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Board 44: CampNav: A System for Inside Buildings and Campus Navigation

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Work In Progress: CampNav: A Navigation System In Complex Buildings and Campus Settings

Abstract

Finding classrooms can often be a time-consuming task. To address this issue, we introduce CampNav, a comprehensive system featuring an Android mobile application displaying 3D visualizations of campus buildings' indoor floor maps. CampNav includes a comprehensive set of tools for automated data collection and processing. Allowing users to integrate new buildings maps into the application efficiently, reducing time and manpower. This application is built on Mapbox, a widely-used, semi-open source mapping API renowned for its lightweight and versatile mapping capabilities. We have enhanced its functionality to support 3D indoor display. A significant aspect of the system is the utilization and integration of CNNLoc, a neural network designed for Wi-Fi-based positioning. The initial testing of CampNav has received positive responses by students and faculty members, showcasing its user-friendly interface and effective navigational capabilities. The Surveys and the Net Promoter Score (NPS), indicates students' strong affinity for this software, with many expressing a willingness to recommend CampNav to their colleagues. The satisfaction rate in terms of time savings is 93% that emphasizes the importance of CampNav.

Introduction

It is typically difficult for students to find an indoor building map that directs them quickly and accurately to their destination classroom or examination room. There exist a few online map tools to assist students nevertheless they are not easily accessible and do not provide indoor positioning. A few factors that cause significant challenges for students to navigate around university's buildings are:

- Campus size is usually vast and comprises hundreds of buildings with intricate indoor layouts.
- Physical maps of the indoor rooms' layouts are scarce and often full of excessive information making it difficult to accurately and quickly locate rooms within buildings.
- Students frequently find themselves disoriented inside buildings and cannot determine their current locations.
- Students become more stressed during exam times and not able to find their examination room in a timely manner that adds to their stress levels.

These limitations make the task of locating an unfamiliar classroom not only time-consuming but also problematic for students who need to quickly locate their classroom for quizzes or exams. One of the existing solutions is ClassFind [1], a website that offers indoor navigation through the use of real photos and textual explanations. However, it comes short in terms of critical features that allows to navigate conveniently and accurately. In particular, ClassFind cannot:

- Display each room location within each floor.
- Determine user current location of the user.
- Map or search offline.

We have designed and implemented a mapping system called CampNav. It is an application software that includes a suite of tools for automation designed to streamline the process of integrating new buildings into the system. Further, this application functions offline, eliminating the need for internet support. The design opts for existing technologies that are free, reliable, and open-source. The application is designed with portability to allow addition of multiple buildings.

The application offers complete indoor layouts. Using React Native[2] with Mapbox API[3], we configured all rooms within seven floors of one of the university building, Bahen Centre for Information Technology. Mapbox plays a crucial role in presenting 3D structures and elevations. However, it does not accommodate labelling when there is a 3D elevation inside the building. To tackle this limitation, we developed our own “pseudo 3D” technique for precisely placing information at specific elevations. This allows automatically room/location labels to move up or down creating a more realistic 3D experience. The current development takes advantage of specialized Convolutional Neural Network, CNNLoc[4]. for accurate and real-time location tracking. This determines a user's position by analyzing Wi-Fi signals from multiple access points in the building. In essence, CampNav represents a significant step towards overcoming the challenges of displaying map information and campus indoor navigation.

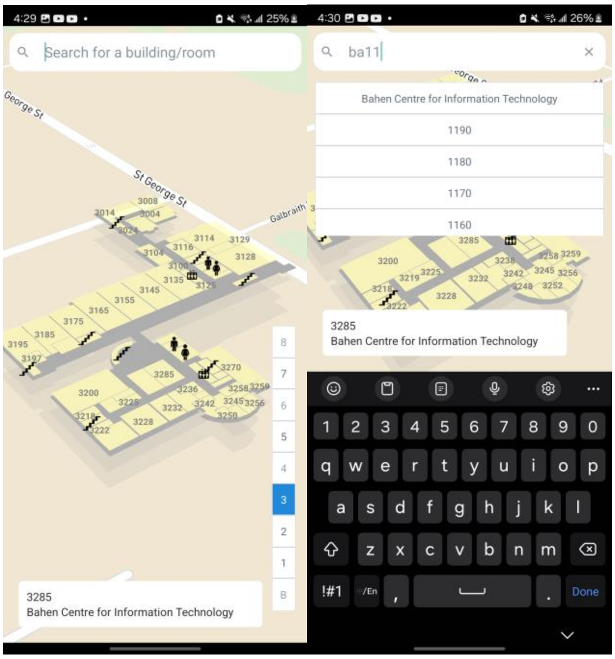


Figure 1: CampNav Application

Technical Design

Figure 1 depicts the framework of the system, which includes the Indoor PDF Layout Conversion Flow, Indoor Wi-Fi Access Point Strength Fingerprinting and Deep Learning, and the CampNav application. The first two components are automated processes that facilitate the easy addition of new buildings by generating the necessary data formats for CampNav. CampNav itself is an application that loads this data and consists of three main subcomponents: Map Visualization, Geospatial Computation, and the Application Interface.

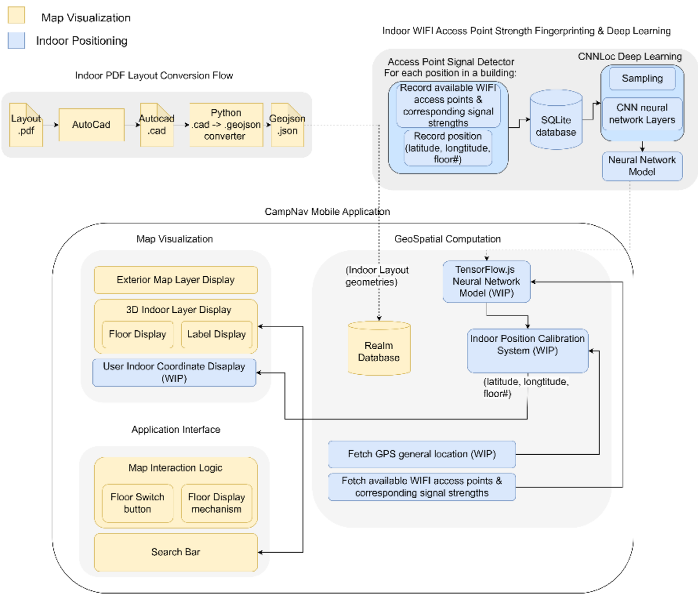


Figure 1: Application framework block diagram

Indoor PDF Layout Conversion Flow (Appendix A)

This flow Converts construction blueprint to rendering data. It starts by redrawing PDF construction layout blueprints in AutoCAD[5] for simplification and standardization, followed by executing a Python script with an AutoCAD driver and geospatial libraries to automate the conversion of mapping the layout into geospatial coordinates in GeoJSON[6].

Indoor Wi-Fi Access Point Strength Fingerprinting and Deep Learning (Appendix B and C)

Within university buildings, there are numerous Wi-Fi access points distributed across every floor. The objective of this procedure is to collect data to train a deep neural network, CNNLoc[4], which is capable of processing the aggregate of Wi-Fi signals received as input and providing users with precise positioning information as output.

An access point signal detector was developed to automate our data collection.

Map Visualization (Appendix D)

We have opted for React Native as our application framework and will be integrating Mapbox[3] as our map framework support. Our primary objectives in this phase include the implementation of foundational features. These features encompass rendering the exterior map and 3D indoor map for visualization, enabling users to interact by moving and rotating cameras.

Application Interface (Appendix E)

An interface that is intuitive and displays information in a manner akin to Google Maps. The application features a database-driven search function, enabling users to quickly find classrooms using a search bar equipped with an intelligent prediction mechanism. It also includes buttons for floor navigation and pop-up information windows for classroom selections. This interface dynamically adjusts the density of displayed information according to the camera's zoom level, providing more or fewer details as users zoom in or out.

GeoSpatial Computation (WIP)

Once the CNNLoc[4] model training has been completed, we are in the process of integrating the CNNLoc Model into the mobile application by employing TensorFlow.js. This integration will enable the React Native environment to execute the neural network model. The application will fetch the current BSSID and signal strength in real time. However, recognizing that the CNNLoc model may not always be precise, we have identified the need for a more refined calibration system. To enhance accuracy, we are developing an Indoor Position Calibration System that will use both the general location data from GPS and the results from the CNNLoc to pinpoint the user's precise location, which will then be displayed on the map.

Performance Evaluation

To assess the effectiveness of CampNav, we compared the number of steps required to locate a classroom using CampNav against the steps needed when not using it and when using Classfind. The table below shows that CampNav requires the fewest steps and the least amount of time.

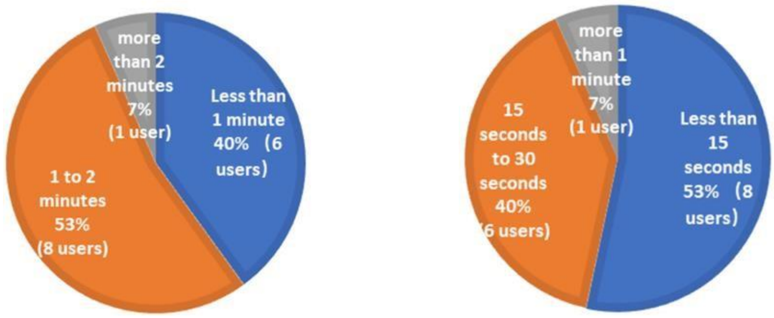
Table 1: Number of Steps Needed to Locate a Classroom by Methodology

Steps	CampNav	Without assistance	ClassFind
1	Open CampNav	Open Browser	Open Browser
2	Type on search bar "BA 1000"	Google which building "BA" refers to at the University of Toronto. **(Time consuming)**	Type Classfind URL
3	Application zooms on BA1000 and shows the layout of Bahen	Open Google Map	Type on search bar "BA 1000"
4		Type on search bar "Bahen Centre for Information Technology"	Scroll to see step by step navigation **(Time consuming)**
5		Walk within Bahen trying to find room 1000 **(Time consuming)**	

Survey Content and Findings

The effectiveness and functionality of the CampNav Application was assessed through a targeted study involving 15 students. These students were unfamiliar with floor plan and configuration of the building. We asked them to use CampNav and Classfind[1] to locate their classrooms. And following their experience with the application, we conducted a survey to gather their feedback and inputs as follows.

The survey first evaluated the time saved using CampNav. The question and the corresponding responses are shown in Figure 2.



(a) ***b)***

Figure 2: Survey results to the questions of **a)** *How much time does CampNav saves you by eliminating the need to arrive early solely for the purpose of locating the classroom?* **b)** *How long does it take to find the desired classroom using CampNav?*

The survey next evaluated the user experience of CampNav with Classfind serving as a benchmark for comparison, utilizing Net Promoter Score scale from 0 to 10. The NPS findings are shown in Figure 3 and 4.

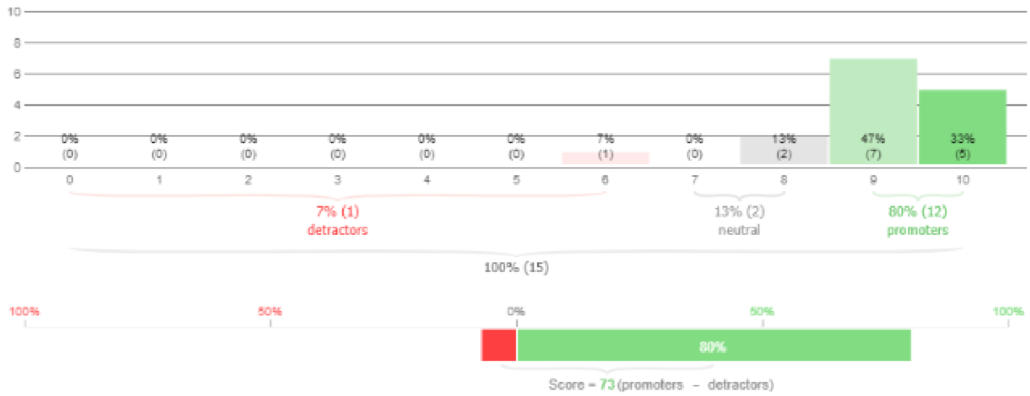


Figure 4: NPS findings to question of: *Do you think CampNav is a more useful application compared with Classfind?*

Figure 3: NPS findings to question of: *Has CampNav affected your punctuality for classes, exams, or meetings on campus?*

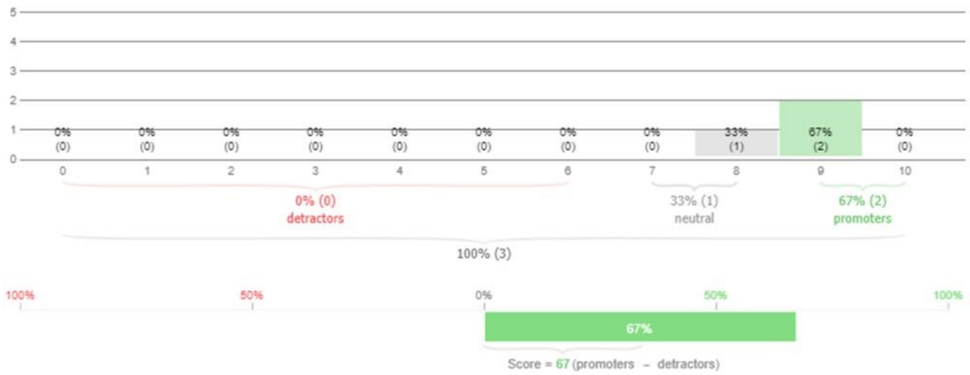


Figure 4: NPS findings to question of: *Is CampNav effective in alleviating stress by simplifying the process of locating classrooms before exams?*

The findings reveal 93% agreement among users on the application's usefulness, surpassing the existing Classfind solution. Most users can locate their classrooms in less than 30 seconds from opening the application, marking a significant time saving. Most users agreed that CampNav saved them 1 to 2 minutes in finding classrooms. The evaluation also underscores the effectiveness of CampNav in alleviating stress associated with finding classrooms before exams. This aspect is particularly noteworthy as it addresses a common challenge faced by students. Often, exams are held in unfamiliar classrooms, compelling students to arrive earlier than necessary just to navigate and locate the room.

CampNav's ability to streamline this process significantly reduces the pre-exam stress that stems from this situation. By simplifying navigation, CampNav appears to contribute to a more relaxed and focused exam preparation environment.

Remarks

CampNav stands as a promising solution to the challenges university students face when navigating unfamiliar classrooms within expansive campuses. By leveraging a diverse set of development environments such as Python, Android Native, and React Native[2], along with the core mapping capabilities of Mapbox[3], CampNav provides a user-friendly indoor navigation experience through its 3D visualization indoor maps and real-time positioning system. The successful automation transformation of architectural blueprints into GeoJSON[6] data has proven instrumental in presenting precise building layouts. The positive evaluation results from university students affirm CampNav's high level of satisfaction and usability. Users reported that CampNav is more user-friendly than any existing solutions, demonstrating quick navigation times and offering positive feedback on map accuracy and intuitiveness. To enhance CampNav's capabilities, future efforts should focus on obtaining additional validation data to further train the CNNLoc[4] neural network to improve indoor positioning. Additionally, detailed configurations to control the number of label displays are recommended to reduce latency. These refinements will contribute to CampNav's continuous improvement and ensure an even smoother and more efficient indoor navigation experience for university students.

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Appendix A: Layout Conversion Flow

Figure A.1 demonstrates one example of building indoor layout that was collected showcasing its complexity. It is formatted as PDF file which can be later on imported into the Autodesk[5] for further configurations.

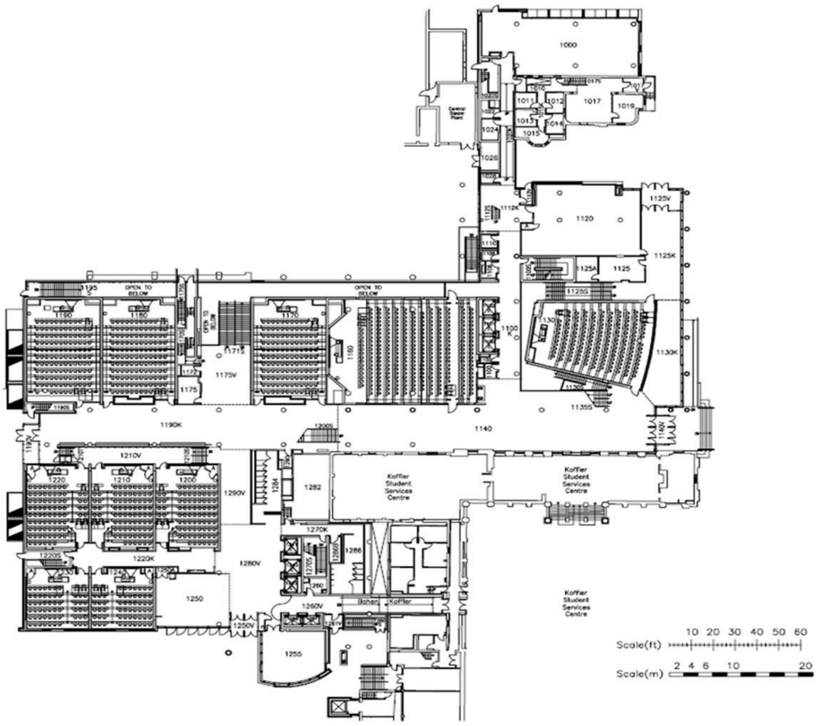

Figure A.1. An example of floor plan layout.

The original PDF file shown in Figure A.1 contains many unnecessary information. Therefore, the file is modified after imported into Autodesk software to extract and filter the necessary information for CampNav. Figure A.2 shows the resulting layout.

Figure A.2. Cad file modified from PDF layout shown in Figure A.1.

The Cad file is then imported into a python script with an AutoCAD driver and GDAL[7] libraries to automate the conversion of mapping the layout into geospatial coordinates in GeoJSON[6] Format.

Appendix B: Access Point Signal Detector

Within university buildings, there are numerous Wi-Fi access points distributed across every floor. The objective of this procedure is to develop a deep neural network algorithm capable of processing the aggregate of Wi-Fi signals received as input and providing users with precise positioning information as output.

An access point signal detector was developed to automate our data collection. This application allows user to pinpoint a location on the digital map, then the Wi-Fi scanner measures the signal strengths at that point and saves the collected signal data along with its corresponding location into a local database system. In total, 290 datapoints are collected.

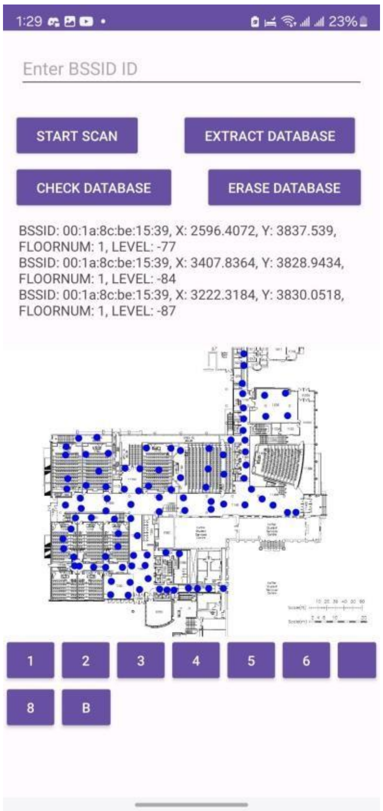

Figure B.1. Interface of Access Point Signal Detector showcasing blue dots.

Appendix C: CNNLoc

CNNLoc is based on 2D convolutional architectures, trained to predict a user's location using Wi-Fi signal data. It incorporates three distinct models dedicated to identifying the user's floor, horizontal coordinates, and building. The diagram shown in Figure E.1 shows how data is processed within the neural network (CNNLoc) model and how the outputs are generated.

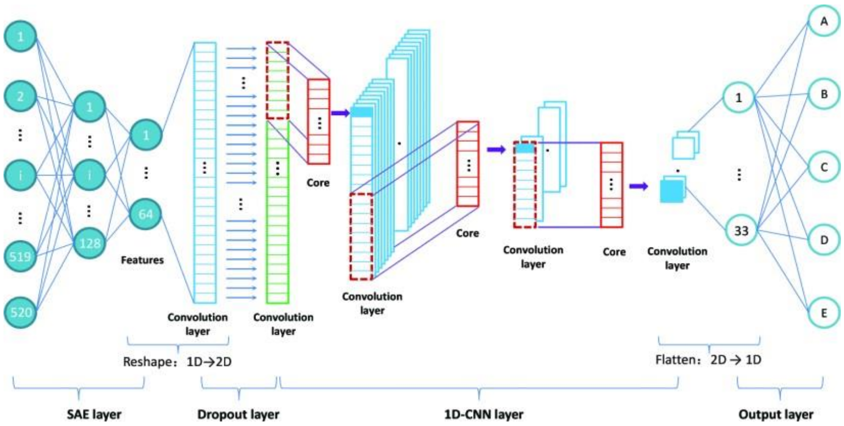

Figure C.1. CNNLoc Floor/Location Model generating outputs.

Appendix D: CampNav Application Rendering

We designed the exterior map for our application using the Mapbox API. We customized the base map by removing labels and building layouts for a cleaner look. The exterior map as shown a smart device is shown in Figure D.1.

Figure D.1. Exterior map imported into the application as shown on a smart device.

The screen shot shown in Figure D.2 displays a floor map using FillExtrusionLayer[9]. The floor outline is in a light grey shade, and rooms are highlighted in orange.

Figure D.2. Floors rendered as exterior layer on the map.

Figure D.3 shows the layout of the second floor where user can recognize icons denoting crucial facilities such as washrooms, elevators, and stairs. Each room is marked with a 3D label showing its room number, enabling users to quickly identify and find specific locations within the layout.

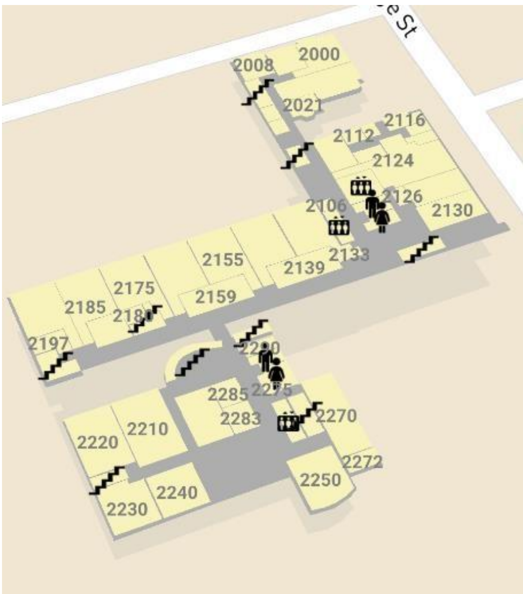

Figure D.3. Second floor with label and text for each room and facilities.

Figure D.4 illustrates our "pseudo-3D" labeling method for using collected data to visualize 3D labels. As Mapbox only supports 2D label display (with the height fixed at 0), we manipulate the label position to create the illusion that it is floating from camera's view point. This is achieved through trigonometric calculations involving the camera's bearing and height[10][11][12], allowing us to pinpoint the location of the "pseudo-3D" label. Whenever the camera moves, the label will update its new position accordingly.

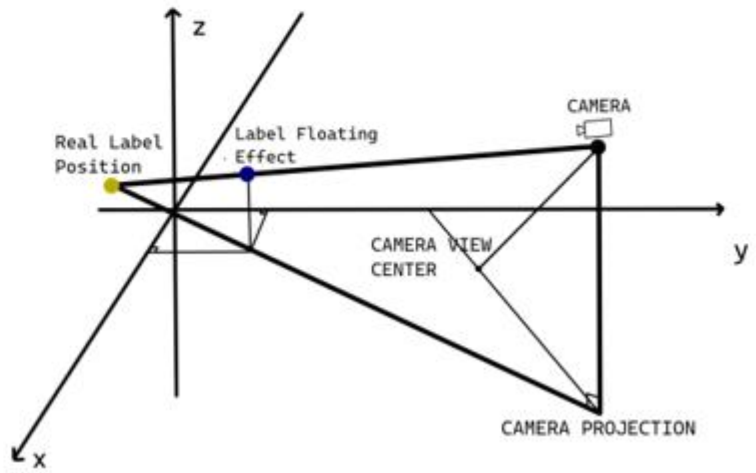

Figure D.4. "pseudo-3D" labeling model.

Appendix E: CampNav Application Interface

The application features a search bar equipped with prediction mechanism. For instance, when type "ba11", the search bar will response all the Bahen classrooms start with room number 11. This is done through sending a query to the Realm Database[8].

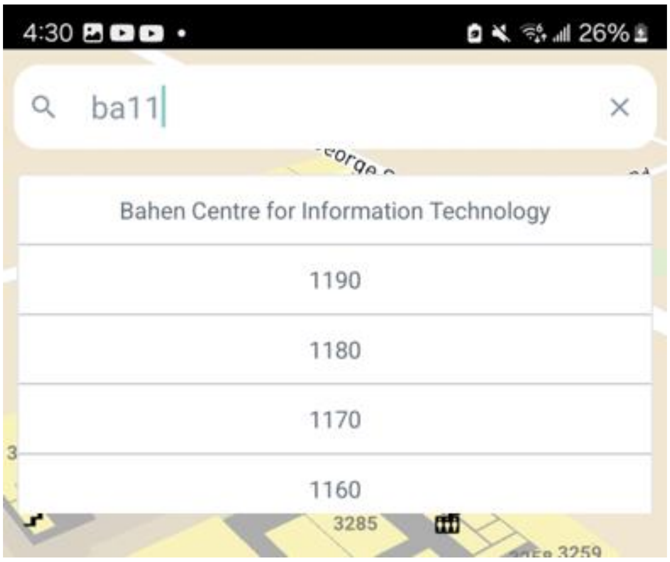

Figure E.1. Search Bar equipped with prediction mechanism.

We also implemented a feature using hooks that lets users click on rooms to see details in a dialog box. We also used Mapbox's button API to make it easy for users to switch between different floor levels by assigning each button to a specific floor. This is shown in Figure D.5.

Figure E.2. User interface after adding intractable components.