Senior Design Project: Cognitive Assistance with LiDAR Localization (C-ALL)

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Team Members and Roles

Neeti

Documentation Manager + User Advocate + Risk Management

Sara

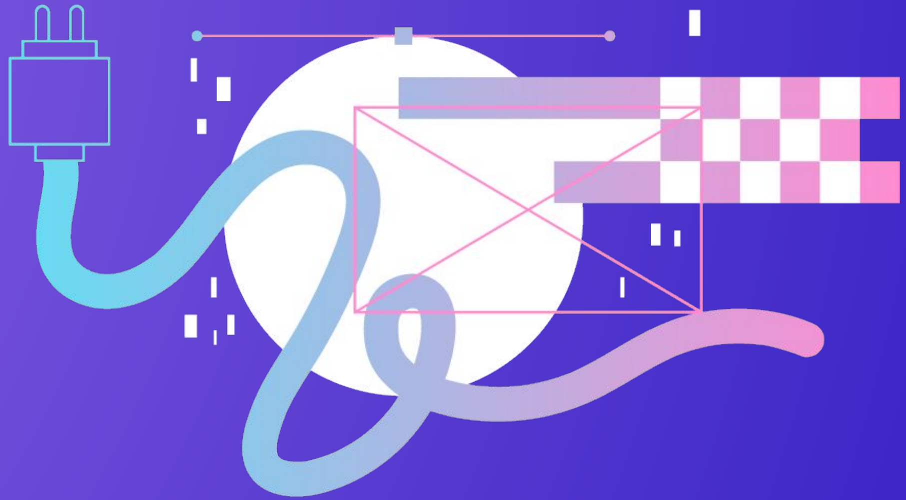
Use Cases + Front-End Lead

Ahmad

Development + Hardware Lead

Sohan

Test Lead + Buildmeister

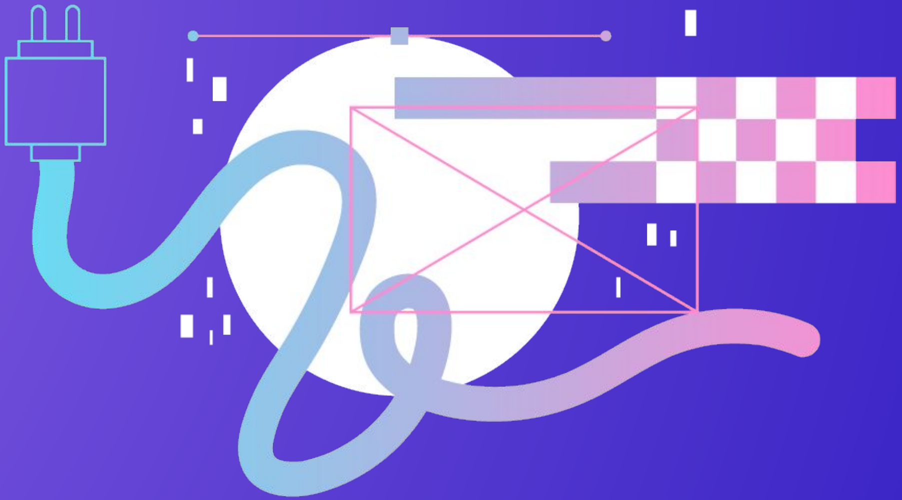


Project Mission

Improve assistive technology for the visually impaired community

Project Mission

- The product we wish to develop, C-ALL (Cognitive Assistance with LiDAR Localization), aims to aid the visually impaired by providing an alternative to current tools..
- The product will consist of 3 main design parts: a LiDAR sensor contained within a smartphone, a physical device describing navigation, and a mobile application.
- The LiDAR sensor will map out the environment in front of the user into a 3D point cloud, where a custom program would be implemented onto the raw data to simplify the detected nodes, which will then be constructed as simple 3D objects in an environment.
- Simultaneous Localization and Mapping (SLAM) will be utilized to ascertain the user's position in the previously mentioned environment.
- The final implementation of the product is expected to be a glove that contains a ball which moves in the direction that the user should move in, with adjusting sensitivity to signal incoming obstacles or changes in direction.

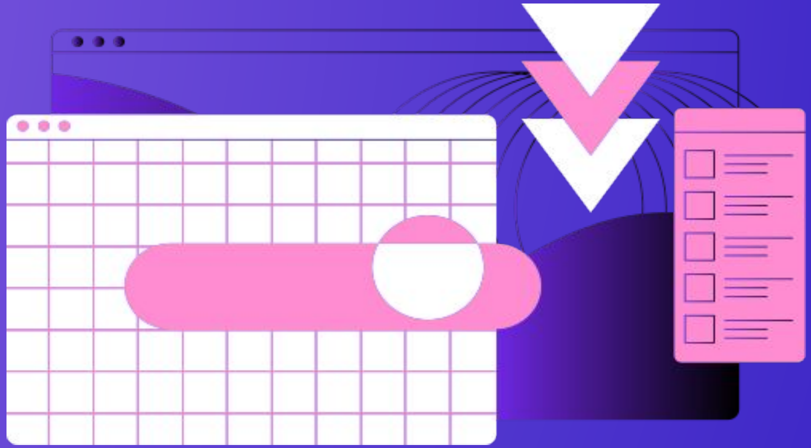


Mission Statement

Empower community and more accessible

Mission Statement

The mission of the C-ALL (Cognitive Assistance with LiDAR Localization) project is to develop an innovative assistive technology solution that empowers visually impaired individuals to navigate their surroundings with greater independence and confidence. By integrating advanced LiDAR technology, sensory feedback, and a mobile application, we aim to create an accessible, reliable, and user-friendly product that provides real-time spatial awareness. Our goal is to address a critical business need in the assistive technology market, enhancing mobility solutions and improving the quality of life for individuals with visual impairments. We intend to deliver a scalable product that can be further developed for broader commercial use, ensuring both technical innovation and societal impact.

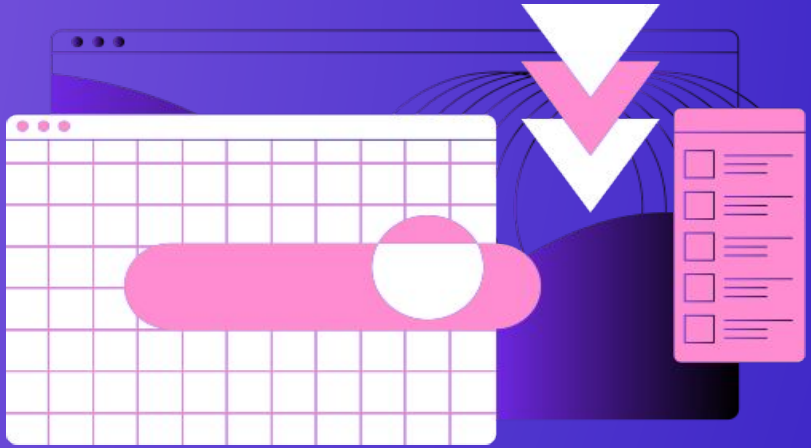


Key Drivers

Driven by the need to provide enhanced mobility solutions for visually impaired individuals

Key Drivers

- The development of C-ALL is driven by the need to provide enhanced mobility solutions for visually impaired individuals.
- Current assistive technologies often rely on limited sensory input or cumbersome devices, leaving significant room for improvement in terms of user experience, accuracy, and real-time feedback.
- The increasing affordability and accessibility of LiDAR technology, combined with advancements in mobile applications and sensory feedback, present a unique opportunity to offer a more intuitive and effective solution.
- Our motivation stems from a desire to bridge this technological gap and address a societal need.
- By leveraging different technologies, we aim to empower visually impaired individuals to navigate their environments with greater confidence, independence, and safety.
- The potential to impact lives in meaningful ways, combined with the opportunity to innovate in the assistive technology space, drives our commitment to this project.



Key Constraints

The development of C-ALL faces several constraints that must be carefully managed to ensure the project's success. These constraints include technical and user-specific limitations, all of which shape the project's scope and feasibility.

Key Constraints

- **Technical Limitations**
  - One of the primary constraints is the computational complexity of processing LiDAR data in real-time.
  - LiDAR sensors generate large volumes of point cloud data that require significant processing power to convert into a simplified 3D representation.
  - In our current set-up, we plan to off-load data processing to a central server during testing, but in the final product, the system will be entirely offloaded onto either AWS or will be entirely enclosed into the build of the application..
  - Balancing processing speed and accuracy within the constraints of limited hardware resources (such as mobile processors or compact GPUs) will be a significant challenge.

Key Constraints

- **User Experience and Accessibility**
  - Designing an intuitive and user-friendly interface for visually impaired users is another constraint.
  - The product must accommodate the diverse needs of users with varying degrees of visual impairment, and any misalignment in the interface or haptic feedback system could lead to confusion or errors.
  - The mobile application must comply with accessibility standards and provide seamless interaction through voice commands or other assistive technologies.
  - This requires thorough user testing to guarantee that it functions effectively across different environments.

Key Constraints

- **Time Constraints**
  - Time management is a significant factor in this project.
  - The development timeline for our senior design project is limited, and achieving all technical milestones within this time frame requires careful planning.
  - Prototyping, testing, and iterating the product to meet the necessary performance and reliability standards will need to be done efficiently.
  - Any delays in one area (e.g., hardware procurement, software development, or testing) could push back our progress and affect the overall project delivery.

Overall Development Plan

Phase 1: Basic Obstacle Avoidance

- **Glove-Mounted Device**: Develop a glove-mounted device using an Arduino and two servos to control a pointer in the x and y directions
- **iOS Application Development**: Create a basic iOS app using Swift and Xcode
- **Obstacle Avoidance**: Implement functionality for the user to maintain a straight path while avoiding obstacles placed in front
- **Data Collection and Processing**:
  - Use ARKit to obtain a 3D depth map from the iPhone's LiDAR sensor
  - Send depth data to a desktop computer for processing using Python
- **Communication**:
  - Relay instructions from the desktop back to the app
  - Use Bluetooth to send commands from the app to the Arduino on the glove
- **Heading Maintenance**: Utilize compass data from the CoreLocation library to keep the user on the correct heading

Overall Development Plan

Phase 2: Navigation System Implementation

- **Destination Input**: Allow users to enter a desired location into the app
- **Route Mapping**: Compute the intended route and establish the required compass heading
- **Guidance System**:
  - Guide the user along the planned path
  - Adjust for obstacles by temporarily altering the user's heading to avoid them
  - Return the user to the original path after obstacle avoidance

Phase 3: Accessibility Enhancements and Hardware Update

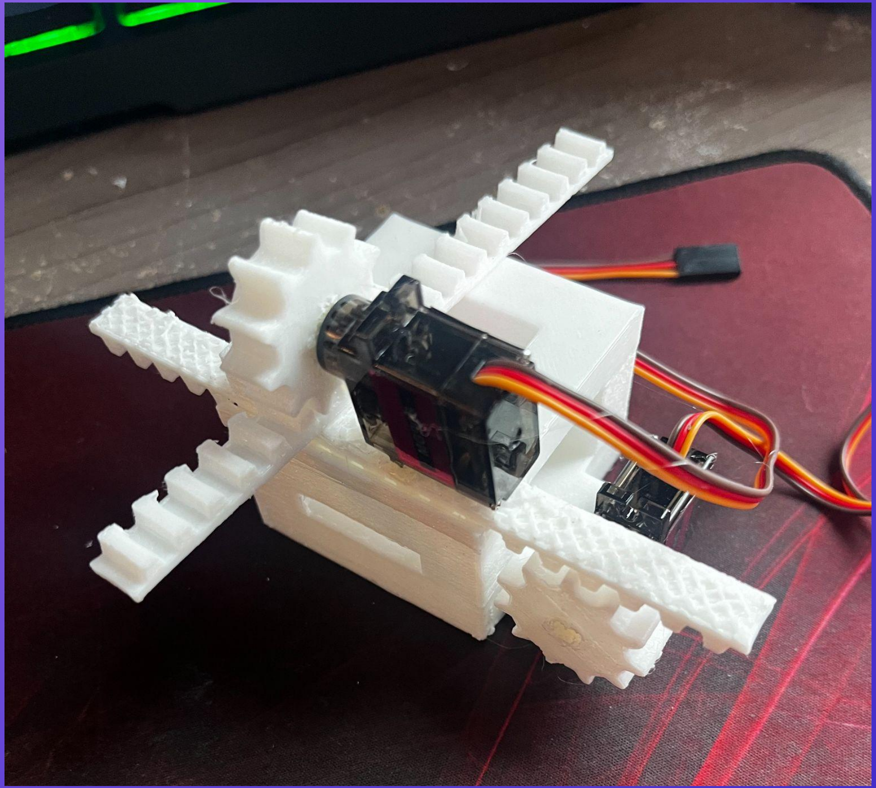
- **App Accessibility**: Apply accessibility settings to the app to improve ease of use for visually impaired users
- **Hardware Improvement**: Update the glove design to be more compact

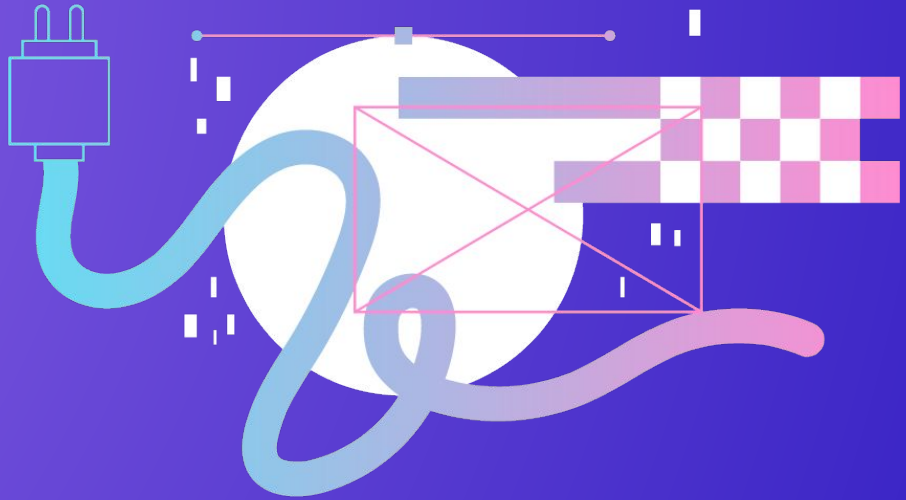
Overall Development Plan

Phase 4: Optimize Data Processing and Transfer

- **Data Transfer Concerns**: Address issues with data transfer speed between the phone, app, desktop, and glove device
- **Solution Exploration**:
  - **Option 1**: Use AWS cloud services as the backend to handle computations and improve communication efficiency
  - **Option 2**: Perform all computations directly on the iPhone to make the app fully independent
- **Testing and Selection**: Test both solutions to determine which offers better performance and suits the project's needs

Phase 1 Prototype





Use Case Interview

Interviewed Jules Jaworowski, a visually impaired college student, who helped us see things from the perspective of the visually impaired community

Use Case Interview Takeaways

Interviewee Profile

- Name: Jules Jaworowski
- School: Kutztown University, PA
- Major: Dual Major in Vision and Special Education
- Age: 20
- Gender: Female

Use Case Interview Takeaways

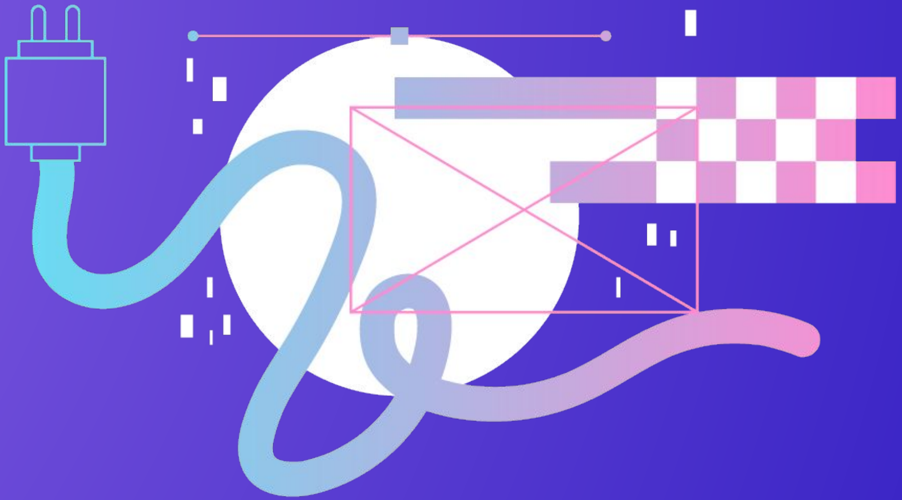
Key Insights

- Comparison of Navigation Tools: Seeing Eye Dog vs. Cane
  - Dogs provide 360-degree awareness and can detect obstacles at face level
  - Canes are limited to ground-level detection, requiring users to run into obstacles
- Navigating Familiar vs. Unfamiliar Environments
  - Her dog quickly learns familiar routes but requires multiple trips (2-3) to acclimate to new routes
  - Navigating unfamiliar areas is more exploratory, with frequent stops for better navigation
- Alternative Guiding Methods
  - In crowded environments, Jules sometimes relies on sighted guides due to her dog's limitations in crowded places
  - Training with both the dog and cane is beneficial for back-up navigation in case dog can't perform
  - Not everyone can have a guide dog due to extensive costs

Use Case Interview Takeaways

Key Insights

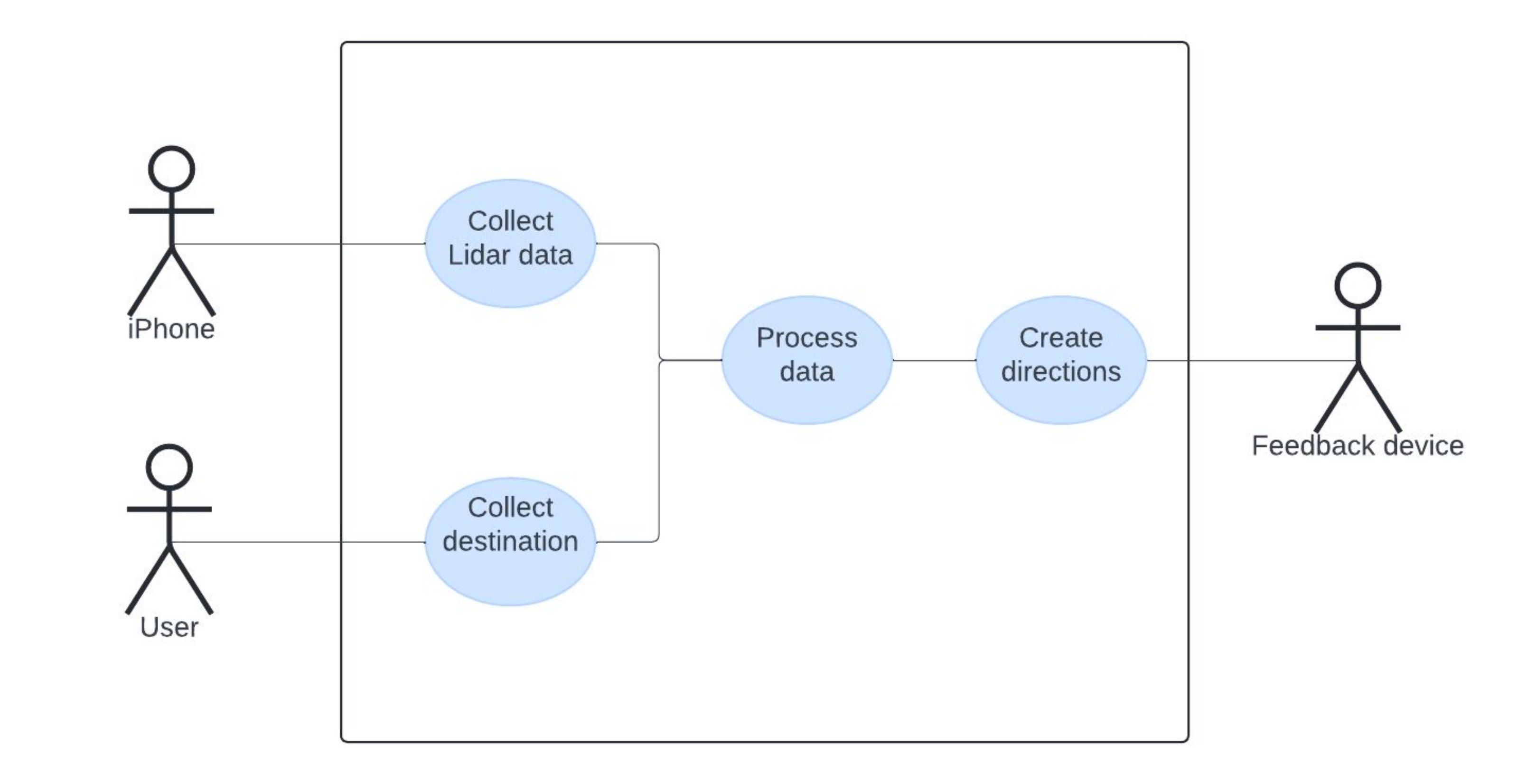
- Desired Features in Navigation Aids
  - A navigation aid should provide descriptive information that highlights significant hazards without overwhelming details
- Ideal Navigation Solution
  - A more personalized navigation option could alleviate **stigma** around using traditional mobility aids like canes or guide dogs
  - Customizable technology options could offer a non-stigmatizing alternative for visually impaired individuals
- Willingness to Test New Technologies
  - Jules expresses openness to participating in testing new navigation technologies, provided they offer customization options to meet individual needs

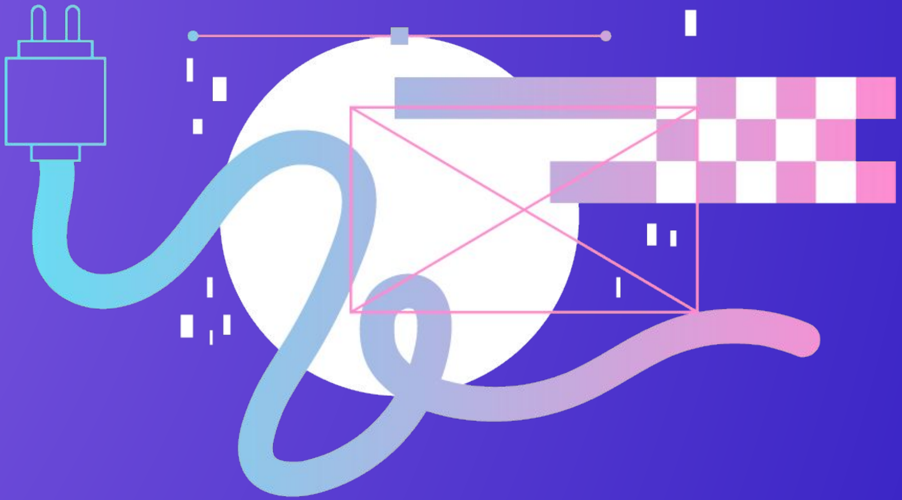


Use Case Diagrams

Summarize details of system's users and their interactions with the system

Use Case Diagram

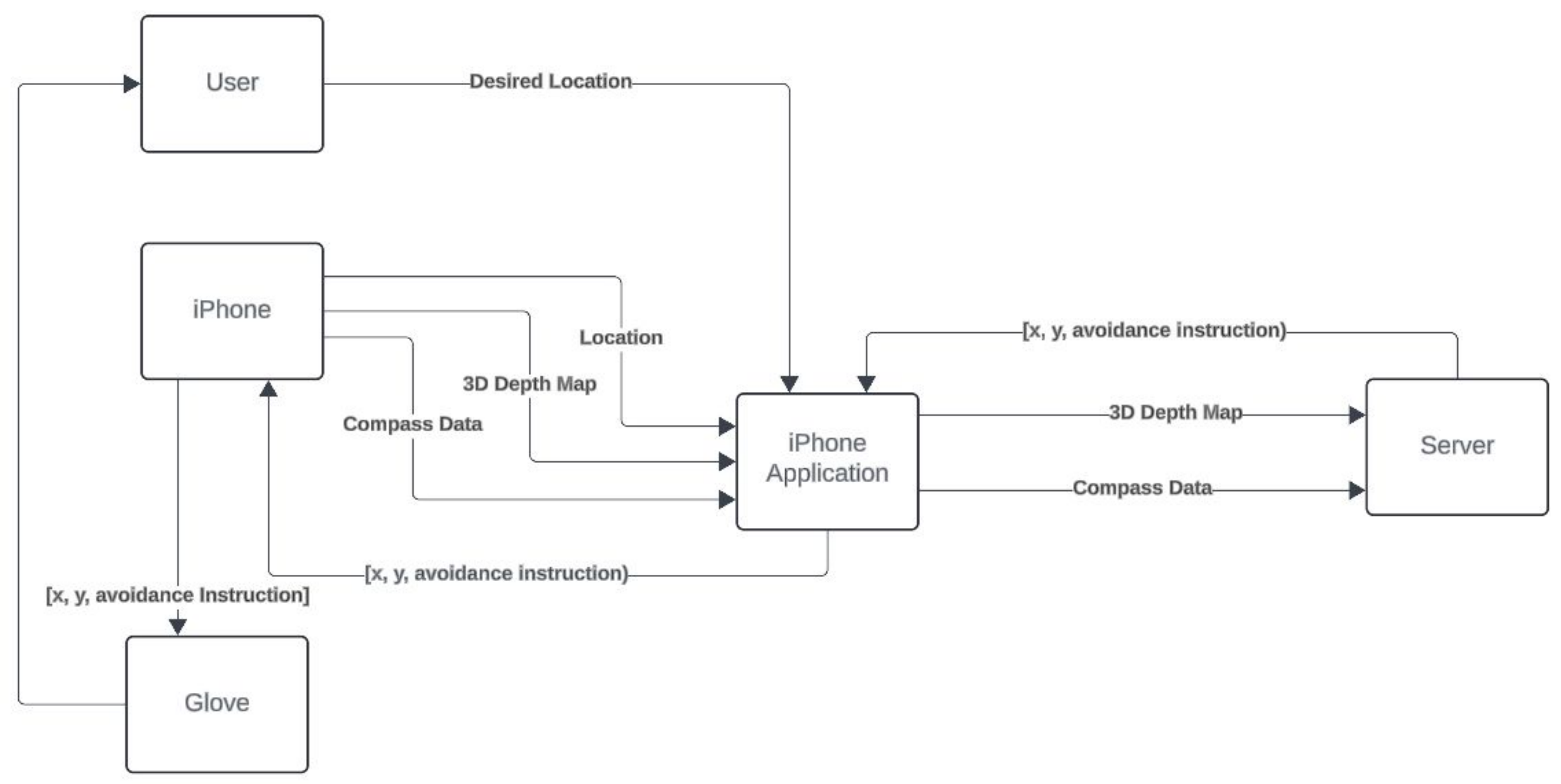




Activity Diagram

Represent the flow of control or data from one activity to another and depict the sequence of activities

Activity Diagram



Thank you!

Any Questions?