the necessary user information as well as the connections and relevant hospital information required. In addition to data storage the database is also responsible for interacting with each individual instance of the application and responding to the individual requests by returning the relevant information and updating the information stored accordingly. We decided to lump the storage and carrying out of the functionality both into the database for simplicity however, the medium allowing for the interactions could be further abstracted to a server. The storage of the information has been left out of the scope of the proposal as it is very implementation specific and would also need to be designed with the help of the software engineers implementing the system so that it is able to integrate effectively. Furthermore, the specific data stored for individuals presented is just a best guess of what may be required and would need refining based on future requirement elicitation. As such a database schema was intentionally left out of this report as it requires too many specific details that have not been fully flushed out.

Another key part of the system is the organization of the different roles a user can have within the program. This specific structure is demonstrated in the class diagram of *Figure 2* and the transitions between these states is observed in *Figure 3*. For further information, refer to the functional requirement 1 section on registration.

Description of How MEDnav Functions

MEDnav functions through the combination of all of its components as outlined through the five distinct major functional requirements. Users must first register through the application as the proper user type according to FR 1, including the case of non-registered users who can use the application for strictly navigational purposes. Registered users can then connect to other users according to FR 2, allowing them to get a much more personalized experience, including access to statuses, locations and navigation instructions to other users. Once connected, users have access to each other's availability statuses, allowing them to see when the other is available or not, as per FR 3. This functionality allows users to keep up to date with their connections and see when they are available to be visited, or to be seen for help. Throughout their hospital experience, MEDnav users can also make reports about conditions to routes or to the environment around them as seen in FR 4. This allows users to be kept up to date with their surroundings in order to stay safe and informed through their hospital experience. Finally, the core functionality of MEDnav is to navigate through the hospital to get to one's desired destination, accomplished through FR 5. The user is able to use MEDnav in order to browse floor plans, and search for where they would like to go. Once a destination is selected, they can generate a route which will be followed using step by step guidance, including an AR display as well as a map to keep the user on track.

Standards Compliance

Visual Graphics

For specific entities (i.e. hospitals) seeking to install MEDnav software on their campus, standards and guidelines for visual graphics and in-app icons must be outlined as per [9]. Similar to hospital signage and maps, approval for posting visual graphics to the app must adhere to regulations outlined by each entity's approval process in [9]. This compliance feature will be built-into the installation process and the data license agreement.

The MEDnav app produces a variety of visual graphics to enhance hospital wayfinding such as room, building, and route signage along with buildings, services, accessibility, and campus specific icons. As diverse facility channels such as research entities, academic institutions, and important sponsors may have a controlling interest in the hospital, both a sound communications strategy and an integrated visual graphics representation are required. In order to deliver a consistent user experience with unique signage and icons, the MEDnav app provides built-in standards integration that is specific to specified brands, logos, and colours. The MEDnav app then requires all relevant logo styles to include a positive, reverse, black, and white image, all with transparent backgrounds. Additionally, for each logo set, a defined colour palette must be formally indicated which includes at least one main colour, and 4 supporting colours. Specified fonts along with bold and italicized features of text are optional features for each logo instance, with helvetica set as the default. Additionally, implementing brand specific icons is an optional feature within the app, whereas default icons will be provided by the Noun Project Library as per [10] for an additional charge. All logos, colour palettes, fonts, and icons must have appropriate licensing agreements in place with the specified institutions before proceeding with final installation, as to not infringe on copyright and/or intellectual property.

Data Privacy

Data privacy is an increasingly important issue surrounding hospitals and other healthcare enterprises as we shift towards a digital world says [11]. Therefore, to ensure data privacy and security within MEDnav, the app MedStack is utilized based on [11]. MedStack ensures digital platforms meet privacy and security expectations up front, before IT diligence even starts. The app enables platform technologies to adhere to the Canadian privacy legislation Personal Information Protection and Electronic Documents Act (PIPEDA) and various provincial health data privacy regulatory bodies to ensure that the app can be used securely all over Canada says [11]. The use of MedStack also enables easy scalability for the app to the United-States market as it has the ability to adhere to the Health Insurance Portability and Accountability Act (HIPAA), the world's most stringent healthcare regulatory body, and the General Data Protection Regulation (GDPR) in Europe as per [11].

Wi-Fi

As Wi-Fi is currently deployed within most hospital network infrastructures, it is important to ensure that the MEDnav app properly integrates with existing Wi-Fi standards as per [12]. Therefore, the MEDnav app has been built to adhere to the most common compliance standard set forth by the Institute of Electrical and Electronic Engineers (IEEE) - Title 802.11n as per [13]. This specific standard provides up to 450Mbps transmission in the 2.4GHz band, which is the most widely used system to date says [13]. Additionally, the specific 802.11n standard inherently benefits mobile apps as it ensures reliability and fast computing speed.

Cellular, Bluetooth, and Ultra Wide Band (UWB)

All cellular, bluetooth, and ultra wide band (UWB) networks used within the MEDnav platform adhere to the standards set forth by The Food and Drug Administration (FDA) as it allows the app to scale to users in the United-States as per [14]. The MEDnav app falls under the category of “Software as a Medical Device (SaMD), as it is defined as a commercial off-the-shelf (COTS) mobile application that aims to improve and facilitate the delivery of patient care as per [14]. Although the FDA would not regulate the sale of the app, it is imperative to follow these guidelines as to increase the validity and reliability of the product. The app is built to adhere specifically to both Code of Federal Regulations (CFR) Title 29 - Occupational Safety and Health Administration based on [15] and CFR Title 21, Article 11 - Data Integrity Compliance based on [16].

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