FIND A SPOT: USING HEAT MAP TO REPRESENT INDOOR SPACE AVAILABILITY

by

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This work is dedicated to

My supervisors and well-wishers Dr. Srinivas Sampalli and Dr. Bonnie MacKay

and

My beloved parents Mr.Kumar and Mrs. Mala for their unconditional support

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ABSTRACT

People find it challenging to locate unoccupied spots during peak hours in public places such as shopping mall food courts, libraries and airports. Users spend extra energy and time trying to locate these unoccupied spots. As well, smartphone technology can now use indoor localization techniques using Wi-Fi signals. This research focuses on solving the problem of finding unoccupied spots with a novel technique which involves no additional hardware except the users' smartphone device. In order to achieve this, an android application has been designed which uses the Wi-Fi signal strength to locate the mobile devices indoors. These located coordinates are then plotted onto a floor map which helps the user to find unoccupied spots. The color of the plotted points represent the density of the people present in that particular location, analogous to a heat map. A user study involving 24 participants was conducted at the Halifax Central Library to evaluate how the application was used to help participants locate unoccupied spot/s (seats). The findings show that the participants found it easy and useful to locate the unoccupied seats using the application. They also provided recommendations for improving the application.

LIST OF ABBREVIATIONS USED

API	Application Programming Interface
APs	Access Points
BLE	Bluetooth Low Energy
BSSID	Basic Service Set Identifier
dBm	decibel milliwatt
GPS	Global positioning system
HIL	High-precision Indoor Localization
INS	Inertial Navigation System
IR	Infra-Red
LBS	Location Based Services
LIL	Low-precision Indoor Localization
MAC	Medium Access Control
NFC	Near Field Communication
OS	Operating System
RF	Radio frequency
RFID	Radio frequency Identification
RMI	Remote Method Invocation
RSS	Received Signal Strength
RSSI	Received Signal Strength Indicator
SSID	Service Set Identifier
TOA	Time of Arrival
UI	User Interface
Wi-Fi	Wireless Fidelity
WoZ	Wizard of Oz
WLAN	Wireless Local Area Network
WSN	Wireless Sensor Network
XML	Extensible Markup language

CHAPTER 1 INTRODUCTION

1.1 PROBLEM DEFINITION

People are always trying to find ways to enhance our day to day lives. A problem which may look simple and trivial may consume a lot of our time. Some proposed solutions for the problems use existing technologies that may be cost-effective and instantly deployable. One such problem which we may come across in our daily lives is to locate a free spot (e.g. seat) in public places such as libraries [68] and shopping mall food courts [69]. For instance, students frequently use libraries to study or research a paper. But during the busy times of the year such as exam periods, it is very difficult to find seats [68]. Students keep roaming around the floors of the library wasting a lot of time searching for empty spots to study. Similarly, other people may find it difficult in locating empty tables in the shopping mall food courts during the weekends and busy hours of the day [69]. This thesis proposes a solution to this problem by using the available technologies including mobile devices, localization techniques and heat maps.

In today's world, mobile devices have become a part of our daily lives. The present mobile devices are incorporated with a number of sensors and other hardware components which avail facilities like motion tracking, localization etc. Mobile devices are capable of accessing the Internet via Wi-Fi along with the traditional cellular network [25]. The Wi-Fi signal is provided with the help of a networking hardware device called Wireless Access Points which connects the mobile device to the wired network [26]. The Access Points usually connect to the router as a standalone device but the current access points are an integral component of the router itself. Each Wi-Fi access point broadcasts its SSID using which the mobile devices connect to the access point.

The percentage of mobile device users has increased and as a result, the use of mobile applications to perform some of our activities, such as exploring a new place, monitoring health etc., has also increased [4]. One such application specific area is indoor localization.

A localization technique used by a positioning system helps the mobile device to deduce its location and make it available for location-based services such as monitoring, navigation etc. The position of the device can be determined outdoors as well as indoors. The techniques used for calculating the position of the device outdoors are Outdoor Localization Techniques [65]. Similarly, the techniques used for calculating the position of the device indoors are Indoor Localization Techniques [55].

Global Positioning System (GPS) is the most popular technology for locating a mobile device outdoors [55]. GPS locates the devices based on the satellite signals it receives. But satellite signals are not available indoors, rendering GPS unsuitable for locating devices indoors [3]. There are various techniques used for indoor localization, for instance, image processing, fingerprinting, trilateration and so on. Since almost every Smartphone is a Wi-Fi compatible device, this removes the need for installation of any extra software or manipulation of the hardware. Thus Wi-Fi signals for indoor localization is the most widespread one [55]. Added to that, studies have shown that public places with Wi-Fi access attract more people [6] and hence, Wi-Fi is facilitated in most public places [7]. Using this Wi-Fi, devices can be tracked, located and displayed on a Smartphone screen for users. This makes indoor localization easily achievable in such public places.

There are different approaches that could be used to represent the tracked and located devices using Wi-Fi. Located devices in an area could be represented using heat maps. Users could then use this heat map to determine the number of people in a particular area based on the color code (e.g., red denotes more people). A heat map, in essence is a representation of the data contained within a matrix which is presented graphically as different colors [56]. Cluster heat map and scalogram are usually preferred by statisticians to represent their data. Among them shading matrices, permuted matrices, hierarchical clustering, two-way clustering and appending trees are the common techniques. Scalogram is used to represent data in three axes and cluster heat maps represent data in two axes along with a legend [57].

This research proposes a solution for finding unoccupied spots at public places with the help of a mobile application which locates mobile devices indoors using Wi-Fi signals and displays it to the users using a heat map visualization approach. The approach does not require the installation of any additional hardware. A proof of concept approach was evaluated with participants using a Wizard of Oz technique at the Halifax Central Library to evaluate the helpfulness of the application to locate unoccupied spot/s.

1.2 RESEARCH CONTRIBUTION

Towards the solution for the problem mentioned in Section 1.1, a proof-of-concept prototype was implemented and a follow-up study was conducted to evaluate the application idea.

The technical contribution of this thesis is the design and development of a mobile application which generates a heat map by plotting the located mobile devices using the Indoor localization technique involving Wi-Fi fingerprinting method as discussed in Section 3.3.

The application was evaluated using a Wizard of Oz methodology with 24 participants in Halifax Central Library. We analyzed the feedback to determine the applicability of the overall idea in real time environment and for suggestions for improvement.

1.3 BRIEF INTRODUCTION OF THE PROPOSED APPROACH

To help with this problem of finding unoccupied seats in busy public indoor spaces, this thesis proposes using a heat map that displays the density of the people in a particular location. In order to avoid the inclusion of any additional hardware to locate people indoors, we are using indoor localization technique which relies solely on the Wi-Fi signals.

The proposed approach uses a mobile application which displays the heat map on the user's mobile device. The mobile application, in the background, sends the Wi-Fi signal strength to a server. This server uses these Wi-Fi signals to locate the devices using the

Wi-Fi fingerprinting technique. These locations are plotted into a heat map and sent back to the mobile device. The user can then locate an unoccupied spot by analyzing the density of points on the map. To increase the ease of use of the map for the users, the density has been color coded. For instance, a single person is represented by a green color and red color represents higher density (≥5 persons in this research work).

To evaluate how helpful this application would be in an indoor public space, a user study was conducted at the Halifax Central Library. Since installing the application on all devices available in a public place is infeasible at this point, a Wizard of Oz technique was used to simulate the mobile application. Participants were asked to use the application that had two different map views to locate quiet/any single seats and groups of seats in the library. We collected user feedback on the application with a post-study questionnaire and a semi-structured interview.

1.4 Outline of the Thesis

This thesis has been organized as follows. Chapter 2 is a literature review that focusses mainly on different localization techniques. Chapter 3 explains the proposed approach and the architectural framework of the proposed approach in detail. Chapter 4 explains the implementation details of the proposed approach. Technical specifications of the implementation are explained in detail along with the code snippets. Chapter 5 contains the detailed description of the study design methodology followed by Chapter 6 which contains the analysis and discussion of the results obtained from the study. This thesis is concluded with limitations and future work in Chapter 7.

CHAPTER 2 BACKGROUND AND RELATED WORK

2.1 MOBILE LOCALIZATION TECHNIQUES

The techniques used for locating a mobile device are discussed in detail here. The localization techniques can be broadly categorized into two; Outdoor and Indoor localization techniques.

2.1.1 Outdoor Localization

Outdoor localization takes place with the help of either multi-lateration of radio signals between cell towers of the cellular networks and the mobile device, or with the help of multi-lateration of the satellites orbiting the earth and the mobile device. Currently the second method is widely accepted. In either of the cases, multi-lateration is needed to pin-point the location of the device [27].

In multi-lateration of the radio signals, the difference in distance between the two known stations at known locations that broadcast signals is measured. This results in numerous possibilities where the device might be located. But these possible positions form a hyperbolic curve. The exact same set of steps are repeated taking into consideration another set of stations. The intersection of the hyperbolic curves, results in the exact location of the device. This is also known as 'Hyperbolic navigation' and is a common technique used in radio navigation systems. The difference in distance is calculated by measuring the "Time Difference Of Arrival" of the signal emitted by a stationary emitter at three or more synchronized receiver sites or from three or more emitter at one receiver location. The difference is measured and they are mapped to the coordinates and the location is displayed [29].

GPS is a popular technology used for locating a mobile device outdoors. By GPS, it actually refers to a GPS receiver. The GPS, Global Positioning System, is actually a collection of 27 satellites orbiting round the Earth [27]. Among the 27 satellites, 24 remain in operation and three are back-ups in case one amongst them fails. Each of the satellites, make two revolutions around the globe per day. These satellites are positioned in such a way that there are at least four visible in the sky. The GPS receiver locates four or more satellites and calculates the distances and uses a technique called Trilateration in three dimension to pin point the location of the device [28]. The functioning of trilateration is very simple. Consider Figure 1 to better understand trilateration in the 2D world.

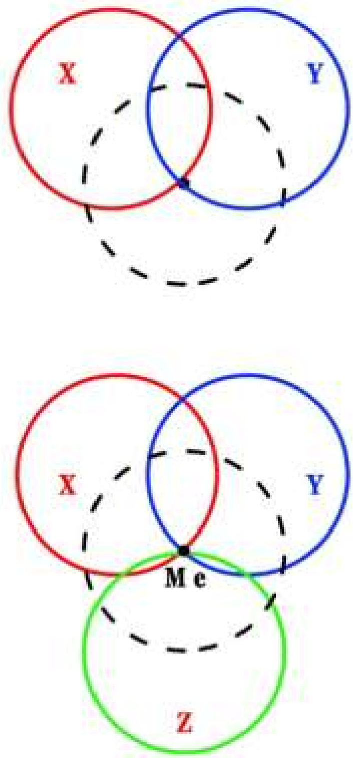


Figure 1 Tri-lateration [27]

Imagine the dotted circle is the area covered by the signals emitted by the device. In order to get the location, the device enquires the two nearest towers for its distance. Based on the signal strength received, the device calculates the distance between itself and the tower. This is the radius to the circle which it draws for each towers, say X and Y. The intersection of the two circles cuts down the possibilities of where the device could be present. Now the device enquires a third tower for its distance and calibrates a circle for it. The intersection of the three circles is the location of the device [27].

This, when extended to 3D space, results in a sphere rather than a circle. Thus the intersection of the spheres results in the location of the device [27]. Introduction of the fourth sphere yields in determining the height of the device as well. These spheres are formed by the radio signals emitted by the satellites above us [27].

2.1.2 Indoor Localization

The GPS signals are not accessible indoors as the signals get deflected or absorbed by the materials used for constructing the houses [27]. Thus using GPS for tracking the device indoors is neither feasible nor accurate. In order to track the devices indoors, many techniques have been proposed by different researchers. The underlying technique remains still the same i.e. trilateration and/or multi-lateration techniques are used to locate the device but instead of using the satellite signals or the cellular signals, Bluetooth signals, infrared signals, Wi-Fi access point signals, signals from other mobile devices etc. are put into use. The distance from the devices emitting the mentioned signals are calculated and the location is identified based on the results of the formerly discussed techniques.

Indoor localization can be classified into different types based on different criteria as shown in Figure 2. The criteria considered are based on Existing Wireless Infrastructure, System Architecture and the Medium Used [51].

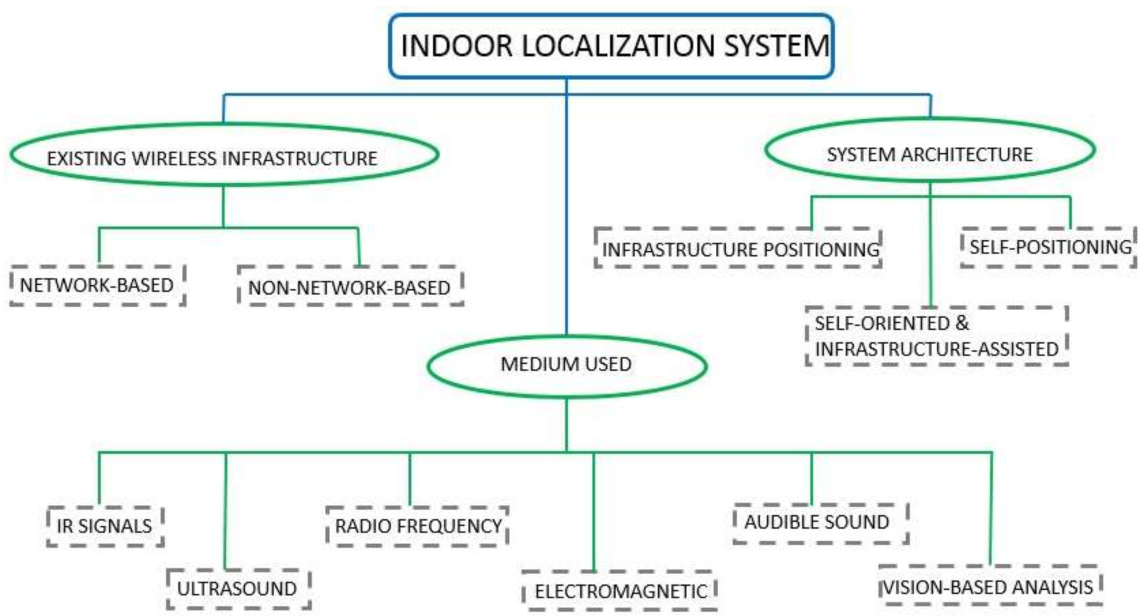


Figure 2 Indoor Localization Types [51]

Under the criteria which are based on Existing Wireless Infrastructure to locate an object, Indoor Positioning Systems can be classified as network-based approach and non-network-based approach. In network-based approach, no additional hardware is required as it makes use of the existing infrastructure installed in the vicinity [51]. In non-network-based approach, additional hardware is required as it makes use of a dedicated infrastructure for locating objects [51]. The advantage of network over non-network-based approach is that, it is cost-effective and the advantage of non-network over network-based approach is its freedom of design and high accuracy [51].

Based upon the System architecture, Indoor Positioning Systems can be classified as Self-Positioning Architecture, Infrastructure Positioning Architecture and Self-Oriented & Infrastructure-assisted Architecture [51]. In Infrastructure Positioning Architecture, the infrastructure tracks the location of the device by itself if it is within the coverage area. In Self-Positioning Architecture, the device calculates its location by making use of the infrastructure [51]. In Self-Oriented & Infrastructure-assisted Architecture, the device has to allow the system to track it so that the infrastructure can send the location as a response to the device requests [51].

There are six types of Indoor Positioning Systems based on the Medium Used. They are: InfraRed (IR) signals, Ultrasound, Radio Frequency, Electro-magnetic, Audible sound and Vision-based Analysis [51].

2.1.2.1 Indoor Localization Technologies

InfraRed Signals

Indoor localization using Infrared signals is less interfering and disturbing when compared to the visible light. Infrared is invisible to human eye, less costly, consumes less power and also has no privacy problems. This makes infrared signals one of the appropriate technologies for indoor localization [58]. The method proposed by Yang et.al [34] for indoor localization is the integration of passive infrared (PIR) with accessible map of the indoor environment. This accessibility map is the accumulated locations of the human based on his visiting habits, indoors. In the proposed approach, the accessibility map is generated initially and then the data from PIR sensor is used to estimate the most probable location of the user. The authors have used a particle filter to refine the localization. They also stated that the proposed approach outperforms the PIR only localization approach.

Sound

Within a medium, a mechanical wave which is generated by the oscillation of pressure being transmitted in the medium, called sound, can also be used by the positioning systems that utilize air and building material as its propagation media. Audible sound and ultrasound are used by the positioning systems for indoor localization. Usually ultrasound is preferred over audible sound as it is relatively simple and offers an effective solution towards finer indoor positioning [58].

The technique proposed by Kharidia et.al [39] is based on audible sound. The technique functions in three phases and improves the accuracy. In the first phase, it measures the distance between each pair of peer devices using acoustic ranging. Then in the second phase, Classical Metric Multidimensional Scaling method is applied to generate a graph of the accumulated distances. Finally, in the third phase, the generated graph is embedded into the graph obtained with Wi-Fi based localization to improve the precision of the localization. Their results show that they have an average error of 1 meter.

Hazas et.al [52] reviews the then existing fine-grained ultrasonic location sensing and its limitations. They describe the various broadband ultrasonic transmitter & receiver units and categorize them. They outline the appropriate spread spectrum signaling method and its capacity for ranging. The reported results were taken using a polled, centralized location system and a privacy-oriented location system. the two systems' performance is analyzed and the benefits of ultrasound location systems are presented.

Electromagnetic

A combination of electric and magnetic fields is used by some of the positioning systems for indoor localization [58]. A training less fingerprinting approach is proposed by Bisio et.al [53] using the electromagnetic propagation models. The reference point values are predicted based on the electromagnetic field distribution within indoors and characterizing the radiating elements. The rest of the location technique remains the same as that of the fingerprint. Removing the training phase is the only novelty they claimed.

Radio frequency

All the signals which are in the band of frequencies suitable for telecommunication are categorized under radio frequency signals [58]. RFID, Bluetooth, Wi-Fi are some of the technologies that make use of radio frequency signals for indoor localization. Jin et.al [54] discusses about LANDMARC which is an indoor localization system using RFID technology. LANDMARC developed by Michigan State University and Hong Kong University of Science, uses the concept of reference tag thus minimizing the number of RFID readers deployed. LANDMARC guarantees the accuracy of localization with lower system cost. The authors have analyzed LANDMARC and provided its limitations. They have also proposed a method which overcomes the limitations of the existing LANDMARC system thereby improving the accuracy of indoor localization.

Two Bluetooth Low Energy (BLE) based localization schemes were proposed by Wang et.al [33]. High-precision Indoor Localization (HIL) which utilize the collected RSSI measurements to generate a small region which would have the greatest probability for the device's presence. Low-precision Indoor Localization (LIL) scheme uses the different power levels to estimate the probable area in which the device is guaranteed to be found. This has less accuracy and hence the authors have proposed HIL scheme which requires a RSSI training phase. In HIL, they split the power ranges into different bands to improve accuracy. Their experimental results show that HIL is more accurate and successful than LIL in most scenarios.

2.1.2.2 Wireless Local Area Networks (WLAN) Techniques

Amongst all of the available radio frequency signals, Wi-Fi is the most popular as it facilitates internet access. It is also used for locating mobile devices which are connected to that Wi-Fi network. WLAN techniques are widely accepted because it does not require line of sight with the WLAN access points in the indoor environments. There are various WLAN techniques proposed by researchers among which Time of Arrival (ToA), Time Difference of Arrival (TDoA) and Angle of Arrival (AoA) are less popular as it incurs higher time delay complexity and involves greater angular measurement complexities. The positioning methods that utilizes Received Signal Strength Indicator (RSSI) such as Triangulation and Fingerprinting are more popular [58]. Angle of Arrival is a technique where the mobile signal's angle of arrival from multiple base stations is taken and a 2D plane is calculated. Geometric relationships are then used to estimate the location of the intersection of the lines. The limitation is that this technique needs antennas to be installed. Also it faces challenges with the signals which are reflected by the walls. Hence this is not mostly preferred for indoor localization [55]. Triangulation, is a technique where the device uses the propagation time, RSSI values of the Access points and calculates the location of the device based on the lateration and/or angulation derivations [55].

Apart from them, Fingerprinting is another technique which is used for tracking the device indoors. In this technique, the strength of the signals at different locations indoors, are stored as a lookup table in advance into the database. These signals could be of the access points, Bluetooth devices etc. Hence when a device requests for its location, it sends the signal strengths it recorded for the emitters to the server. The server then performs some operations between the received value and the values stored in the database. The value of the lookup table for which the best match is found, its corresponding location is retrieved and sent as the possible location of the device. Many studies have been conducted to improve the accuracy of the fingerprinting technique as well [55].

The human mobility on university campuses was studied by Meneses et al. [37] where the authors collected the data from access points in the campus for several months, regarding the devices that were logged to them. They developed a relationship between space features and human motion using the collected data. The results showed the attraction places along the day and the places that are strongly connected. The analysis of time profiles showed that inbound and outbound flows are very similar. Finkel et al. [35] classified the top five exhibits in the Ian Porter Museum of Art at the University of Melbourne, where the data collected was analyzed using a range of Wi-Fi Received Signal Strength Indication (RSSI) fingerprinting techniques with various machine learning algorithms. The data was collected over a few weeks with dozens of users using a no-infrastructure indoor visitor tracking application. They have implemented numerous indoor tracking algorithms and suggested that Random Forests, although have the best performance among them, can be improved by calibrating the average differences in RSSI.

A summary of similarities and differences between the trilateration & fingerprinting methods are briefly discussed by Wei et.al [40]. They also compared the strengths and weaknesses of these methods. Fingerprinting requires a database with a detailed signal strength information for each point whereas trilateration does not require any such databases. The trilateration technique is more flexible than fingerprinting as it calculates the location in real time instead of finding a match in the database. Fingerprinting considers attenuation in the signals which helps it to have a better accuracy over trilateration when signal strength data is used for calculating the location. The performance of multi-trilateration and fingerprinting localization techniques in mobile applications are discussed and compared in the works of Boonsriwai et al. [2]. Their experiments proved that fingerprinting yields better accuracy when compared to multi-trilateration technique. They also showed that when there are 3 access points, fingerprinting technique yields higher success rate over multi-trilateration. As the number of access points increases, the error rate also increases.

An approach based on the fingerprint clustering of Wi-Fi and other sensor outputs, proposed by Razavi et.al [38] uses a K-Means based technique for floor estimation. Their results show that their approach achieves a floor estimation accuracy close to the one with Nearest Neighbor fingerprinting which reduces the complexity and increases the speed of detection. They transmit only the cluster heads of the floor instead of transmitting the entire database for floor estimation. Their results also show that there is a significant reduction in the size of the fingerprint database being used for its localization in comparison to the conventional fingerprinting approach.

There are many setbacks for the indoor localization techniques. Some of the most common include, attenuation, absorption of the signals by the walls and interferences by other electric devices. The signals' emitter in this context carry a serious energy constraint. The signals emitted by the emitter are usually low in magnitude, they are not of the same strength as those emitted by the cellular towers or satellites and hence their area of coverage is limited to within the boundaries of the building they are installed. As a result of the low magnitude, these are easily absorbed by the wood and other materials used in the walls, the interferences caused by the devices etc. [27].

The current indoor localization techniques have advanced to a great extent. Various techniques and algorithms have been proposed to improve the accuracy. There are various other techniques such as Dead reckoning, Map matching and Signal Property based method which are devised for indoor localization [27].

2.2 User Studies on Indoor Applications

To evaluate any UI and get the user feedback, often a user study is conducted. There are different study methodologies that can be used to understand the user's interaction with the UI [36]. The Wizard of Oz (WoZ) technique is a method in the field of Human Computer Interaction, that indulges the participants of a study to interact with a system where the participants believe to be automatic, which in reality is being completely or partially controlled by a hidden researcher (wizard) [31].

In a WoZ, the real time system responses are simulated based on the user's activities and presented to the users by the hidden "wizard". Usually the users believe that the system is functioning in real time and they are unaware of the hidden "wizard" simulating the responses in the background. The outcome of this technique helps the researcher to explore the various kinds of problems users experience while interacting with the system [31]. It allows to check the technique proposed for a particular problem before developing a fully functional model. In short, it helps in gathering entire information regarding the usability and interaction with the prototype [31].

Liu et.al [41] designed an indoor wayfinding application prototype for individuals with cognitive impairments such as Alzheimer's disease. They evaluated the prototype by simulating a location system using the Wizard of Oz approach. They used a within-subjects design and the participants were asked to traverse three routes of varying complexities using the designed application prototype. All the participants were unfamiliar with the study area. A 'location wizard' followed the participant and sent the location and orientation information to the 'navigation wizard' who then sent instructions to the participant's device on which image/text to be displayed and audio to be played. The results of the study showed that for any indoor wayfinding application to effectively guide users, location accuracy was not the only factor but rich knowledge about the environment also played a major role. Also, it not only helped them to understand what types of wayfinding directions were useful but also to determine when and where these directions had to be given to the user. Firouzian et.al [42] developed a wearable Indicator-based smart glass for senior citizens to assist them with daily navigation tasks. The system provided visual cues to the users as navigational commands. They conducted a study using the Living Lab, Wizard of Oz methods for obtaining quantitative results to evaluate the system. In the study, the 'wizard' was in possession of an android application which had the directions on the interface. The chosen direction was sent to the smart glass via Bluetooth from the android application. The routes for the participants were fixed and each route had a specific set of rotations. The navigation tasks were based on these pre-defined routes and the participants were asked to follow the navigational commands to reach the destination. The performance of the participants was affected by the severity of dementia. Also, it was found that designing the visual cues based on the individual's preference would increase the efficiency of the system.

The limitations of the Wizard of Oz approach is that the researcher may misinterpret the technique as perfect, missing out the imperfections within [32]. In addition, the wizard has to be consistent and be trained to minimize errors. The role of wizard can be exhausting. It might be difficult to mimic all the elements for every environment [32]. For instance, the issues stated by [43] regarding Wizard of Oz for their study usually go unnoticed.

Polacek et.al [43] used the Wizard of Oz approach to study an indoor navigation system for blind people that used audio-based commands for navigation and identified issues present in their Wizard of Oz study. They recruited 10 participants, eight amongst them would guide the remaining two who are blindfolded. The 8 wizards were given an android application in a tablet which had buttons for each action and task such as 'Wrong way", 'Stairs", "door" etc. with the responsibility to guide the blindfolded participant. When the wizards pressed these buttons, audio command was sent to the blindfolded participant's device who navigated accordingly. The results showed that, the chosen audio commands were almost complete and only a few more navigation commands were needed to be added. They stated that the participants were satisfied with the Mobile wizard but had issues with the tool as a whole. The issues included battery drain, connection losses, weight of the device used and varying screen sizes.

Maps are one of the interactive UI for localization and navigation. However, the outdoor maps' design might not be appropriate for indoors [62]. The User Interface (UI) requirements for designing indoor maps was discussed by Puikkonen et.al [62]. They stated that the indoor maps should have visible landmarks, with a simplified version for a heavily architectural floor. In addition the map should maintain the consistency between the UI & real world objects. The influence of landmarks on indoor navigation was discussed by Nurmi et.al [63]. Their study involved 20 participants and showed that the users were more confident in their navigation decisions by making less navigational errors. They also experienced a lower cognitive load while using landmark-based instructions. But the users were less aware of the surroundings due to the increased amount of attention on searching for landmarks.

2.3 RELATED APPLICATIONS

StreetLine [44] is a mobile application which uses the in-car GPS navigation system to display the available parking spots. This application is available for only few cities. It has features such as a built in timer which reminds the user before the parking timer expires. It also has "Walk-to-car" feature which provides the users with directions to the parked car. It also has filters which would show only the spots that meet the users' requirements such as payless parking, multi-storey car parking etc. Google maps is used in Cartogram [61] where the information about the stores are updated manually by the store owners but the location of the user is updated automatically with the help of GPS and Wi-Fi localization techniques.

AisleConnect [60] tells about the location of the books in the aisles of a store. The books' locations are manually updated by the store owner in the database. etouches [45] is an online event management application which enables to create seat plans, rules to assign seats etc. A drag-and drop feature allows the users to place the attendees in the desired position. It also allows the users to color code the designed table layout and room plan. Allseated [46] is similar to the former application but it allows the users to have a 3-D view of the planned layout. Similarly, [48] helps in assisting and organizing wedding events' table layouts. [49] and [50] are the applications which help the restaurant operators to organize the tables and their layout.

Leck [47] discusses a two-year pilot project launched by Queen's University and Alma Mater Society at Stauffer library of Queen's University. The pilot-project uses an online tool that shows the users how many people have entered and left the library. They have used sensors and cameras for counting the number of people entering and leaving the library. The operational cost for 2 years is around $1,500 and it would cost the University $4000 to implement. Bluetooth beacons are used for geo-fencing the artifacts and exhibits available in the floor, in QualcommMuseumTourApp[59]. It does not display the location of the user but updates the contents of the display based on the location of the user. LEDTrayable [69] makes use of the trays which are built with hardware such as LED and switches attached to it. The tables have a casing which would fit in the trays. As soon as the tray is placed in the casing, the switch is turned on. The turned on switch triggers an event which marks the table as occupied by activating the LED on the LED board. In LibrarySeatingAvailabilityCheckingSystem [70], the users have to swipe-in their library card and click on the seat they desire to occupy. The selection is done on the interface that is displayed on the Kiosk at the entrance of the library. The interface on the Kiosk would display the available seats and the occupied seats with other options such as computer seats and cubicles.

2.4 SUMMARY

Several researchers [35-40] have dealt with Indoor localization using Wi-Fi technology while researchers [33, 34, 52, 53, 54] have dealt with Indoor localization using technologies other than Wi-Fi. Some of the researchers [35, 36, 38-40] use fingerprinting technique to locate indoors where researchers [38, 40] proved that fingerprinting has a better accuracy than other techniques. The authors of [41-43] have dealt with the use of the Wizard of Oz technique for checking the usability of their respective proposed systems. The authors of [43] also present the issues and concerns of the Wizard of Oz approach. The works done by the authors of [62, 63] have dealt with the guidelines of designing indoor maps. [44-50, 59-61] are examples of some of the mobile applications which are related to this research work. Some of them have used the applications for planning the seating arrangements while some have used it for obtaining the population of people available in the vicinity. Added to that, some applications have used color codes for ease of use and identification for the users. [69, 70] display the seat availability where [69] makes use of hardware such as LED and switches while [70] does not update the seat availability unless the user manually updates it. Table 1 contrasts existing applications that use indoor navigation techniques with our proposed approached. Since none of the current indoor navigation applications, to the best of our knowledge, have generated heat maps (a collection of individual values, displayed graphically) and used it to guide the user to a specific area (i.e., less populated areas), the approach in this thesis has been proposed as a solution to find unoccupied spots in public places like libraries and food courts.

Table 1 Overview of the existing applications relevant to the idea

Applications	**Purpose**	**Medium**	**Update Method**	**Map Type**	**Environment**
Find A Spot [our proposed approach]	***Finding unoccupied seats***	***Wi-Fi***	***Automatic***	***Heat map***	***Indoors***
StreetLine [44]	Finding parking spots	GPS	Automatic	Google map	Outdoors
eTouches [45], AllSeated [46], WeddingWire[48]	Wedding seat management	Online	Manual	Floor map	Indoors
Queen's LibraryApp[47]	Counts people entering and leaving library	Cameras, Sensors	Automatic	--	Indoors
QMuseumTour [59]	Finding Exhibit/artifact information	Bluetooth	Automatic	--	Indoors
AisleConnect [60]	Displays the location of books	Database	Manual	Floor map	Indoors
Cartogram [61]	Find things indoors for shopping	GPS, Wi-Fi	Manual	Google map	Indoors, Outdoors
LEDTrayable [69]	Finding unoccupied seats	LED lights and switches	Automatic	Floor map	Indoors
Library Seat Availability Checking System [70]	Finding unoccupied seats	Buttons on Kiosk	Manual	Floor map	Indoors

CHAPTER 3 SYSTEM DESIGN

3.1 PROPOSED APPROACH

The proposed approach is as follows: A mobile application collects the Received Signal Strength Indication (RSSI) values from the access points and sends them to a remote server in the background. The server receives these values and uses an Indoor Localization technique to calculate the location of the device. This device's location along with the location of the other devices, are then plotted into a map. The plotting is such that at a particular location, a green circle represents one device, a pink circle represents two devices, a blue circle represents three to four devices and a red circle represents more than 5 devices transmitting the signal to the server. The mobile application then receives the plotted heat map sent by the server and displays it to the user in the foreground.

3.2 ARCHITECTURE OF THE PROPOSED APPROACH

The proposed architecture is analogous to the Remote Method Invocation (RMI) architecture [66]. In the RMI approach as shown in Figure 3, the remote device is communicating with the remote server over the internet. Both the device and the server are spaced far apart i.e. they are not in the same physical location.

Figure 3 Remote Method Invocation structure [66]

The proposed approach replaces the Remote Device with a Smartphone and the Remote Server with a laptop. Even in this structure the smartphone and the laptop are not in the same physical location. The activity of the internet is handled by the Sockets. Socket programming is used to attain the desired RMI functionality. Figure 4 represents the structure of the proposed approach.

Figure 4 Proposed approach structure

The architecture of the proposed framework, as shown in Figure 5, involves 3 access points and 2 servers. When the accelerometer sensor of the mobile device is triggered, it gathers the RSSI values of the signals being emitted by the Access points and then sends them to the first server. The server which receives the RSSI values, calculates the distance between the received values and the values that are stored in the training data. The co-ordinates for the values which yield the minimum distance are then retrieved from the training data sheet and then forwarded to the second server. The second server receives the co-ordinates, plots them into the map and forwards them to the mobile device which sent the RSSI values to the first server. While the second server is performing its task of plotting and sending, server one receives and performs its task for another set of received values. Also, once the mobile device sends off a set of values to the server one, it remains dormant until it receives the map from the second server. The mobile device repeats the process of gathering the RSSI values, sending them to the first server and receiving the heat map from the second server until the user closes the application or leaves the vicinity of the research area. In such scenarios where the application is terminated or the mobile device is beyond the vicinity of the access points, the entry concerned to that specific device is deleted from the map. If the accelerometer sensor stops detecting any motion, the mobile device ceases to perform the above discussed process and the last known location of the device is plotted on the heat map. Also, there is no restriction over the use of the number of access points or the servers. We used 3 access points and 2 servers for our convenience. Added to that, Boonsriwai et.al [2] stated that better accuracy is obtained when 3 access points are used for the fingerprinting technique. This count may vary as per the requirements and the needs.

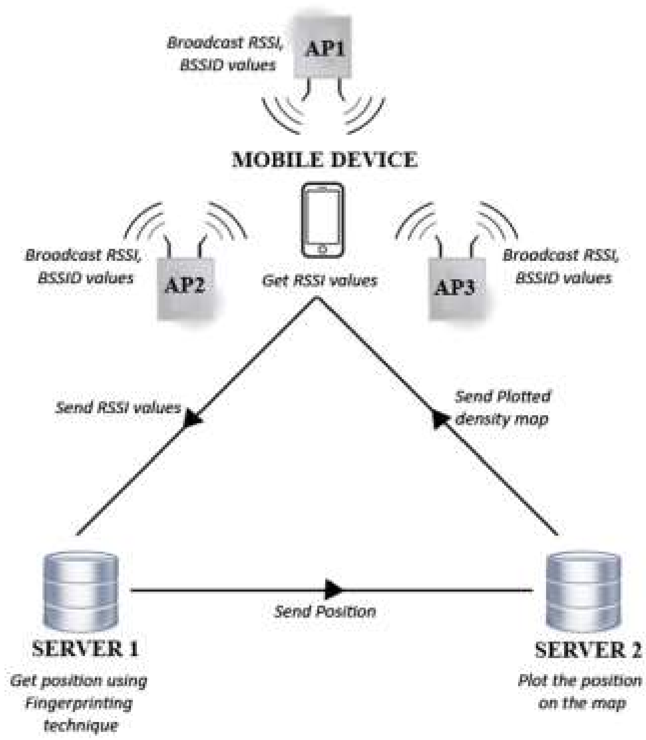


Figure 5 Architecture of the Proposed approach

3.3 FINGERPRINTING TECHNIQUE

Fingerprinting technique involves splitting of the test area into grids. The RSSI value and the BSSID of the access points are collected within each grid [55]. The collected values are stored into a database. This database acts as the training data. During the testing phase, the devices are located on the same grid layout. This is done by mapping the collected RSSI, BSSID values with that of the training data. Once a match is found, that particular grid location from the database is retrieved as the device's location [55].

In this research work, the training data was collected using a mobile application which would collect the RSSI values on the click of a button and then send them to the server. This server would then store the received values against the position index in the database. This position index would correspond to a particular location in the test area. These positions are later mapped to the map co-ordinates in the second server mentioned in the Section 3.2.

For this research work, the Euclidean distance between the collected RSSI values and the stored RSSI values in the training data is calculated. The position index corresponding to the values with the minimum distance (d_{min}) indicates the device location. The formula for calculating the Euclidean distance is as follows [2]:

$$Euclidean\ distance\ (d) = \sqrt{\sum_{i=1}^{n}(v_{train(i)} - v_{test(i)})^2}$$

Where, n is the number of access points, v_{train} is the RSSI value in the training dataset and v_{test} is the RSSI value sent by the device.

CHAPTER 4 IMPLEMENTATION

4.1 DEVELOPMENT ENVIRONMENT AND LIBRARIES USED

The mobile application is developed using Android OS in Android Studio IDE. The servers are configured using Java in NetBeans IDE. The access points are configured using CISCO IOS using Command Line Interface (CLI). The detailed explanation of each platform is as follows:

4.1.1 Android platform

Android is an operating system (OS) for mobile platforms such as smartphones, tablets etc. It was founded in Palo Alto in 2003, acquired by Google in 2005 and unveiled in 2007. It is based on Linux kernel and is primarily for touchscreen devices [64]. The following are the modules which is used for developing the applications required for this research work:

- Application framework: It is the frontline for application development. The APIs included by the application developers are mapped directly to the Hardware Abstraction Layer (HAL) interfaces [8]. Following are the services available in application framework [9]:
    - *Activity Manager* - Application lifecycle and activity stack are controlled by activity manager.
    - *Content Providers* - Links all applications with one another and enables sharing of data amongst themselves.
    - *Resource Manager* **-** Handles the functionalities related to user interface layouts, displayed strings and colour settings
    - *Notifications Manager* **-** Handles alerts and notifications to the users.
    - *View System* **-** Used for creating application user interfaces such as placement of buttons, text views etc. on the screen.
    - *Sensor Manager* - Handles all the sensors such as accelerometer, proximity, light etc.
    - *Wi-Fi Manager* - Features such as Wi-Fi signal strength, MAC address etc. are provided by Wi-Fi manager.
- Linux Kernel: This is the base layer for the entire architecture. It is responsible for handling device drivers, memory management, process management, networking,

system administration, hardware components and equipment drivers like display, camera, keypad etc. [8]

- Hardware Abstraction Layer: It defines a standard interface to implement functionalities without disturbing the higher layers. It is loaded automatically loaded by the android system [8].
- Activity Life cycle [10]: All activities are placed in an activity stack. The running activity is on top of the stack and the other activities are ordered below the current activity. Figure 6 shows the activity life cycle.
    - The entire activity life cycle takes place between the onCreate() and onDestroy() functions. All resources are allocated in onCreate() function and released in onDestroy().
    - onStart() method makes the activity visible to the user and onStop() method hides the activity from the user. The activity may be running in the background maintaining the resources required for its execution while it is in-between these two methods.
    - In-between onResume() and onPause() methods, the activity is on top of all other activities in the stack. It is here that the user can interact with the activity.
    - An activity can frequently call the onCreate() & onDestroy() and onResume() & onPause() methods.

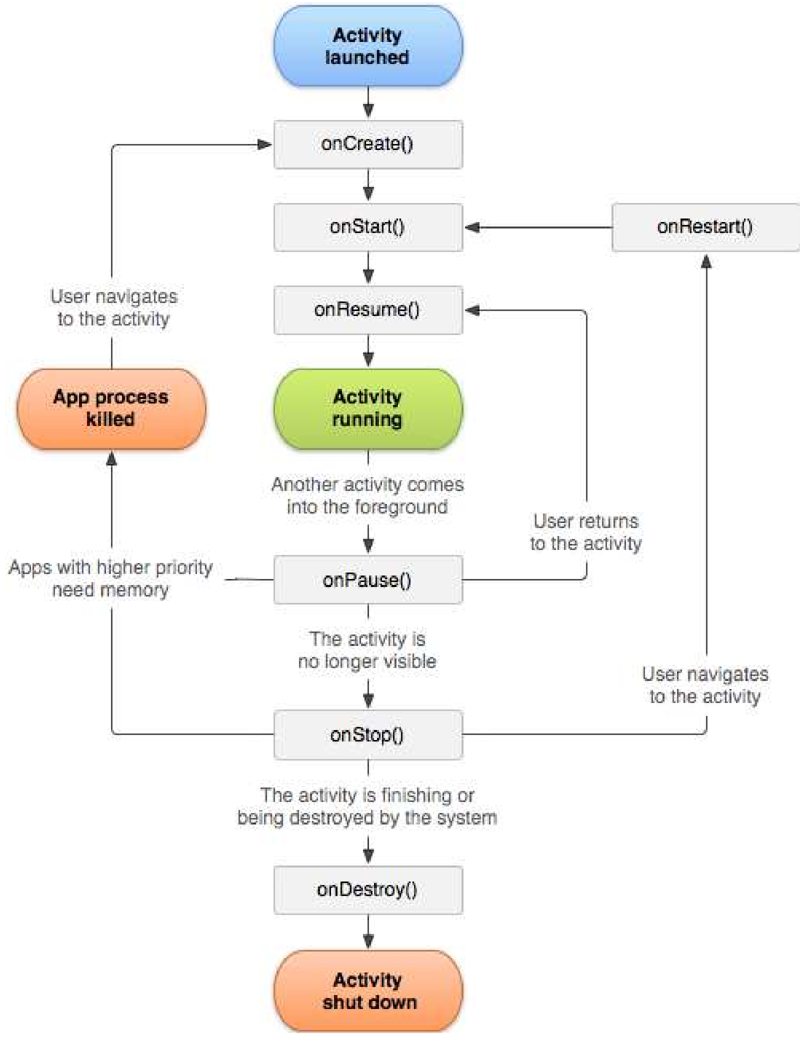


Figure 6 Android activity life cycle [10]

Table 2 Programming languages used in the application development

Android SDK version	Icecream Sandwich (4.0.1) and above
User interface	XML
Programming Language	Java 1.8.0_25
Devices	Samsung Galaxy Note 4 and Samsung Galaxy S6
Android Studio Version	1.0.1

4.1.2 Java platform

Java, originally developed by James Gosling and later acquired by Oracle Corporation, is a programming language which can be written once and executed anywhere, any number of times. It is platform independent as its bytecode, which is generated after compilation of the code, runs on the Java Virtual Machine(JVM). Java was first released by Sun microsystems in 1995. Oracle acquired Java from Sun Microsystems, in 2010 [12]. Of the many features which Java and its packages provides, we are discussing the two major aspects which played a vital role in this thesis.

- Network Programming [11]: When we want our code to communicate over multiple devices and perform different tasks independently, we make use of *java.net* package. This package consists of classes and interfaces such as ServerSocket, Socket, DataOutputStream, etc. which help in communicating between devices across platforms. In order to establish a TCP connection between two computers,
    - The server, using a port number, initiates a session using which another socket can communicate with it.
    - Then it runs the accept() method of the ServerSocket class to accept any client connection at the listening port. It is now in its listening or waiting state.
    - While the server is waiting, the client initiates a Socket object and its constructor tries to connect to the server using the server name (IP address in our case) and the port number.
    - Once the connection is made, the server returns a reference to the client indicating the communication session.
    - After the data transfer is done, the close command is used to terminate the connection.
- Digital Image Programming: When we want our code to manipulate or process digital images, we make use of the various classes and methods available in *java.awt* package. Following are the classes used in this thesis:

- *java.awt.Image:* It represents digital images as two dimensional array of pixels. *Image* is the superclass of all the classes dealing with image processing and *image* is the interface containing all the required abstract methods for the very same purpose. [13]
- *java.awt.image.BufferedImage:* It is the subclass of the Image class which manipulates the images in the memory. It also has methods which stores, interprets and retrieves pixel data. In short, it has an API which helps in direct manipulation of the image data. The constructor used in this work takes width, height and image type (BufferedImage.TYPE_INT_ARGB) as arguments. [14]

  BufferedImage(int width, int height, int imageType) [14]
- We also made use of the *createGraphics()* component to create an image with the required width and height dimensions.

- Graphics2D API: *java.awt.Graphics2D* is an abstract class with *java.awt.Graphics* as its subclass. These classes help us in manipulating 2D shapes, texts, lines etc. [15]. It also has methods which help us in extending the 2D rendering functionality.
  - The setPaint() method helps us in setting the color to be used in the graphics. The setPaint takes the Color.*colorname* or *colorname* as its parameter.
  - The fillOval() is used to create an Oval shape on the image. The fillOval takes x co-ordinate, y co-ordinate, width and height as its parameters.
- ImageIO API: It is present in the *javax.imageio.ImageIO* package. This API has functionalities which help us in creating the image with the desired format such as JPEG, PNG etc. [16]

  ImageIO.write(BufferedImage,"FORMAT_TYPE",filename)
- Collection Framework: Arrays are static in nature i.e. the size of the array is fixed. This framework helps in overcoming this limitation of the arrays. It provides pre-packaged data structures and algorithms for the manipulation of the classes and interfaces offered. Using this framework,

the size of the data structure can be increased whenever required. This framework comprises of Collection Interface which consists of List Interface, Map Interface, Set Interface etc., and Collections Class which consists of ArrayList, LinkedList, HashMap, TreeSet etc. Collection Interface can be manipulated independently whereas Collections Class is reusable data structure. Iterator and/or Enumeration classes are used to perform operations such as insert, delete etc. on the contents of the framework. Java.util package contains the set of interfaces and classes that are described by this framework [24].

Table 3 Platform Specifications

Netbeans IDE version	8.0.2
Programming Language	Java 1.8.0_25

4.1.3 Cisco IOS

Cisco IOS stands for Cisco Internetworking Operating System is a software used for configuring the Cisco routers and switches. This operating system has functions such as telecommunication, internetworking, switching and routing. All the commands needed for manipulating the routers and switches are provided through the Command Line Interface (CLI) of this IOS. The different modes available in this IOS are: User EXEC Mode, Privileged EXEC Mode, Global Configuration Mode, ROM Monitor Mode, Setup Mode and more than 100 configuration modes & submodes.[17]

- USER MODE: In this mode, we can read the configuration of the Access Points but can't edit or alter them. The "ap>" prompt is visible during this mode by default [18].
- ROOT/EXEC MODE: In this mode, we can make small or minute outlier changes of the access point. The command used to enter into the EXEC mode is "enable" followed by the password when prompted. This will take us to "ap#" prompt [18].
- CONFIGURE MODE: In this mode, we can make changes which require permissions higher than those of the EXEC MODE such as altering the

changes in the interfaces of routers and switches. The "**configure terminal**" command allows us to enter into this mode with the "ap(config)#" prompt [18].

- CONFIGURE INTERFACE MODE: In this mode, we have the permissions to configure the interface we choose. For instance, "interface Dot11 radio0" will allow us to configure the 802.11g radio0 interface. This command will also take us to the "ap(config-if)#" prompt. [18]

Table 4 Access Point Specifications

Access Point model	AIR-AP1220B-A-K9
Cisco IOS	C1200-K9W7-M
Cisco IOS version	12.3 (8) JA2, Release S
Frequency	2.4 GHz
CCK Transmitter power	20 mW
OFDM Transmitter power	20 mW
Input voltage	48 V- 380mA

4.2 Implementation Details of the Proposed Approach

4.2.1 Test Bed Layout

MyTech laboratory in Goldberg Computer Science Building, Dalhousie University is the test bed (Figure 7) for this thesis work. The dimensions of this laboratory are 9m x 11m. Three access points are installed in the laboratory. The first access point (AP1) is installed in the midpoint across the width of the laboratory. The other two access points (AP2 & AP3) are installed on the opposite corners of the first access point.

The laboratory is plotted using 20 points with 4 points across the width and 5 points across the length. The width of the laboratory is split into 5 parts. The distance between the left wall & the first point is 2m and the distance between the last point & the wall is 1m. Similarly, the length of the laboratory is split into 6 parts. The distance between the front wall & the first point is 1m and the distance between the last point & the back wall is 2m. Each point is spaced equidistant with a distance of 2m.

The 20x20 resolution mentioned for the heat map is specific only for the preliminary evaluation of our proof of concept. There is no restriction whatsoever on the resolution determined for the heat map. With the increase/decrease of the dimensions of the indoor area, the corresponding resolution can be increased/decreased. The resolution can also be influenced by other factors such as the number of access points and number of seats in the intended area.

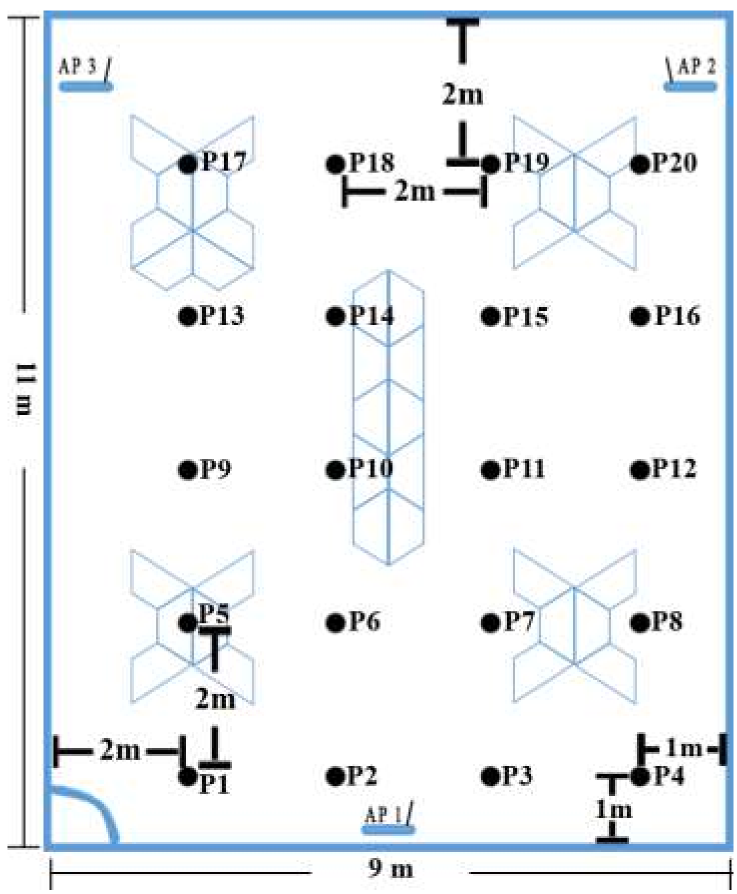


Figure 7 Test bed layout

4.2.2 Configuration of Access Points

Toshiba (TECRA S2) laptop with a serial port was used to handle the access points. All the three access points were configured using the CLI of Cisco IOS and the respective access point's GUI. The steps we followed to configure the access points are as follows:

- Connect the access point to the laptop via the serial port using the serial cable.
- Open the "Putty" terminal and select "Serial" as the Connection Type.
- Once inside the Putty Terminal, you will see the Access Point configuration details in the terminal window such as the OS version, Model number, IP Address etc.
- When all the reset configuration process is completed you will see "ap>" prompt which is the USER MODE (Read Only)
- Now in order to broadcast from the Access Point, in the putty terminal, Type "enable" and then enter the password when prompted. By default, the password is "Cisco" (case-sensitive). This will take you to "ap#" prompt which is the ROOT/EXEC MODE [18].
- Then Type "configure terminal" (case-insensitive) which takes to the "ap(config)#" prompt which is the CONFIGURE MODE [18].
- Once inside the configure mode, make changes to the configuration of the Access Point's Interfaces. This particular Access Point has 2 interfaces Interface Dot11 radio 0 and Interface Dot11 radio 1 representing 2.4 GHz and 5 GHz respectively. To deal with Radio 0 interface mainly, enter "interface Dot11 radio0" and it enters into the "ap(config-if)#" prompt which is the CONFIGURE INTERFACE MODE [18]
- Now, in order to broadcast the packets from this Access Point via/to a different router (such as D-Link router), enter "ip broadcast-address 192.168.0.101". Once this is done, the IP address of the access point is displayed in that particular router's interface.
- Type that IP address in the Address Bar of the Browser and it redirects to the Access Point's UI where one can Enable/Disable interfaces or Setup SSID values or Broadcast them etc. and so on.

- In the "HOME" tab, set the name of the Access Point. For this research work, the names are set as ap-Wise1, ap-Wise2, ap-Wise3 respectively.
- In the "EXPRESS SETUP" tab, set the SSID and enable the "Broadcast SSID" option. For this research work, the SSIDs are set as ap1, ap2 and ap3 respectively.
- In the HOME/EXPRESS TAB, set the IP address as Static (i.e. uncheck the Dynamic checkbox and tick the Static checkbox) and type in the desired IP ADDRESS. For this research work, 192.168.0.101, 192.168.0.102, 192.168.0.103 are used as address to Access Point with SSID ap1, ap2 and ap3 respectively.
- In the "NETWORK INTERFACES" tab, select the "Radio1-802 11A" and then in the "SETTINGS" tab, disable this interface. This research work didn't need the Access Points to broadcast the signals in two different frequency levels. 2.4GHz would suffice the needs of this research work. The Access Point used has a Power of 4W which has a huge coverage (0.5W covers ~20miles Line Of Sight), so emitting the signals on different frequencies would yield redundant and/or different values for signal strengths and hence one of the interfaces can be turned OFF. Radio1-802 11A is chosen and all other interfaces are turned OFF.
- Once the "radio1-802 11A" interface has been disabled, go to the "Radio1-802 11G" interface and set the "CCK Transmitter Power", "OFDM Transmitter Power", "Limit Client Power" to 20. The values have been set by us to 20 based on reading displayed in [19] and also in our Trial and Error attempt, we found that 20 is optimum for our purpose.

  Where CCK stands for Complementary Code Keying, which is for the manipulation of the signal scheme so that it better fits in the narrowband thus yielding better output and throughput [20], OFDM stands for Orthogonal Frequency Division Multiplexing which is used for managing multiple carrier signals on the wideband [21], Limit Client Power is for Limiting the Clients' transmission power [19].

- Among the two antennas of the access point for 2.4GHz, the RIGHT antenna is the PRIMARY and the LEFT is the SECONDARY. This research work used only the primary antenna for transmitting and receiving the signals. This can be configured by setting the "Receive Antenna" and "Transmit Antenna" option to "RIGHT".

This marks the end of configuring the Access Point and later these are connected to the Switch. The cable connecting the Ethernet port of the Access Point and the Switch also acts the power source for itself.

4.2.3 Implementation details of the Server

This research work makes use of the server for two important jobs. One is to handle the training Data and the other is to handle the data during the testing phase & plot the heat map accordingly.

4.2.3.1 Server handling the Training Phase

During the training phase, the researcher initiates the server and mobile application in the device. The researcher then goes to each position as discussed in Section 4.2.1 in the laboratory and clicks on the button placed on the application's interface. On button click, the application collects the RSSI values and sends them to the server which is stored into the 'Fingerprint.xls' training data file. The in-depth representation of the actions performed by the server is dealt in the following paragraphs.

As soon as the server is initiated, it creates a Microsoft excel file with the name 'Fingerprint.xls' to store the received RSSI values from the device. The excel files are dealt using the JXL library ('jxl.jar') [22]. Workbook, WritableWorkbook and WritableSheet are the classes which are used in this work. The class "Workbook" has a method named "createWorkbook", which takes the file object as its parameter. This method helps in creating the required excel file with the desired name. "WritableWorkbook" class helps in editing the created excel file. The class "WritableSheet", has "createSheet" method which takes the excel sheet name and excel sheet number as parameters and creates the Sheet in the excel file with the specified name. It is on this sheet, that “WritableSheet” would be writing the specified values using the “addCell” method which takes the “Label” class’s object. This object of “Label” class has the column index, row index and the value to be stored in that particular column-row index [23].

```
//Creation of the excel file and excel sheet
WritableWorkbook wb1 = Workbook.createWorkbook((new
File("Fingrprint.xls")));
WritableSheet wsht1 = wb1.createSheet("Sheet_1", 0);
//Writing values to the jth column and ith row in the excel
sheet
Label lb1=new Label(j,i, rssi_val);
wsht1.addCell(lb1);
```

After the creation of excel sheet, a ServerSocket is instantiated. For this research work, port numbered 89 is used to communicate with the device. Using this server socket object, a socket is created which accepts the incoming socket connection requests using the accept() method of the ServerSocket class. The incoming stream of data is received using the InputStreamReader and BufferedReader classes among which the InputStreamReader takes the getInputStream() method as its argument and the BufferedReader takes the object of InputStreamReader. The ObjectOutputStream class, which takes the getOutputStream() method of the Socket class as argument, is used to send the data from the server. Close() method of the Socket class is used to terminate the established connection.

```
//Creation of Server Socket
ServerSocket server_Sock = new ServerSocket(89);

//Listening to incoming socket connection requests
Socket client_Sock = server_Sock.accept();
```

```
//Receiving the incoming stream of data
InputStreamReader inputStreamReader = new
InputStreamReader(client_Sock.getInputStream());
BufferedReader  bufferedReader = new
BufferedReader(inputStreamReader);
String msg = bufferedReader.readLine();
inputStreamReader.close();

//Closing the socket
if(m2.equals("stop"))
{
pw.close();
store_msg_from_client(f, wb1, wsht1);
client_Sock.close();
System.exit(0);
}
```

The format of the incoming message from the device is of the form
{'position_value' [space] 'ap1_rssi' [comma] 'ap2_rssi' [comma] 'ap3_rssi'}

Intially, this message is split into two using 'space' as a token. The first half of the message is stored as the position index and the second half is split again into three parts using 'comma' as a token, where each part corresponds to the RSSI value of each access point.

```
//Storing the message from the Client inside
store_msg_from_client(f, wb1, wsht1) method
while(msg!=null){
String[] cols =  msg.split(" ");
for(int l=0;l<cols.length;l++){
if(l==1){
```

```
String[] dots = cols[1].split(",");
for(int d=0;d<dots.length;d++){
if(dots[d].equals("ap1")){
ap1=dots[++d];
}
else if(dots[d].equals("ap2")){
ap2=dots[++d];
}
else if(dots[d].equals("ap3")){
ap3=dots[++d];
}}
cols[l]=ap1+","+ap2+","+ap3;
}
Label lb1=new Label(l,j,cols[l]);
try {
wsht1.addCell(lb1);
} catch (Exception e) {
e.printStackTrace();
}}
msg=br1.readLine();
j++;
}
wb1.write();
wb1.close();
```

4.2.3.2 Server handling the Testing Phase

Sockets send and receive datum using the Stream readers and writers which have a flush command in order to send the entire data to the other end of the socket. This when done, closes the session as well. Due to this setback aspect of the socket, we are making use of two separate instances of the servers running in two different computers performing two separate tasks. One server is dealing with the reception of the message from the device and forward it to the second server while the other deals with reception of the message from the first server and forward the plotted heat map to the device.

Following are the actions performed by the first server:
As soon as the server is initiated, it fetches the stored ‘Fingerprint.xls’ file (which contains the training data) and stores its contents into an array each dedicated for each access point i.e. the stored RSSI values of access point ‘ap1’ for all the positions are stored into the array ‘ap1[ ]’ and so on. Their ‘array index+1’ value represents their Position on the actual floor map.

```
//Storing the values from the training data file to arrays
wb1=Workbook.getWorkbook((new File("Fingrprint.xls")));

//reading values from excel file
Sheet sht=wb1.getSheet("Sheet_1");
int rows=sht.getRows();
int cols=sht.getColumns();

//Copying signal values from excel to separate array lists
for(int i=0;i<rows;i++){
Cell c=sht.getCell(1,i);
xl = c.getContents();
String[] token =  xl.split(",");
ap1_train[i] = (Integer.parseInt(token[0]));
ap2_train[i] = (Integer.parseInt(token[1]));
ap3_train[i] = (Integer.parseInt(token[2]));
```

A HashMap is created to store the hashed MAC ID as the key and the corresponding position as the value. Then a server socket and a socket are created for receiving the incoming messages. The received message is split into four parts using ‘comma’ as the token. The first part is the hashed MAC ID and the remaining parts are the RSSI values of access points ap1, ap2 and ap3 respectively. This hashed MAC ID is used to uniquely identify the devices and stored as the key of the HashMap. Using the formula discussed in Section 3.3, the positions are calculated from the RSSI values in the incoming message and the values in the training file. If the HashMap contains the hashed MAC ID, it replaces the existing positon value else a new entry is created in the HashMap with the hashed MAC ID-Position key-value pair. This hashmap is then forwarded to the second server.

```
//Calculating the position using the training data and the
received RSSI values
for (int i=0;i<ap1_train.length;i++){
dist = (int)(Math.sqrt((Math.pow((ap1-ap1_train[i]),2.0)) +
     (Math.pow((ap2-ap2_train[i]),2.0)) + (Math.pow((ap3-
          ap3_train[i]),2.0))));
dist_list.add(dist);
```

Following are the actions performed by the second server:
As soon as the server is initiated, the arrays for x and y co-ordinates are generated with an initial set of values mimicking the positions on the floor map discussed in Section 4.2.1. Thus the x-coordinates range from 2 until 8 and the y-coordinates range from 1 until 9. These values are later multiplied with 100 while plotting them onto the floor map.

```
//Generating the arrays for x and y co-ordinates
int temp_cord = 0;
for (int j = 1; j <= 9; j++) {      `
for (int i = 2; i <= 8; i++) {
x_cord[temp_cord] = i;
y_cord[temp_cord] = j;
temp_cord++;
i++;}
j++;
```

Then, a server socket and a socket are created to receive the incoming message from the first server and broadcast packets from the device. A HashMap is also created which stores the position as key and the count of the number of devices on a particular position as value. The HashMap is instantiated with the position values ranging from 1 through 20 as Keys and their corresponding Values as zeroes.

```
//Creating and updating the position-count HashMap
HashMap<Integer, Integer> count_map = new HashMap<Integer,
          Integer>();
int i = 1, count = 0;
while (i <= 20) {
count_map.put(i, 0); i++;
```

Then, the position values are retrieved from the message received from the first server and the corresponding count value in the HashMap is incremented by 1. This HashMap bearing the position and count values, is then used to plot the heat map.

```
//Updating the position-count HashMap
Iterator it = clnt_pos_map.entrySet().iterator();
 while (it.hasNext()) {
Map.Entry pair = (Map.Entry) it.next();
int pos = (int) pair.getValue();
count = count_map.get(pos);count++;
count_map.put(pos, count);
```

The x and y co-ordinates are retrieved from their respective arrays with the help of position value which represents (array index+1) and multiplying it with 100 in order to map to screen co-ordinates. The count value corresponding to this position is multiplied by 30 which is used as the radius of the circle to be plotted. While plotting, at any given position, different colors are used to represent the density on the map as shown in Table

5. The plotted heat map is stored as an image file with ".png" extension. Table shows the color code for different densities.

```
//Plotting the heat map
while (it.hasNext()) {
Map.Entry pair = (Map.Entry) it.next();
int loc = (int) pair.getKey();
if ((int) pair.getValue() != 0) {
if ((int) pair.getValue() >5) {
ig2.setPaint(Color.RED); }
if ((int) pair.getValue() <=5 && (int)pair.getValue() >=4 )
{
ig2.setPaint(Color.BLUE);
}
if ((int) pair.getValue() <4 && (int)pair.getValue() >=2) {
ig2.setPaint(Color.YELLOW);
}
if ((int) pair.getValue() == 1) {
ig2.setPaint(Color.GREEN);
}
r = (int) pair.getValue() *30;
x = x_cord[loc] * 100;
y = y_cord[loc] * 100;
ig2.fillOval(x, y, r, r);
}
else if ((int) pair.getValue() == 0) {
}}
ImageIO.write(bi, "PNG", file);
```

Table 5 Color code for different densities

COUNT	COLOR
1	Green
2	Pink
3 or 4	Blue
>5	Red

This generated heat map is then sent to the device which sent the RSSI value of the access points to the first server and is now in the listening state.

```
//Sending the generated heat map to the device
byte[] bytes = new byte[(int) file.length()];
BufferedInputStream bis = new BufferedInputStream(new
FileInputStream(file));
bis.read(bytes, 0, bytes.length);
ObjectOutputStream oos = new
ObjectOutputStream(socket.getOutputStream());
oos.writeObject(bytes);
oos.flush();
```

4.2.4 Implementation details of the Android device

This section discusses the implementation of the android applications developed for the training phase, testing phase and the user study.

4.2.4.1 Application used in the Training Phase

The purpose of the application is to gather the RSSI values of the access points on the positions specified in Section 4.2.1 and send them to the server on a button click. A StringBuilder object is used to store all the data to be sent to the server. The in-depth representation of the actions performed by the application is dealt in the following paragraphs.

As soon as the application starts, a StringBuilder object is instantiated. When the researcher clicks the button provided on the UI, a method bearing the implementation for collecting the required data is called.

```
//Button functionality
StringBuilder sb = new StringBuilder();
bt1.setOnClickListener(new View.OnClickListener() {
@Override
public void onClick(View v) {
getSignalStrength(); });
```

WifiManager and WifiScanReceiver are used to gather the details of the access points detected by the device. The getScanResults() method of the WifiManager class returns a list containing the details of all the detected access points. This includes the Service Set Identifier (SSID), Broadcast SSID(BSSID), capabilities, level, frequency and timestamp. Among these, the SSID represents the name of the access point and the level represents the RSSI value. Hence from the list returned by the getScanResults() method, the ones having the "SSID" value as ap1,ap2 & ap3 are selected and their corresponding "level" value is extracted. These extracted "level" values along with the respective "SSID" values are stored into the StringBuilder object.

```
//getSignalStrength() method
WifiManager mainWifiObj = (WifiManager)
     getSystemService(Context.WIFI_SERVICE);
WifiScanReceiver wifiReciever = new WifiScanReceiver();
registerReceiver(wifiReciever, new IntentFilter(
WifiManager.SCAN_RESULTS_AVAILABLE_ACTION));
List<ScanResult> wifiScanList =
               mainWifiObj.getScanResults();
sb.append("P[" +i+"]");
sb.append(" ");
```

```
ArrayList<String> ssid_list = new ArrayList();
Iterator<String> itr = ssid_list.iterator();
for (ScanResult result : wifiScanList) {
if(ssid_list.contains(result.SSID)){
}
else if (result.SSID.equals("wise1")) {
sb.append(result.level+",");
ssid_list.add(result.SSID);
}
else if (result.SSID.equals("wise2")) {
sb.append(result.level+",");
ssid_list.add(result.SSID);
}
else if (result.SSID.equals("wise3")) {
sb.append(result.level+",");
ssid_list.add(result.SSID);
 }}
```

The StringBuilder object is then converted to String and is sent to the server. Once the string is sent, the StringBuilder object's contents are cleared.

```
//Sending the data to the server
String data = sb.toString();
Socket client_Socket = new Socket(ip_addr, port_no);
PrintWriter printwriter = new
PrintWriter(client_Socket.getOutputStream(), true);
printwriter.write(data);
printwriter.flush();
printwriter.close();
//Clearing the contents of the StringBuilder object
sb.replace(0,sb.length(),blank);
```

4.2.4.2 Application used in the Testing Phase

The application used in the testing phase can be split into two modules. The first module gathers the RSSI values of the access points specified in Section 4.2.1. when the accelerometer sensor detects a motion and then sends them to the first server. Then it triggers the second module which sends connection request to the second server and enters into the listening state. Once the second server responds with the image of the heat map, the device moves out of the listening state, receives the sent image and displays it to the user on the screen. The in-depth representation of the actions performed by the application is dealt in the following paragraphs.

When the application runs,
getDefaultSensor(Sensor.TYPE_LINEAR_ACCELERATION) method of the SensorManager class is triggered to detect for any changes in its sensor values. The change in the sensor value represents the presence of movements. The method containing the code snippet for collecting the RSSI values and setting up of the heat map to the user is called from within the method which detects the change in sensor.

```
//Instantiating the sensor manager
SensorManager sensor_manager = (SensorManager)
getSystemService(Context.SENSOR_SERVICE);
Sensor accelerometer_sensor =
     sensor_manager.getDefaultSensor(Sensor.TYPE_LINEAR_ACC
ELERATION);
sensor_manager.registerListener(MainActivity.this,
accelerometer_sensor, SensorManager.SENSOR_DELAY_NORMAL);

//Method detecting the change in sensor
if (event.sensor.getType() ==
     Sensor.TYPE_LINEAR_ACCELERATION) {
if(event.values[0]!= 0) {
getSignalStrength();}}
```

getSignalStrength() method is the same as that of the one mentioned in Section 4.2.4.1. Once the data is sent to the first server, the application waits for the reception of the image from the second server. This image serves as the heat map which is displayed to the user. Upon reception of the image, it is set as the image in the ImageView which spans across the entire screen.

```
//Reception of the Image
ListeningSocket = new Socket(ServerTwoIP,
     ListeningSocketPort);
File file = new
     File(Environment.getExternalStorageDirectory(),
"UsersLocations.png");
ObjectInputStream ois = new
     ObjectInputStream(ListeningSocket.getInputStream());
byte[] bytes;
FileOutputStream fos = null;
bytes = (byte[])ois.readObject();
fos = new FileOutputStream(file);
fos.write(bytes);
fos.close();

//Setting the image in ImageView
hmap.setImageResource(android.R.color.transparent);
File f = new
     File(Environment.getExternalStorageDirectory(),
          "UsersLocations.png");
Uri uri = Uri.fromFile(f);
hmap.setImageURI(uri);

//Attributes of ImageView
<ImageView
android:layout_width="fill_parent"
```

```
android:layout_height="fill_parent"
android:id="@+id/hmap"
android:layout_centerHorizontal="true"
android:layout_marginTop="0dp" />
```

4.2.4.3 Applications used in the User study

The applications detailed in this subsection is as per the Wizard of Oz approach discussed in Section 5.2. There are two applications developed, one for the researcher to update the heat map and the other application for displaying the heat map to the participant.

Following are the actions performed by the application on the researcher end:
The background image of this application is the floor map of the study area. The seats on the map are overlaid with buttons. When these buttons are clicked, a method containing the code snippet for the pop-up is called.

```
//Attributes of the seat button. (20,15) is the location of
first seat on the map
<Button
style="?android:attr/buttonStyleSmall"
android:layout_width="15dp"
android:layout_height="20dp"
android:layout_marginTop="15px"
android:layout_marginLeft="20px"
android:id="@+id/button"
/>

//Seat button functionality
button.setOnClickListener(new OnClickListener() {
@Override
public void onClick(View v) {
if (p != null)
```

```
buttonPopup(MainActivity.this, p, "c23",x,y);
}});
```

When the buttons on the seats are clicked, a pop-up containing another set of buttons representing the color codes is displayed. As soon as the method handling the pop-up activity is triggered, it sets the attributes for the pop-up to be displayed.

```
//Attributes of the pop-up
int popupWidth = 400;
int popupHeight = 1000;
LinearLayout viewGroup = (LinearLayout)
context.findViewById(R.id.popup);
LayoutInflater layoutInflater = (LayoutInflater) context
.getSystemService(Context.LAYOUT_INFLATER_SERVICE);
View layout = layoutInflater.inflate(R.layout.popup_layout,
     viewGroup);
final PopupWindow popup = new PopupWindow(context);
popup.setContentView(layout);
popup.setWidth(popupWidth);
popup.setHeight(popupHeight);
popup.setFocusable(true);
int OFFSET_X = 30;
int OFFSET_Y = 1200;
popup.setBackgroundDrawable(new BitmapDrawable());
popup.showAtLocation(layout, Gravity.NO_GRAVITY,  OFFSET_X,
OFFSET_Y);
```

When the button on the pop-up is clicked, its concerned task is performed. For instance, if the button with text “G” is clicked, a circle of the specified radius, filled with green color is drawn on the exact location of the clicked seat button.

```
//Pop-up button functionality
Button green = (Button) layout.findViewById(R.id.green);
green.setOnClickListener(new OnClickListener() {
@Override
public void onClick(View v) {
button_colour.put(button_id,1);
Bitmap bitmap = Bitmap.createBitmap(Integer.parseInt(x),
Integer.parseInt(y), Bitmap.Config.ARGB_8888);
Canvas canvas = new Canvas(bitmap);
Paint paint = new Paint(Paint.ANTI_ALIAS_FLAG);
Iterator it_colour = button_colour.entrySet().iterator();
Iterator it_coordinates =
     button_coordinates.entrySet().iterator();
while(it_coordinates.hasNext()){
Map.Entry pair = (Map.Entry) it_coordinates.next();
String[] xy = ((pair.getValue().toString().split(",")));
if(button_colour.get(pair.getKey())!=0){
if(button_colour.get(pair.getKey())==1){
int ag = Color.argb(alpha, 0, val, 0);
paint.setColor(ag);
canvas.drawCircle(Float.parseFloat(xy[0]),Float.parseFloat(
xy[1]),20,paint);
}
if(button_colour.get(pair.getKey())==2){
int ay = Color.argb(alpha, val, 0, val);
paint.setColor(ay);
canvas.drawCircle(Float.parseFloat(xy[0]),Float.parseFloat(
xy[1]),30, paint);
}
if(button_colour.get(pair.getKey())==4){
int ab = Color.argb(alpha, 0, 0, val);
paint.setColor(ab);
```

```
canvas.drawCircle(Float.parseFloat(xy[0]),Float.parseFloat(
xy[1]), 40, paint);
}
if(button_colour.get(pair.getKey())==6){
int ar = Color.argb(alpha, val,0,  0);
paint.setColor(ar);
canvas.drawCircle(Float.parseFloat(xy[0]),Float.parseFloat(
xy[1]), 85, paint);
}}}
imageView.setImageBitmap(bitmap);
bitmap.compress(Bitmap.CompressFormat.PNG, 100, new
FileOutputStream(new
     File(Environment.getExternalStorageDirectory(),
     "UsersLocations.png")));
popup.dismiss();
}});
```

Once the image is updated, the IP address displayed on the user's device is used for creating a connection socket between the researcher's application & the user's application and the image is sent.

```
//Sending the updated image to the application on the
user's device
File file = new File
(Environment.getExternalStorageDirectory(),
"UsersLocations.png");
byte[] bytes = new byte[(int) file.length()];
BufferedInputStream bis;
bis = new BufferedInputStream(new FileInputStream(file));
bis.read(bytes, 0, bytes.length);
ObjectOutputStream oos = new
ObjectOutputStream(socket.getOutputStream());
```

```
oos.writeObject(bytes);
oos.flush();
```

Following are the actions performed by the application on the User end:

The background image of this application is the floor map of the study area. The IP address of the user's device is also displayed on the screen which is used to create a socket connection between the researcher's application and this application. Added to that the background image is toggled between the floor map with landmarks and without landmarks using a button.

```
//Button functionality to toggle between the two background
images
show.setOnClickListener(new View.OnClickListener() {
@Override
public void onClick(View v) {
show.setVisibility(View.INVISIBLE);
noshow.setVisibility(View.VISIBLE);
rl.setBackgroundResource(R.drawable.maplandmarks);
}});
noshow.setOnClickListener(new View.OnClickListener() {
@Override
public void onClick(View v) {
show.setVisibility(View.VISIBLE);
noshow.setVisibility(View.INVISIBLE);

rl.setBackgroundResource(R.drawable.mapnolandmarks);
}});
//Displaying the IP address
TextView infoip = (TextView) findViewById(R.id.infoip);
infoip.setText(getIpAddress());
```

Then, a server socket and a socket are created to receive the incoming image file from the researcher's device. Since the image generated in the researcher's end is in PNG format, hence it has the transparent property i.e. the portion of the image which doesn't have the colored circles over it, is transparent. Thus the received image from the researcher's device is overlaid on top of the background image thus displaying the heat map to the user. This makes the observer to have an illusion that the whole floor map has been plotted.

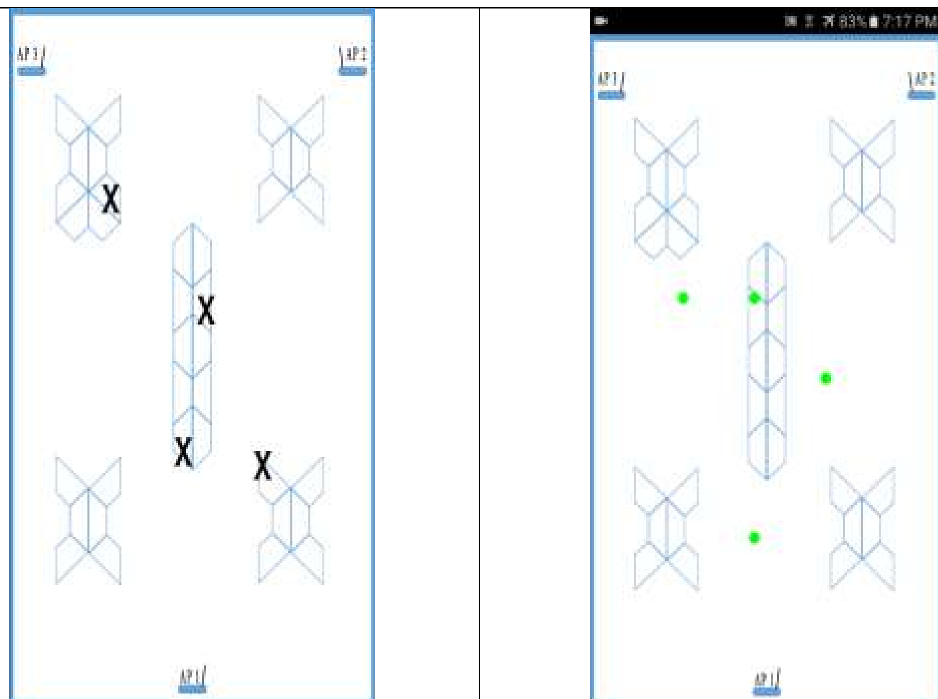
```
//Receiving the image from the researcher's device
File file = new
     File(Environment.getExternalStorageDirectory(),
                        "UsersLocations.png");
ObjectInputStream ois = new
     ObjectInputStream(hostThreadSocket.getInputStream());
byte[] bytes;
FileOutputStream fos = null;
bytes = (byte[])ois.readObject();
fos = new FileOutputStream(file);
fos.write(bytes);
OutputStream outputStream =
     hostThreadSocket.getOutputStream();
PrintStream printStream = new PrintStream(outputStream);
printStream.print(msgReply);
printStream.close();

//Displaying the received image
imageView.setImageResource(android.R.color.transparent);
imageView.setScaleType(ImageView.ScaleType.FIT_XY);
File f = new
     File(Environment.getExternalStorageDirectory(),
     "UsersLocations.png");
```

```
Uri uri = Uri.fromFile(f);
imageView.setImageURI(uri);}});
```

4.3 Proof Of Concept

The implemented application and the servers' functionalities were tested within the test bed by placing the four mobile devices at various random locations. The letter 'X' indicates a single mobile device in Figure 8, two mobile devices in Figure 9 and four mobile devices in Figure 10.

In the first arrangement, an attempt was made to check the singleton conditions i.e. each mobile must be identified as individual points. Figure 8 shows the placement of the devices and the respective heat map generated.



a). Placement of mobile devices on the Test bed	b). Generated heat map

Figure 8 Singleton condition

In the second arrangement, an attempt was made to check the paired conditions i.e. two mobile devices must be identified as a single point. Figure 9 shows the placement of the devices and the respective heat map generated.

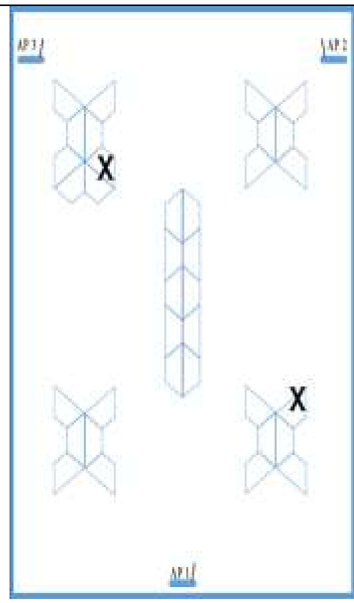
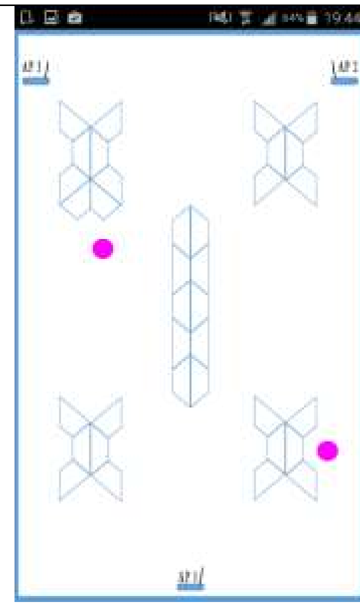
	
a). Placement of mobile devices on the Test bed	b). Generated heat map

Figure 9 Paired condition

In the third arrangement, an attempt was made to check the group conditions i.e. more than three mobile devices must be identified as a single point. Figure 10 shows the placement of the devices and the respective heat map generated.

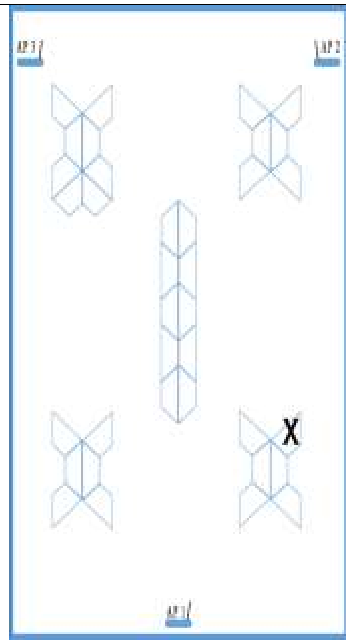
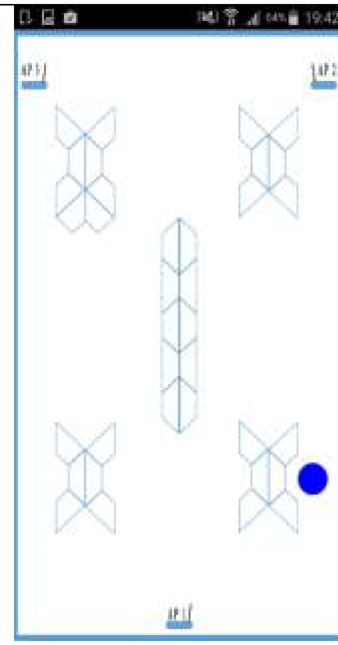
	
a). Placement of mobile devices on the Test bed	b). Generated heat map

Figure 10 Group condition

4.4 Summary

We implemented the proposed approach in Java and performed preliminary evaluations in the Test bed. We considered three basic test cases as discussed in Section 4.3 and observed that there were fluctuations in the locations plotted on the heat map. The observed fluctuations can be minimized by using better indoor localization algorithms. As our main focus was to verify whether any of the localization techniques can be applied towards the proposed approach, we did not consider minimizing the fluctuations and improving the accuracy. Added to that, installing this application on all the devices available in a public place seemed to be infeasible at this point of time. Hence in order to evaluate the helpfulness of the application in real time, we conducted a user study with 24 participants by simulating the actual application using a Wizard of Oz technique as discussed in Section 5.2.

CHAPTER 5 USER STUDY DESIGN

5.1 OVERVIEW OF THE STUDY

To evaluate the helpfulness of the application to a user in real environment, we conducted a user study. Since there were fluctuations observed in the application developed as a proof of concept and also installing the application on all devices available in a public place was infeasible at this point of time, a Wizard of Oz technique was used for the study. The purpose of the research study was to observe how users use the generated heat maps representing populated areas in the library to find individual quiet/any space to study (e.g., unoccupied desks) and to find a quiet/any space where a small group could meet. The users used an application which was installed on a smartphone device that displayed the density of people present in the study area as a heat map. Using this heat map, they had to navigate to the respective areas. The study was conducted in the Halifax Central Library with 24 participants. A main researcher and a co-researcher were involved in the study. The main researcher's role was to assign tasks to the participants, video record them while they are performing the tasks and take notes of the observations made while the co- researcher acted as a "wizard" who updated the heat map and sent to the participant's device. Questionnaires and semi-structured interview were used to get the feedback from the users.

5.2 WIZARD OF OZ APPROACH

The Wizard of Oz technique was used to simulate the actual application. In order to accomplish this, a pair of mobile applications, one for the "wizard" and another for the participant was developed. The mobile application at the wizard's end allows him to manually plot the location of the devices on button clicks. These buttons are placed on the locations which can be occupied by people. When the button is clicked, a pop-up consisting of buttons dedicated to each color is displayed. The wizard then selected the desired color and the selected color is plotted on the map. Before the commencement of the study, the wizard walked around the study area and plotted the heat map manually that was then sent to the participant's device. Also, while the participants were performing the tasks, the wizard kept updating the heat map and sending the updated map to the participant's device.

The mobile application at the participant's end displayed the plotted map received from the wizard's mobile application.

5.3 Recruitment of participants

To participate in the study, participants had to have experience using a Smartphone and be comfortable walking around with the mobile device for about 20-25 minutes. The participants were recruited by emails through Notice Digest (notice.digest@dal.ca) and through the computer science mailing list (csall@dal.ca). In addition, a recruitment notice was posted on the researcher's Facebook page. The participants were compensated with $10 (CDN) for their participation in the study. The email recruitment script is shown in Appendix A.

5.4 Study Environment And Equipment Used

The study was conducted in the third floor of the Halifax Central Library. The layout of the study area is shown in the Figure 11. The areas marked with crosses were not included in the study. i.e. the participants could not opt to choose a seat in those locations because they were reserved for events and library staff. During the demonstration session, the participants were informed about the boundaries of the study area. A compass was also placed on the image to help the participant navigate.

The set of devices that were used for the study included two smartphones and a tabloid. One smartphone (Samsung Galaxy S6) that was installed with the application which displayed the heat map was given to the participant. Another smartphone (Samsung Note 4) that was used by researcher who was acting as the wizard was installed with the application that had buttons which would allow him/her to generate the heat map. The tabloid device (Asus Nexus 7) was used to video tape the participants as they performed the tasks and also audio record during the interview session.

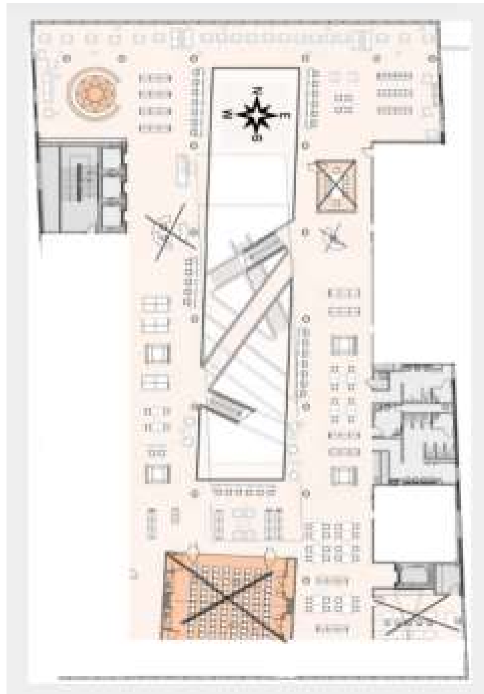


Figure 11 Floor Map of the third floor of Halifax Central Library

5.5 STUDY PROCESS

Before starting the study, participant gave consent (Appendix B) and filled in a background questionnaire (Appendix E). The study was then explained to the participants. They were shown a print-out of the layout of the study area and explained about the boundaries of the study area. They were also informed about the study rooms and specific seating areas which were not included in the study.

Then the participants were shown the application on the Smartphone and were given a short demonstration of the application. They were introduced to the two interfaces (map with landmarks and map without landmarks) on the application, the button to toggle between these two interfaces, and what the colors on the heat map represented i.e. which color represented how many people were occupying that particular seating area. For example, as shown in Figure 15, a green dot on the map indicates that, currently there is one person sitting on that seating area.

Upon the completion of the demonstration, they were asked to perform a set of tasks using the application to find either a single seat for himself/herself or find a seating area for a group of people for different scenarios. The tasks are explained in detail in Section 5.5.1. The heat map on the user's device was updated using a Wizard of Oz approach as discussed in Section 5.2

Before the participant performed each task, the co-researcher updated the floor's heat map based on the seat occupancy by the general public. This map was then sent to the participant's mobile application. The participant was then asked to perform the set of activities required by each task. While they performed the tasks, observations of their behavior were noted on paper. Also, as a backup to the observation notes, the participants were video recorded.

While the participant was performing the tasks, the co-researcher (the 'wizard') continuously sent the updated heat map to the participant's device. After completing the first set of tasks on one of the interfaces, the participant filled in a post-task questionnaire (Appendix C) for each pair of tasks. Then the participant was taken to the new location as per the order in Table 8, and asked to perform the next set of tasks using the other interface. They then filled in a post-task questionnaire (Appendix C) for this set of tasks. The questionnaires collected feedback on the ease of using the application to perform the tasks of finding quiet/any single seat and a group of seats using each interface. After all the tasks were performed by the participant, a semi-structured interview (Appendix D) was conducted by the researcher to gain more insight on the user's experience of finding unoccupied seats using the application. Their feedback along with answers to the questionnaire are analyzed in Chapter 6.

Each participant was compensated $10 for participating in the study. The study took about 45-60 minutes per participant. Table 6 shows the breakdown of the time commitment of the study.

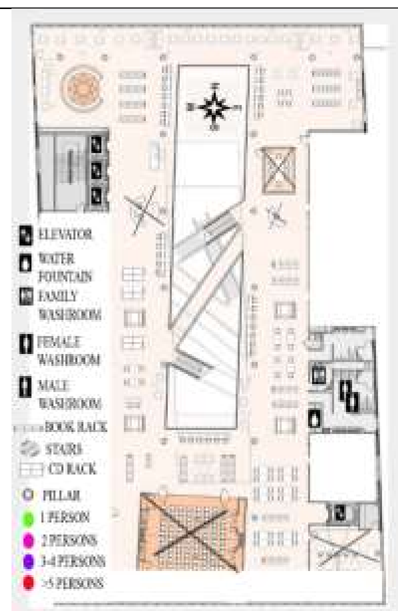
Table 6 Time breakdown of the Study

PROCESS	TIME (min)
Quick explanation of the study, Background questionnaire	5-10
Explanation of floor map and quick demonstration of the application	3-5
All the tasks + Questionnaires	20-25
Semi-structured interview	15-20

5.5.1 Study Tasks

There are two interfaces in the application for the user study. The first interface (I1) shows the heat map with N, S, E, W directions that the participants can use to navigate to different areas as shown in Figure 12a. The second interface (I2) shows the heat map with N, S, E, W and some landmarked features (such as the elevators, washrooms etc.) to help orient the participants as shown in Figure 12b.

a) Heat Map - no landmarks



b) Heat Map - with landmarks

Figure 12 The two map interfaces (Heat Map with no landmarks and Heat Map with landmarks)

Participants performed two sets of tasks using both map interfaces. The tasks were created to represent possible scenarios when a person or group of people may look for quiet/any spot in a public place like a library. Examples of the task scenarios used are shown in Table 7.

Table 7 Task Examples

INTERFACE	TASKS	EXAMPLE SCENARIOS
I1	SQ	Find a quiet location that is not too near other people E.g. you want to concentrate on some important document or do banking etc.
	GQ	Find a quiet location for you and three of your classmates/friends working on a project. You will be talking a lot so you do not want to bother people.
I2	SA	Find any single spot for you to do a work which doesn't need much of your concentration (doesn't matter even if others are around you). E.g. Listen to music, catch up on Facebook etc.
	GA	Find any spot for you and a group of 3 of your friends together but it doesn't need to be private. E.g. You are here to work on your own but sometimes need to discuss with your friends for clarifications on your assignment.

The tasks were broken down as follows:

- Single (S): Participants needed to find two individual unoccupied seats in the library. They were asked to find a single seat that would be quiet (Q) (e.g., to study) and to find any unoccupied seat (A).
    - A Single Quiet Seat (SQ) depicted a scenario where the user would like to have a quiet space for his/her personal work.
    - A Single Any Seat (SA) depicted a scenario where the user would not mind the presence of people around him/her.
- Group (G): Participants needed to find an unoccupied space where a small group could meet for group work. They were asked to find a group of seats that would be quiet (Q) and to find any group of unoccupied seats (A).
    - A Group of Quiet Seats (GQ): depicted a scenario where a group of users would like to have a quiet space for their work.

- A Group of Any Seats (GA): depicted a scenario where a group of users would not mind the presence of people around them.

Two specific locations (L1 & L2) within the study area were chosen and the participants were asked to start the tasks from the locations mentioned in Table 7. This was done to increase the participants' experience with the use of landmarks and seating plans so that they do not choose the same seats repeatedly. Figure 13 shows locations L1 and L2 on the floor map.

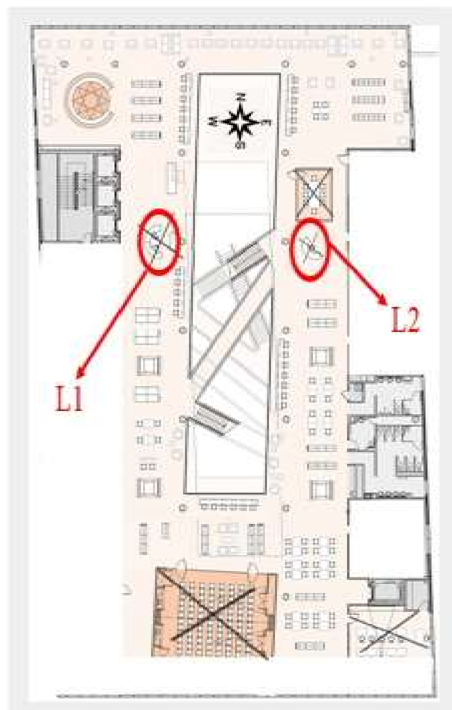


Figure 13 Floor map showing Locations L1 & L2

The study was a within design and we ordered the tasks along with the interfaces such that each participant performed all the tasks using each interface for each scenario mentioned in Table 8. Table 8 shows the allocation of tasks with scenarios for each interface to different participants. For instance, participant P1 starts from location L1 in search of unoccupied seat/s for Single Quiet (SQ), Single Any (SA), Group Quiet (GQ), Group Any (GA) scenarios respectively using interface I1. Then, the participant is asked to start from location L2 in search of unoccupied seat/s for Single Any (SA), Single Quiet (SQ), Group Any (GA), Group Quiet (GQ) scenarios respectively using interface I2.

Please note that the focus of the study was on evaluating the helpfulness of the application to locate unoccupied spot under different scenarios using different interfaces because of which we considered the variations in the ordering of Quiet, Any and Interface with Landmarks, Interface without Landmarks for both Single and Group.

Table 8 The Order of Tasks and Interfaces

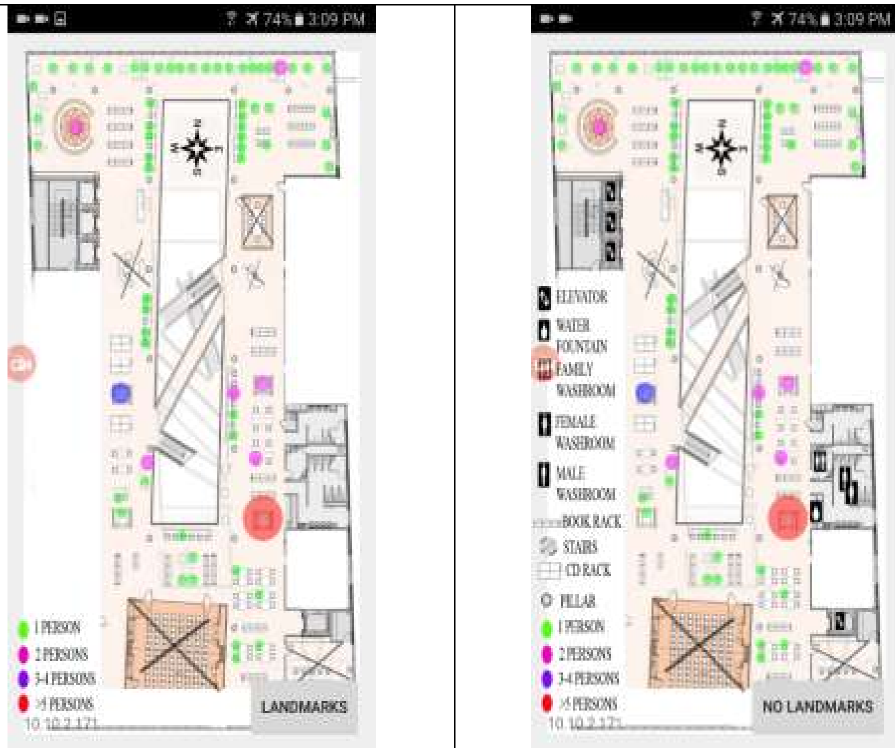
Participants	**Start from L1**		**Start from L2**	
	I1	**I1**	**I2**	**I2**
P1, P5, P9	SQ, SA	GQ, GA	SA, SQ	GA, GQ
P13, P17, P21	SA, SQ	GA, GQ	SQ, SA	GQ, GA
	I2	**I2**	**I1**	**I1**
P2, P6, P10	SA, SQ	GA, GQ	SQ, SA	GQ, GA
P14, P18, P22	SQ, SA	GQ, GA	SA, SQ	GA, GQ
	Start from L2		**Start from L1**	
	I1	**I1**	**I2**	**I2**
P3, P7, P11	SQ, SA	GQ, GA	SA, SQ	GA, GQ
P15, P19, P23	SA, SQ	GA, GQ	SQ, SA	GQ, GA
	I2	**I2**	**I1**	**I1**
P4, P8, P12	SA, SQ	GA, GQ	SQ, SA	GQ, GA
P16, P20, P24	SQ, SA	GQ, GA	SA, SQ	GA, GQ

5.5.2 User Interfaces

The user interface of the application on the researcher's device comprises of buttons placed over each of the seats present on the floor map, as shown in Figure 14.

Figure 14 User Interface on the researcher's device

The user interface of the application on the participant’s device with the heat map for each interface is shown in Figure 15.



a) User Interface showing the heat map without landmarks	b) User Interface showing the heat map with landmarks

Figure 15 User Interface on participant’s device

5.5.3 Data Collected during the study

The participants were asked to fill a background questionnaire before starting the study. The background questionnaire (Appendix E) had demographic questions such as age, gender and questions related to the frequency of use of navigation applications and frequency of searching for unoccupied spots in public places.

Two sets of post-task questionnaires comprising of the same questions, were used to get the feedback from the participants after the completion of four tasks. The questions were designed to learn the participants’ experience with the application while performing the tasks and to get the participants’ feedback on their experience while locating and navigating to the unoccupied spots. As well we checked to see if once they got to the spot

they wanted to get to, if it was still occupied. If it was, we asked them to tell us how many times they needed to search for an empty spot.
After the study, the participants were asked to take part in a short semi-structured interview session (Appendix D). The semi-structured interview had questions pertaining to the experiences of the participants while using the application to perform the tasks. Added to that, the participants were asked questions based on the observations of the researcher. It also had questions to get the user's suggestions on improving the application. During the interview, the entire session was audio-recorded and notes were taken to highlight the important points.

As well, the researcher took notes about how the participants performed the tasks on paper and video recorded them as well to use as a backup to the notes. The researcher observed the participants for specific things as listed in Appendix I while they were performing the tasks and noted down the observations on a paper at the end of each task (i.e. when the participants stopped at the particular seat chosen for the task).

CHAPTER 6 ANALYSIS AND DISCUSSION

This chapter presents the analysis of the results obtained from the user study. The data was collected using demographic questionnaire, questionnaire for different tasks and a semi-structured interview. The organization of this chapter begins with Section 6.1 where the demographics of the participants is analyzed. This is followed by the analysis of task specific questionnaires data in Section 6.2. Data obtained from Observations and Video recordings are presented in Section 6.3. The data obtained from semi-structured interview is presented in Section 6.4. Finally, in Section 6.5, the summary of the results are presented.

6.1 PARTICIPANTS' DEMOGRAPHICS

All the participants were in the age group of 20-32. The mean age was 25 and the median was 26 with 20 as minimum and 32 as maximum. There were 4 female and 20 male participants. Four out of 24 participants were Undergraduate students and the remaining were graduate students. Two of the 24 participants were non-Computer Science students. All of the remaining participants belong to the Computer Science Department. Appendix H contains the full break down of the demographics for all the participants.

In the demographic questionnaire, we asked the participants where they currently search for empty spots (e.g., seats). As shown in Figure 16, participants frequently searched for empty spots in food courts and libraries. The participants rarely searched for empty spots at airports.

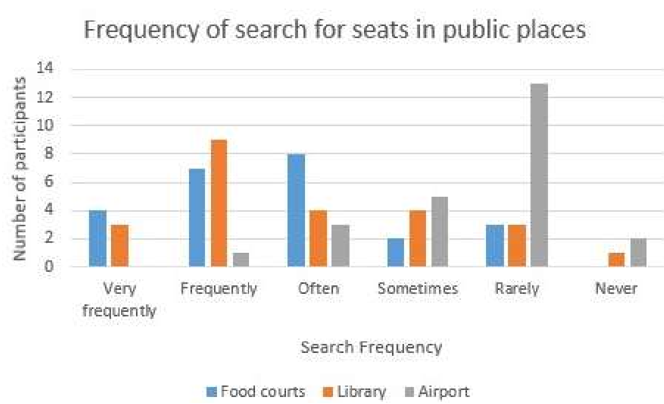


Figure 16 Graph depicting how frequently participants search for seats in public places

Figure 17 shows how frequently the participants use outdoor navigation maps. Based on the responses of the participants, smartphone applications were the most preferred for outdoor navigation. Yelp and Paper maps were seldom if ever used.

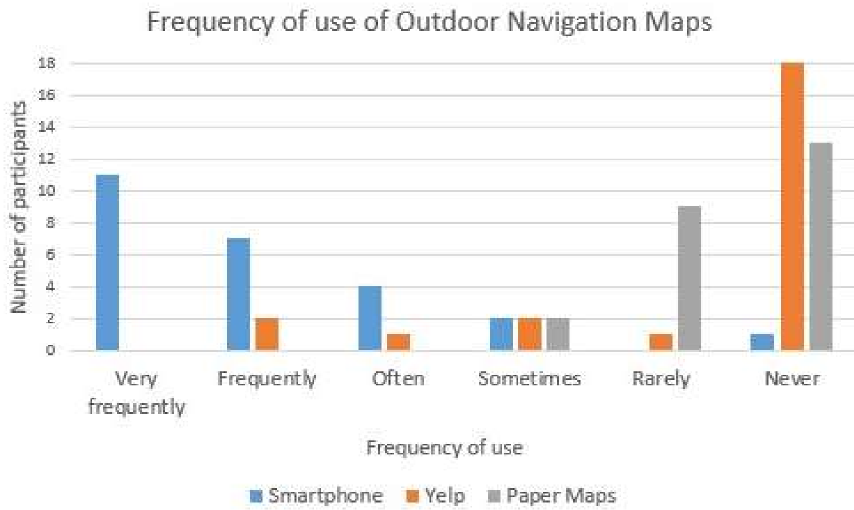


Figure 17 Graph depicting how frequently participants use different outdoor navigation maps

Figure 18 shows how frequently the participants use indoor navigation maps. It is interesting to observe that there are few participants who have used smartphone applications/paper maps for indoor navigation. Most of the participants have never used smartphone applications for indoor navigation.

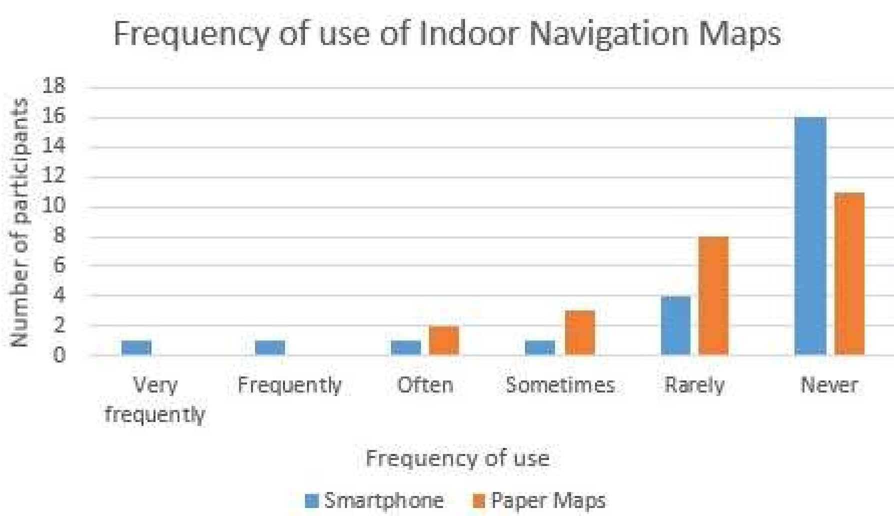


Figure 18 Graph depicting how frequently participants use smartphone applications/paper maps for indoor navigation

Table 9 shows how often the participants have visited the Halifax Public Library since it first opened in December 13th, 2014 [67]. Six participants never visited the library. Thirteen participants have visited between one to five times, while 5 participants have visited up to 10 times. Among all the participants, four were familiar with the layout of the third floor whereas the remaining participants were not familiar.

Table 9 Visits range Vs Number of participants

Visits (since opening)	Number of participants
0 visits	6
1-5 visits	13
6-10 visits	5

6.2 TASK QUESTIONNAIRES

As discussed in Section 5.5.3.2 participants were given two sets of questionnaires after the completion of four tasks (Appendix C). These questionnaires contained same questions and the participants were asked to answer them based on their experience during locating an unoccupied spot and navigating to that spot. The responses from the participants were analyzed based on the Interface used, task performed and the scenario they were assigned. The following subsections discuss each of them in detail.

The participants were asked to answer the set of questions in the questionnaire based on their experiences for the following:

i. Interface without landmarks: ‘QUIET’ scenario
ii. Interface without landmarks: ‘ANY’ scenario.
iii. Interface with landmarks: ‘QUIET’ scenario.
iv. Interface without landmarks: ‘ANY’ scenario.

Interface without landmarks: ‘QUIET’ scenario

In Figure 19, we have combined the responses for the questions related to how easy it was for to locate and navigate to a quiet empty single seat or group of seats using the interface with no landmarks.

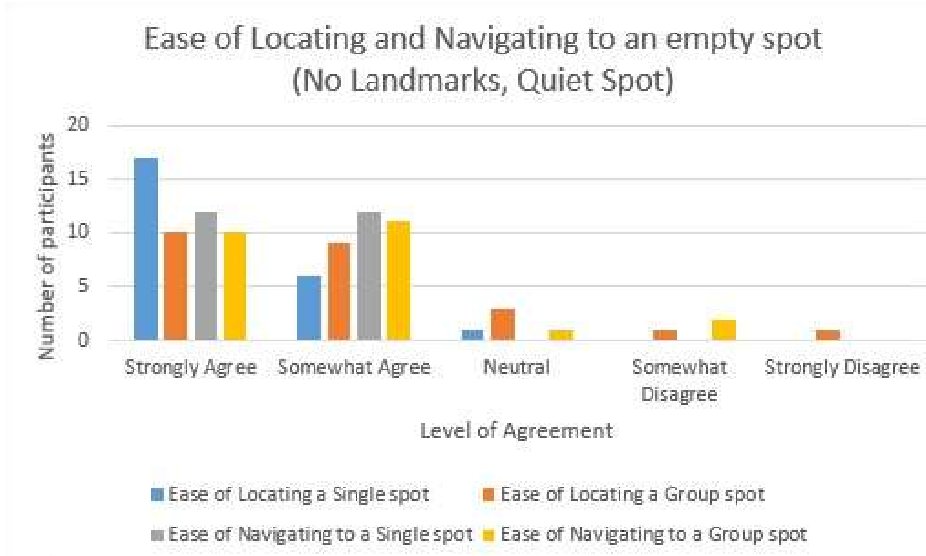


Figure 19 Ease of locating and navigating to a quiet spot (single and group) using the Interface without Landmarks

The average response (where 5 represents Strongly Agree) for locating a single seat in a quiet area was 4.66, navigating to single seat was 4.5, locating a group spot was 4.08 and navigating to group spot was 4.20. Seventeen of the 24 participants found using the application easy to locate single spots whereas only 10 of 24 participants found it easy for locating group spots. The responses for navigating to both single and group spots are almost equally distributed between ‘Strongly Agree’ and ‘Somewhat Agree’. There were two participants who did not find it easy to locate group spots. Also there were two more participants who did not find it easy to navigate to the located group spot using the application.

Only three participants said that the seat/seats they were trying to locate were occupied by the time they got there. These three participants were not able to find a spot for the ‘Single’ task and there were no participants who were not able to find a spot for the ‘Group’ task, in their first attempt. Of the three participants who could not find a spot for the ‘Single’ task, two participants (P1 & P14) were able to find another spot in their next attempt but participant P10 made two more attempts to find one.

Interface without landmarks: 'ANY' scenario

In Figure 20, we have combined the responses for the questions related to how easy it was for to locate and navigate to any empty single seat or group of seats using the interface with no landmarks.

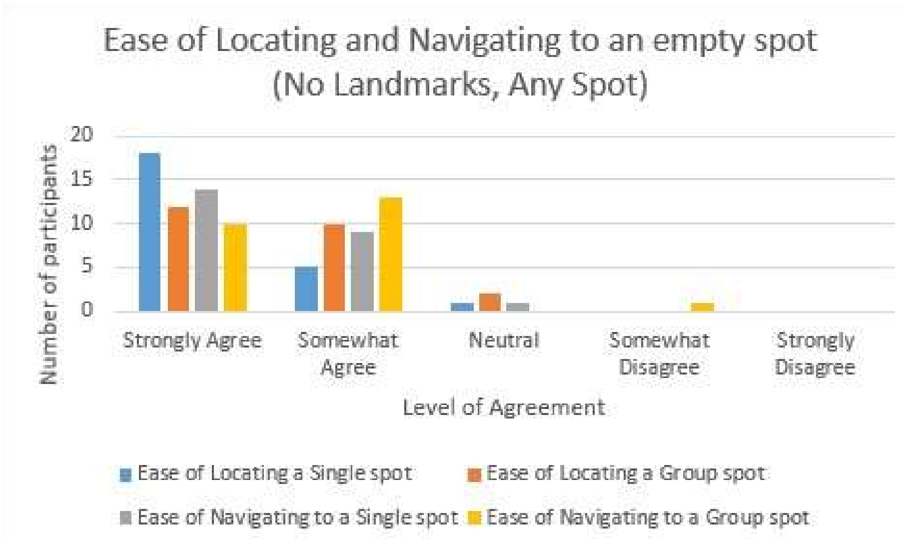


Figure 20 Ease of locating and navigating to any spot (single and group) using the Interface without Landmarks

The average response (where 5 represents Strongly Agree) for locating a single seat in a quiet area was 4.70, navigating to single seat was 4.54, locating a group spot was 4.41 and navigating to group spot was 4.33. Eighteen of 24 participants found using the application easy to locate single spots whereas only 12 of 24 participants found it easy for locating group spots. Fourteen of 24 participants found using the application easy to navigate to the located single spots whereas only 10 of 24 participants found it easy for navigating to the located group spots. There was one participant who did not find it easy to navigate to the located group spot using the application.

Only four participants said that the seat/seats they were trying to locate were occupied by the time they got there. These four participants were not able to find a spot for the 'Single' task and one participant was not able to find a spot for the 'Group' task, in their first attempt. Of the four participants who could not find a spot for the 'Single' task, three participants (P1, P14, & P18) were able to find another spot in their next attempt but participant P10 made two more attempts to find one. Participant P17 took one extra attempt to find a spot for the ‘Group’ task.

Interface with landmarks: ‘QUIET’ scenario

In Figure 21, we have combined the responses for the questions related to how easy it was for to locate and navigate to a quiet empty single seat or group of seats using the interface with landmarks.

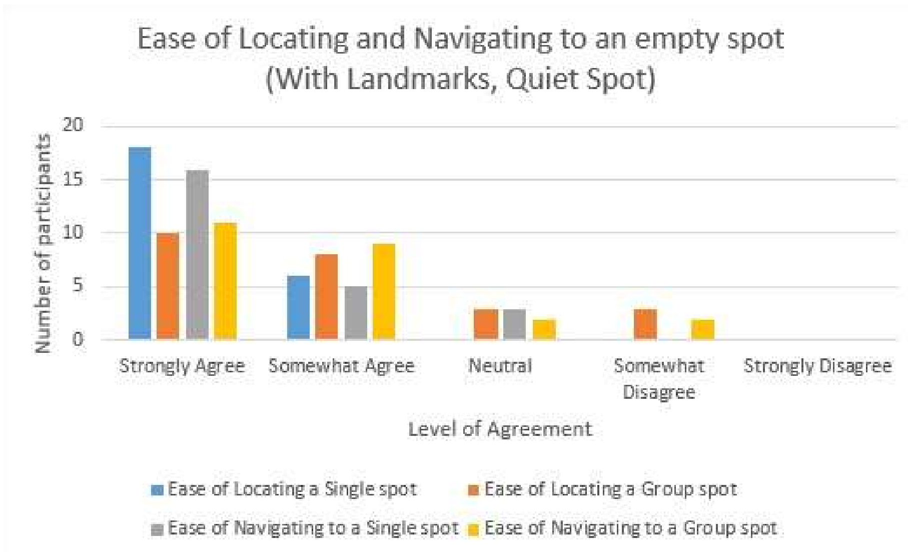


Figure 21 Ease of locating and navigating to a quiet spot (single and group) using the Interface with Landmarks

The average response (where 5 represents Strongly Agree) for locating a single seat in a quiet area was 4.75, navigating to single seat was 4.54, locating a group spot was 4.04 and navigating to group spot was 4.20. Eighteen of 24 participants found using the application easy to locate single spots whereas only 10 of 24 participants found it easy for locating group spots. The responses for navigating to group spots are almost equally distributed between ‘Strongly Agree’ and ‘Somewhat Agree’. There were few participants who did not find it easy for locating and navigating to the group spots.

Only one participant said that the seat/seats he was trying to locate was occupied by the time he got there. That one participant was not able to find a spot for the ‘Single’ task and four participants were not able to find a spot for the ‘Group’ task, in their first attempt. Of the four participants who could not find a spot for the ‘Group’ task, three participants (P3, P8, & P23) were able to find another spot in their next attempt but participant P10 made two more attempts to find one. Participant P1 took one extra attempt to find a spot for the ‘Single’ task he was assigned to.

Interface with landmarks: ‘ANY’ scenario

In Figure 22, we have combined the responses for the questions related to how easy it was for to locate and navigate to any empty single seat or group of seats using the interface with landmarks.

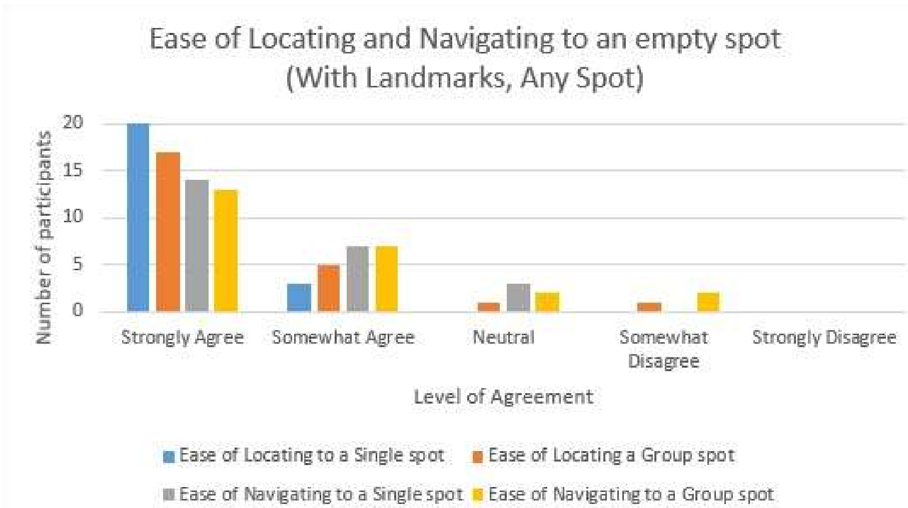


Figure 22 Ease of locating and navigating to any spot (single and group) using the Interface with Landmarks

The average response (where 5 represents Strongly Agree) for locating a single seat in a quiet area was 4.87, navigating to single seat was 4.45, locating a group spot was 4.58 and navigating to group spot was 4.29. Twenty-one of 24 participants found using the application easy to locate single spots and 17 of 24 participants found it easy for locating group spots. Fourteen of 24 participants found it easy to navigate to the located single and group spots. Seven participants opted for ‘Somewhat Agree’ for navigating to the located single and group spots. There was one participant who did not find it easy to locate the group spot and two participants who did not find it easy to navigate to the located group spot.

All the participants were able to find a spot for the ‘Single’ task and only two participants were not able to find a spot for the ‘Group’ task, in their first attempt. Of the two participants who could not find a spot for the ‘Group’ task, participant P5 was able to find another spot in his next attempt but participant P10 made two more attempts to find one.

6.3 OBSERVATION/VIDEO DATA

While participants performed the tasks, observations of their behavior were noted on paper. As well, as a backup to the observation notes, we video recorded the participants. Once the study was complete, all the paper observations were transcribed and were labeled according to similar and distinct behaviors. The video was used mainly as a backup when notes were not clear. All the observations made for each participant are listed in Appendix I.

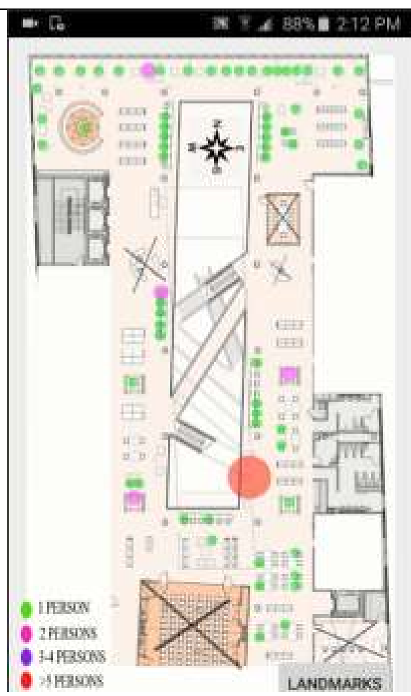
For both ‘Single’ ‘Any’ and ‘Single’ ‘Quiet’ scenarios, 17 participants opted for spots near windows/corners. Only if those spots were occupied, they looked for other available single spots. This behavior though varied for Group Tasks. Table 10 shows the choice of group seats by participants.

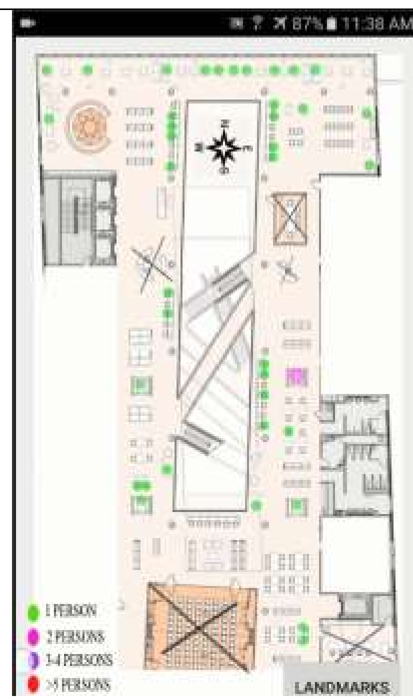
Table 10 Choice of Group seats

Choice of group spots	**Any**		**Quiet**	
	Without Landmarks	**With Landmarks**	**Without Landmarks**	**With Landmarks**
Specific group spots	7	9	10	11
Join chairs and made group spots	16	14	13	11

Overall, nineteen of 24 participants chose to join the chairs and make them group spots for the “Any” scenario whereas only 11 of 24 participants opted for separate group spots such as cabins, round discussion table etc. Similarly, in the case of “Quiet” scenario, 13 out of 24 participants chose to join chairs and create group spots whereas 12 participants chose separate group spots.

From the video data and screen capture data, it was observed that during the study, some of the participants encountered a more crowded study environment (Figure 23a) while for the others, the study environment was relatively less crowded (Figure 23b). Of the total 119 seats available in the study area, the maximum occupancy was never more than 75% of the total seats (i.e. 89 seats) for the study. Hence we decided to set the threshold limit of 50% of the total seat occupancy (i.e. 59 seats) for determining whether the study area was more crowded or less crowded. In short, if more than 59 seats were occupied by the people during the time of study, it was considered as 'More crowded' and if less, it was considered 'Less crowded'. In Figure 23 a) 72 of 119 seats are occupied and thus it is categorized under the 'More crowded' while Figure 23 b) has 39 seats occupied of the 119 seats and is thus categorized as 'Less crowded'. Ten participants did the study when the library was 'More Crowded' and the remaining fourteen participants performed the study when it was 'Less Crowded'.

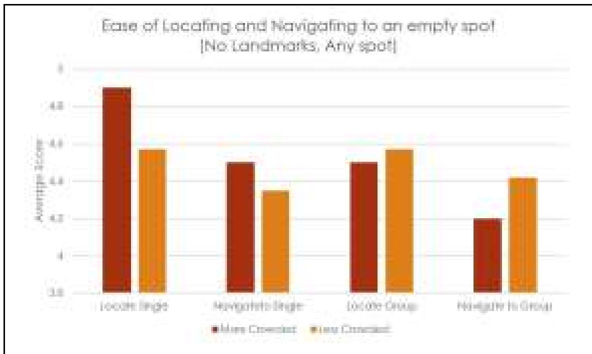




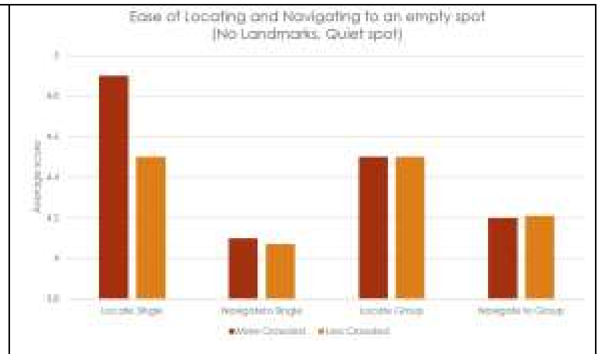
a) 'More Crowded' study environment	b) 'Less Crowded' study environment

Figure 23 Screen capture of 'More Crowded' and 'Less Crowded' study environments

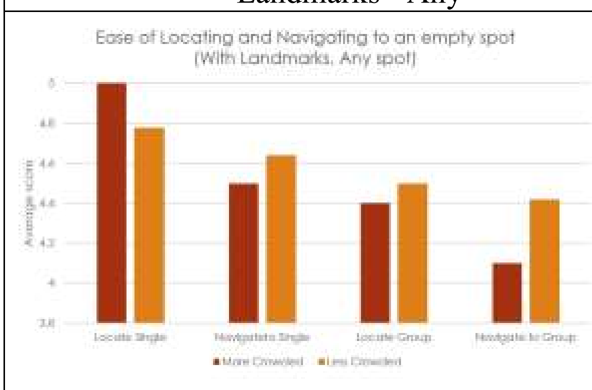
The analysis of the questionnaire data based on 'More Crowded' and 'Less Crowded' is shown in Figure 24. The responses of the participants are categorized based on 'More Crowded' and 'Less Crowded' study environments and it was observed that there was little difference in the average scores in both the cases. It was also observed that the application was more helpful for locating Single spots during 'More Crowded' than the 'Less Crowded' study environment. Irrespective of the crowd in the study environment, ease of locating group spots remained similar.



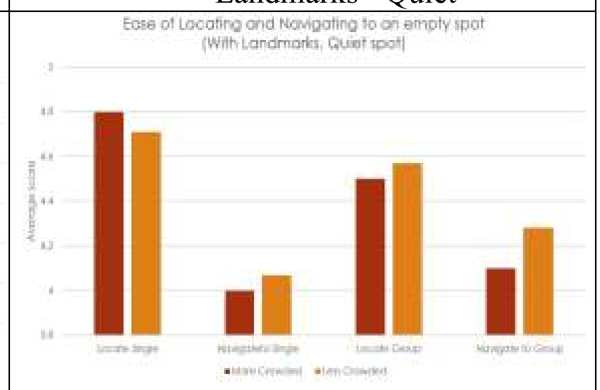
a) Average scores for interface without Landmarks - Any



b) Average scores for interface without Landmarks - Quiet



c) Average scores for interface with Landmarks - Any



d) Average scores for interface with Landmarks - Quiet

Figure 24 Comparison of average scores for More Crowded and Less Crowded days

We analyzed four sample videos and screen captures each of participants who performed the study in "More Crowded" and "Less Crowded" study environments to check the number of times the heat map was not updated by the wizard in comparison with the real environment in the study area. From the videos and screen capture of the participants who performed tasks in the "More Crowded" study environment, there were three cases where the heat map did not match with the real study environment whereas in the "Less Crowded" study environment, there were only two such occurrences as shown in Table 11.

In the case of "More Crowded" study environment, while participant P21 was performing the tasks, there were actually three people sitting on the red circular seat near the window. But the screen capture of the participant's device showed as only one person sitting on that seat. In this case, the participant did not aim for that seat for his task. Similarly, while Participant P4 was navigating to the top row corner seat on the right side for his task of finding Single Quiet spot, that seat was still available as per the heat map. But when he reached the location, one person was actually occupying that seat. He saw the map again and then located another spot for his task. Likewise, while participant P10 was heading to the top row left corner orange seat, the seat was shown as available on the heat map. The map was actually updated just few seconds before he reached that spot. So he did not notice it and made another attempt to locate a seat for his task.

In the case of "Less Crowded" study environment, participant P13 chose the 4-cushion chairs near the conference room for his task of finding Group Quiet spot. But exactly when he arrived at that spot, two people in front of him were just occupying that spot. So the map was not updated in this case. He then located another spot from the map for his task. Similarly, while participant P14 was performing his task of finding Single Quiet spot, two seats on the top right corner were not updated on the heat map. Those seats were actually occupied but the map showed that they were available. But the participant was not actually targeting for those seats for his task.

Table 11 Observations on the accuracy of the wizard

More Crowded		Less Crowded	
Participant ID	Number of errors	Participant ID	Number of errors
P17	0	P13	1
P21	1	P2	0
P4	1	P14	1
P10	1	P23	0

6.4 SEMI-STRUCTURED INTERVIEW

This section focusses on understanding the participants' views towards the application when implemented in real world scenario. For this purpose, the interview questions were categorized into different themes. Each theme is analyzed in the following sub-sections.

6.4.1 Current user behavior when finding unoccupied spots in public places

When we asked the participants how they currently find unoccupied spots in public places such as shopping mall food courts and libraries, their two main responses were "Walking around" and "Eyeballing". "Walking around" refers to moving around the area in search of empty spots. For instance, one participant (P2) described how he walks around a food court mall as "I experienced worst part in malls having food tray in hand and walk until you find an empty spot to sit. It was very difficult to search and also the food becomes cold by that time". "Eyeballing" refers to standing in a location and looking around the area in search of empty seats. P5 described his/her experience with eyeballing as "Just see whichever is nearer to me and go to that place". Table 12 shows the number of participants who opted for each of the two methods mentioned.

Table 12 Mode of search for unoccupied spots

Method	Number of participants
Walking around	22
Eyeballing	2

We asked participant how long they take on average to find empty spots in public places. Table 13, shows their responses regarding how long they often take to search for unoccupied spots during the busy hours. For instance, participant P21 said "I experienced a situation where the mall was overcrowded and I couldn't search for empty spots. So I had to stand and eat". This participant was grouped under ≥30 minutes category.

Table 13 Time taken to search for unoccupied spots

Time (in mins)	Number of participants
<10	10
≥10 and <20	9
≥20 and <30	3
≥30	2

From the responses, ten participants said that they take less than 10 minutes on an average to locate unoccupied spots during busy hours and two participants take more than 30 minutes. Among the rest, nine participants, locate empty spots within 20 minutes and three participants within 30 minutes.

6.4.2 Participants' Opinion about the application

We also asked participants their opinion on the application to help us determine how useful the application was and for suggestions for future iterations on the design of the application. Table 14 lists the top reasons mentioned by the participants for finding the application useful. When questioned about, whether they have found the application useful or not for finding unoccupied spots, one of the participants (P19) said "Usually I don't waste time to go to the spots near windows (even though they are my favorite spots) because I know that it will be definitely occupied. But while using this application, I looked for my favorite window spots and chose those spots if they were unoccupied". Another participant (P21) said "Pretty easy to locate. I can directly go to that place instead of roaming here and there", participant P14 stated "If I am on the one corner of the floor, and I can easily see for the empty spot on the other corner without wasting time and energy" and participant (P10) said "[the application] gives real time data, very useful especially when I want to find spot of my choice". Overall, twenty two participants responded with a 'Yes' and the remaining two participants said 'Somewhat useful".

Table 14 Top reasons provided for finding the application useful

Reasons	Number of participants
Saves time and energy: No need to roam around	6
Very useful in checking the occupancy of hidden spots	3
Easy to locate the empty spots	5
Very useful in busy areas	3
Very useful for searching the desired/favorite spots	2
Shows information on density of people	1

6.4.3 Interface preference

We asked participants their opinion on the two interfaces they used to help us understand which interface or features were preferred by participants. While mentioning the reasons for their preferences, participant P15 said "[the] interface doesn't make a difference because this place is not very big. In cases of big malls etc., landmarks would be better" while participant P12 stated that he liked the interface "…With landmarks, since it contains more information and it is more easy to use" than the interface without landmarks, and participant P8 mentioned "…without landmarks as it is less cluttered, easy to see the floor plan". Table 15 shows count of the participants who preferred the respective interface.

Table 15 Number of participants preferring the respective Interface

Interface	Number of participants
Interface without landmarks	3
Interface with landmarks	13
No Interface preference	8

Of the 24 participants, three participants preferred the interface without landmarks over the interface with landmarks. Thirteen participants preferred the interface with landmarks over the other. There were 8 participants, stated that the interface did not make any difference to them for finding an unoccupied spot. The reasons provided by the participants for choosing the respective interface are as follows;

- Reason for "Interface does not make difference":

    - Do not need any specific landmarks for small areas, only for huge malls, landmarks would be useful.
- Reason for preferring "Without landmarks":
    - Neat and simple
- Reason for preferring "With Landmarks":
    - He/she is new to the place and hence needed landmarks
    - Contains more information and easy to locate

6.4.4 Ease of finding Single/Group seat/s

We asked participants to explain whether they found the application easier to use while finding a single seat or a group of seats. Eighteen of the participants found it easier to use the application to find a single spot while 6 found it about the same for finding both a single or group seat.

When asked the reasons for finding searching group spots difficult, participant P15 said "Group spot was little tricky because from the objects, first of all, you need to figure out the single and group spots and then check the occupancy.", participant P23 stated "seating arrangement is little bit different on the map than in real" and participant P24 stated "There are less group seats in the floor but single seats are available a lot". Among the reasons provided by the participants who did not find it easy to search for group seats using the application, the top reasons are presented in Table 16. Some participants misunderstood the objects on the map such as CD racks and book shelves as seats. While some of the participants felt that the seating arrangement in the study area was not appropriate for group discussions, others felt that there were relatively less number of spots for group discussions.

Table 16 Top Difficulties of Finding a Group of Seats.

Reason	Number of participants
Objects on the map were confusing	7
Seating arrangement in the library was not favorable for group	4
Only less number of group spots are actually present	4

6.4.5 Suggestions & Improvements

Participants had several suggestions for improving the proof of concept application used in the study. These suggestions classified into six themes as presented below:

1. Navigation feature and automatic orientation (17 of 24 participants' suggestions)
    - The application should have a self orienting feature which would re-orient itself based on the users' movement. It would track the user with a small cursor navigating over the map to display when and where that particular user was moving.
2. Highlight the unoccupied seats (2 of 24 participants' suggestions)
    - Along with the existing feature of displaying the densities of the locations, there should be an additional feature or option where the application shows only the unoccupied spots hiding the density of people on the map.
3. Filtering option for the unoccupied seats (3 of 24 participants' suggestions)
    - The unoccupied seats should be filtered from the occupied ones and on the press of a button, it should clearly display the seats designated for groups of people and the seats designated for single persons.
4. Show recommendations for most occupied areas (6 of 24 participants' suggestions)
    - Recommendations should be made regarding the areas on the floor which tend to be busier or more preferred by the users. These recommendations should be based on data which the application accumulates.
5. Pinch and Zoom feature (4 of 24 participants' suggestions)
    - The interface should be facilitated with the pinch and zoom feature in order to be able to zoom into the objects more clearly if needed.
6. Alert when the selected spot is vacated (1 of 24 participants' suggestions)
    - One participant suggested that the user should be notified with a message when a desired spot is vacated.

6.4.6 Application areas

The participants noted several areas where they felt that this application could be used. They are listed below;

- University campuses
- Conference
- Cinema halls
- Airport lounge /Ferry terminals
- Sports stadiums
- Hospitals
- Over crowded buses
- Pubs/bars/Restaurants
- Public Parks
- Parking spots
- Theme parks
- Exhibitions
- Concerts

6.5 DISCUSSION

Among the 24 participants, 20 were not familiar with the layout of the third floor. During the study, six participants visited the library for the first time. The participants in the study were interacting with a mobile application, which they believed was autonomous, but in reality another researcher (the 'wizard') was updating the application in the background. From the results of the demographic questionnaire, it is observed that participants frequently search for unoccupied spots in places like libraries and food courts.

In Figure 25, we looked at the ease of locating and navigating to single seats and groups of seats by their average according to each interface and each scenario (Quiet, Any). On the whole, whether it was the Quite scenario or Any scenario, participants found using the application easier for locating single spots than group spots.

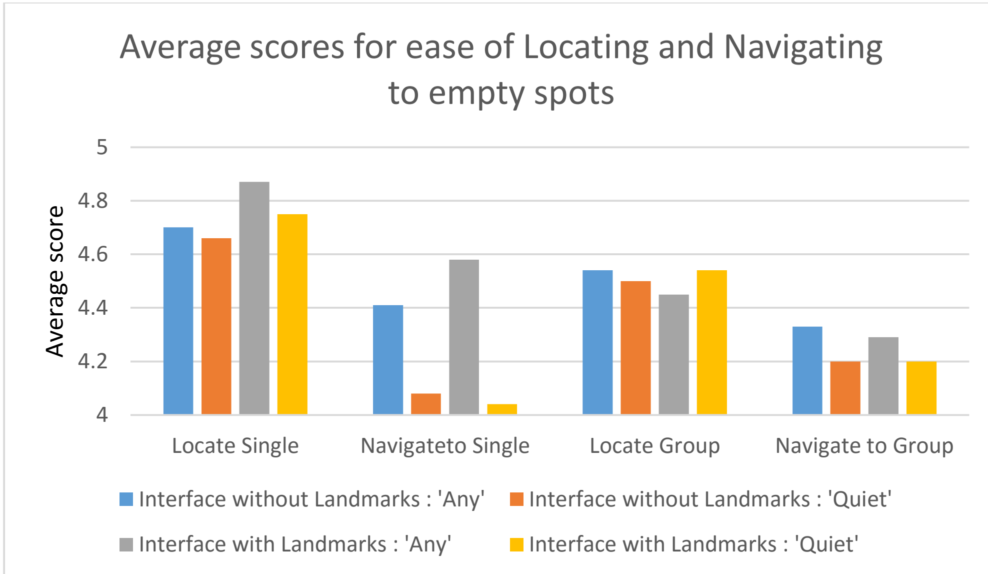


Figure 25 Average scores for ease of Locating and Navigating to empty spots

In addition, it was found that, irrespective of the scenario (Quiet, Any), participants found it easy to locate single spots using the Interface with landmarks when compared to that of the Interface without landmarks. Irrespective of the interfaces and scenarios, ease of locating a group spot was rated lower than single spots. Amongst the responses recorded for Navigating to the located spot, navigation during the 'Any' scenario was found to be easier in comparison with navigation during the 'Quiet' scenario in both 'Single' and 'Group' tasks. The navigation for the 'Single' task under the 'Quiet' scenario was found to be less easy than that of the 'Group' task but the navigation for the 'Single' task under the 'Any' scenario, it was found to be easier to do than the 'Group' tasks. Overall, when compared to locating the spots, navigating to the located spots was not as easy as just locating a spot.

The participants' responses on navigating versus locating a spot on the questionnaire data was also observed during the study and was reiterated from the participants in the interview. The drop in the ease of use for the navigational task may have been due to the lack of the orientation and navigation feature in the application. From the observation data, seats which were mostly preferred by the participants for the 'Single' 'Quiet' tasks were usually located in the corners of the study area that were hard to see due to the pillars and book shelves. Also, the arrangements of the chairs in the study area was altered by the public and hence the location of some of the spots was not matching with those on the interface displayed on the application. Hence, a drop in the ease of use for navigating to the quiet single spots was observed. From the responses of the semi-structured interview, participants found it more difficult to search for group spots than single spots because there are only few spots in the entire floor which could accommodate groups of people. Also, finding group spots was tricky as the participants had to distinguish on the map between the seating areas from the CD shelves, book shelves etc.

To summarize, most of the participants were not familiar with the study area and also most of them frequently search for unoccupied spots in public places like libraries and food courts. In general, the participants preferred utilizing the interface with landmarks over interface without landmarks. Searching for a spot under the 'Any' seat scenario where the participant has no restriction in determining his/her choice with the seat, was found to be easier than finding seats under 'Quiet' scenario. Also searching for a single spot was relatively easier than searching for a group spot/s using the application. Additional navigation features such as user tracking was most often requested by the participants.

CHAPTER 7 CONCLUSION AND FUTURE WORK

7.1 CONCLUSION

The objective of this research work was to provide users with a mobile application which could help them identify the unoccupied spots in public places like libraries, food courts and airports without installing any extra hardware in the vicinity. For this purpose, an android application was developed which would use an indoor localization technique to identify the location of the device and display their locations. The mobile application sends the Wi-Fi signals to a server which locates the device using the Wi-Fi Fingerprinting technique. The server plots the locations of the devices and generates a heat map which is sent to the mobile device by which the users can identify the unoccupied spots. The application displays the density of the devices present in a particular location. The presence of a device is assumed to be the presence of a person. In essence, the application displays a heat map to the user from which they can clearly identify the unoccupied spots.

Table 17 shows the limitations of the related existing applications. The most common limitation in each of the applications is the lack of mobile access where, by mobile access, we mean the accessibility of the application to the user. In our proposed approach, the user can see the updates irrespective of his location with the condition that he/she is within the vicinity of the access points. But in other applications, the user is bound to the condition that he has to come to the entrance of the food court/ library to check for the seat availability if in case he/she wants to go to another spot because the availability is displayed only on a single screen/LED board at the entrance. The next common limitation is the use of floor maps. The existing applications display only the layout of the seats but our application displays the seats' locations along with the other objects like elevator and stairs present in the indoor area. Automatic refresh refers to the update of seat availability in real time without requiring any triggers from the user. Among the existing applications, Library Seat Availability Checking System [70] requires the user to manually update the seat occupancy by clicking on the buttons on the Kiosk representing the seats.

Table 17 Comparison of the related applications with our application

Applications	Identification of Empty seats	No Requirement for Additional Hardware	Automatic refresh	Mobile Access	Use of Floor map
LEDTrayable [69]	√	x	√	x	x
Queen's Library Occupancy tool [47]	x	x	√	x	x
Library Seat Availability Checking System [70]	√	√	x	x	x
Find A Spot [our proposed approach]	√	√	√	√	√

A user study was conducted at the Halifax Central Library to understand how helpful the application was to identify the unoccupied spots. Since installing the application on all the devices in a public place was infeasible, Wizard of Oz technique was used to simulate the mobile application. The user feedback was collected with the help of a post-study questionnaire and a semi-structured interview.

From the user feedback, it was found that people frequently search for unoccupied spots in public places assuring that there is a need for such applications. Also from the observations and responses of the participants about the application, participants found it is easy to locate the unoccupied spots using the application. But navigating to those spots was not as easy as locating them since the application lacked enough orientation and navigation features. Searching for a spot under the 'Any' seat scenario where the participant had no restriction in determining his/her choice with the seat, was found to be easier than searching for a spot under 'Quiet' scenario. In addition, the application was found to be easier to use while locating single spots than that of group spots since the study area had less spots which could accommodate group discussions. Also, finding group spots was tricky as the participants had to distinguish on the map between the seating areas from the other library structure such as CD shelves and book shelves. It was also observed that participants found using the interface with landmarks more intuitive than the one without the landmarks.

7.2 LIMITATIONS

The following are the limitations of the proposed approach:

- Since the application is installed on mobile devices, the presence of a device is necessary to display a spot as occupied. For instance, if a person receives a call and he walks away from the spot to answer the call, leaving his belongings behind, the application would identify the spot as unoccupied.
- The localization precision determines the resolution of the heat map.
- All the devices must be connected to the Wi-Fi at all times. If a device fails to connect to the Wi-Fi, it neither receives the updates nor is plotted on the heat map. Thus Wi-Fi signals must be available everywhere in the intended area.

Following are the limitations of the user study design:

- The heat map used in the study was generated based on the Wizard of Oz technique which might have hid some of the issues and/or challenges that had been generated using a proposed approach with true entities and subjects.
- The population was small and all were students. Also most students were Computer Science majors which represents a more technically advanced group.
- Unfortunately, in the study design, we did not consider the alternative ordering for 'Single' and 'Group' since our focus was on evaluating the helpfulness of the application to locate unoccupied spot under different scenarios using different interfaces.
- The study population was not very familiar with the study vicinity. Further study with participants who are familiar with the study area may show additional data.

7.3 FUTURE WORK

Towards the goal of improving the application, navigation and orientation features would be possible add-ons to the existing application. We aim at using average RSSI values instead of a single value to improve the localization precision. We also plan to conduct more studies using the actual application in order to understand the differences in requirements in different public settings.

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Appendix A: Recruitment Notice

We are recruiting participants to take part in a study to observe how users navigate large spaces to find unoccupied areas using an indoor tracking app. We are recruiting participants from the Dalhousie community who have experience using a Smartphone. Participants should be comfortable walking around with the mobile device for about 20-25 minutes. No technical expertise is required.

The study will be conducted in the Halifax Central Library. You will be provided with a Smartphone to use during the study. You will be videotaped while you perform some navigation tasks in the library using the app on the Smartphone. Participants will finish by filling in a questionnaire and giving an interview to find out what they think about the app.

The entire study will take approximately 45-60 minutes and participates will be compensated $10(CDN) in the study.

This study will take place in a public space and therefore we cannot guarantee your anonymity; however, all your data will be treated anonymously and confidentially by not associating your name with any data collected.

If you are interested in participating, please contact Anitha Kumar by email at AnithaKumar@dal.ca.

Appendix B: Informed Consent

Project title: Find A Spot: using Heat Maps to represent indoor space availability

Principal Investigators: Anitha Kumar, a graduate student at Faculty of Computer Science, AnithaKumar@dal.ca

Contact Person: Anitha Kumar, Faculty of Computer Science, AnithaKumar@dal.ca
Supervisor: Dr. Srinivas Sampalli, Faculty of Computer Science, srini@cs.dal.ca
Co-Supervisor: Dr. Bonnie MacKay, Faculty of Computer Science,bmackay@ca.dal.ca

Introduction:
We invite you to take part in a research study being conducted by Anitha Kumar, a student at Dalhousie University as part of my computer science degree program. Your participation in this study is voluntary and you can withdraw from the study at any time. Your decision of taking part in the study or withdrawing will not impact your employment or performance evaluation. The study is described below in detail. It includes all the risks and benefits you might face during the study. You should discuss any questions you have about this study with Anitha Kumar (AnithaKumar@dal.ca). The other researcher, Sridhar Matta will be assisting the principle investigator in videotaping the participant's movements while performing the tasks.

Purpose:
This research study aims at helping users locate unoccupied areas in public spaces, such as seats in the libraries, food courts etc.

Who Can Take Part in the Research Study:
The population for the study will be composed of Dalhousie community who use Smartphones. Participants should be comfortable walking around with the mobile device for about 20-25 minutes while being videotaped.

What You Will Be Asked to Do:
The study will be conducted in the Halifax Central Library. First, you will meet the researcher, where the study will be explained in detail and you will be asked for an informed consent and you will fill in a background questionnaire. After this, the researcher will give you a Smartphone with an application installed and you will be shown how to use the application to locate unoccupied areas in the library.
You will then be given four tasks and asked to perform these tasks using the application. You will be videotaped while you perform these tasks and the Smartphone will log your interactions with the device and will screen capture this as well.
At the end of the study, you will in fill in a post-study questionnaire, followed by a short interview.

At the start of the study, you will give consent, fill in the demographic questionnaire and take part in a quick demonstration of the app. You will then perform four tasks (for example, to find a free spot in the library to study) using two different interfaces. At the end of the study, will fill in a questionnaire and take part in an interview. The whole study should take 45-60 minutes to complete.

You will be compensated $10 for participating in the study; you can withdraw from the study at any time without consequence.

This study will take place in a public space and therefore we cannot guarantee your anonymity; however, all your data will be treated anonymously and confidentially by not associating your name with any data collected. All personal and identifying data will be kept confidential. Anonymity of textual data will be preserved by using pseudonyms. All data collected in the logs, questionnaires, video, and interviews will use pseudonyms (e.g., an ID number) to ensure your confidentiality. The informed consent form and all research data will be kept in a secure location.

Possible Benefits, Risks and Discomforts

There is a low risk that you may become frustrated or embarrassed while performing the tasks during the study but there is a researcher available during the study to answer any questions. If you feel uncomfortable at any time of the study, you are free to withdraw. There is no direct benefit to the participants but we may learn more about how to present indoor tracking information to help users locate less populated areas.

If you have any concern about your participation or any other aspect of the research you may contact Catherine Connors, Director, Office of Research Ethics Administration at Dalhousie University's Office of Human Research Ethics for assistance: phone: (902) 494-1462, email: catherine.connors@dal.ca.

"I have read the explanation about this study. I have been given the opportunity to discuss it and my questions have been answered to my satisfaction. I hereby consent to take part in the study. However, I understand that my participation is voluntary and that I am free to withdraw from the study at any time."

Participant	Researcher
Name: ________________________________	Name: ______________________________
Signature: _____________________________	Signature: ____________________________
Date: ________________________________	*Date:* ________________________________

"*I understand and consent that my participation in the experiments will be video recorded for the purpose of analysis. I understand that this is a condition of participation in the study, and I understand that this video recording will not be used in publication or presentation of results.*"

Participant Researcher

Name: ________________________________ Name: ______________________________

Signature: _____________________________ Signature: ____________________________

Date: ________________________________ *Date:* ________________________________

"*I agree to let you directly quote any comments or statements made in any written reports without viewing the quotes prior to their use and I understand that the anonymity of textual data will be preserved by using pseudonyms.*"

Participant Researcher

Name: ________________________________ Name: ______________________________

Signature: _____________________________ Signature: ____________________________

Date: ________________________________ *Date:* ________________________________

☐ *"I want to read direct quotes prior to their use in reports and I understand that the anonymity of textual data will be preserved by using pseudonyms."*
[if this option is chosen, please include a contact email address: ______________________________]

If you are interested in seeing the results of this study, please check below and provide your email address. We will contact you with publication details that describe the results.

☐ *"I would like to be notified by email when results are available via a publication."*
[if this option is chosen, please include a contact email address: ______________________________]

Appendix C: Task Questionnaire

PID: _______
Interface: _______
Task Group ID: _______

Please circle the rating that best describes the statement:

Please respond to the following statements using the given scale (circle response):

1	*2*	*3*	*4*	*5*
Strongly Disagree	*Somewhat Disagree*	*Neutral*	*Somewhat Agree*	*Strongly Agree*

SPECIFIC FEATURE QUESTIONS						
1.	It was easy to locate/find on the map, a single unoccupied seat.	1 Strongly Disagree	2 Somewhat Disagree	3 Neutral	4 Somewhat Agree	5 Strongly Agree
2.	It was easy to locate/find on the map, a group of unoccupied seats.	1 Strongly Disagree	2 Somewhat Disagree	3 Neutral	4 Somewhat Agree	5 Strongly Agree
3.	It was easy to navigate to this particular single seat using the mobile application.	1 Strongly Disagree	2 Somewhat Disagree	3 Neutral	4 Somewhat Agree	5 Strongly Agree
4.	It was easy to navigate to this particular group of seats using the mobile application.	1 Strongly Disagree	2 Somewhat Disagree	3 Neutral	4 Somewhat Agree	5 Strongly Agree
5.	The single seat was still unoccupied when I reached the location.	Yes		No		
6.	If not, then how many times did you need to search for a seat?	1 Time	2 Times	3 Times	4 Times	_______ If others, Specify the Number of times.
7.	The group of seats were still unoccupied when I reached the location.	Yes		No		
8.	If not, then hoe many times did you need to search for the seats?	1 Time	2 Times	3 Times	4 Times	_______ If others, Specify the Number of times

Appendix D: Semi-structured interview

1. How do you search for unoccupied seats in public places such as libraries or shopping mall food courts?
2. Did you find the application useful to locate the unoccupied tables in the library? How or how not?
3. How was this application's map helpful in giving you the information about the locations and availability of seats?
4. Which interface did you find better? Why?
5. Amongst Single and Group tasks, for which one did the application seem easy to use?
6. How did you deal with the situation where you found out a particular spot as occupied although the map was displaying it as unoccupied?
7. When or where else would you see this mobile application useful?
8. What possible changes/improvements would you suggest for this application? What additional features can be added to the existing application?
9. Imagine that you are the owner of a store or a librarian, what are the added features would you wish to see in this application?

Appendix E – Demographic Questionnaire

1. What is your age?

2. Gender: (Place a Tick [✓] Mark)
____ Male ____ Female ____ Other

3. Enrollment in Dalhousie: (Place a Tick [✓] Mark)
____ Under-graduate Student
____ Graduate Student
____ Faculty
____ Staff
____ Alumni

4. If you are a Student, which program are you enrolled in at Dalhousie?

5. How often do you look for empty seats or spots in the following locations?

	Very frequently (daily)	Frequently (4-5 times a week)	Often (2-3 times a week)	Sometimes (5-6 times a month)	Rarely (2-3 times a year)	Never
Food courts in malls						
Library						
Airport						
Others: ______________________						

6. How often do you use the following to help you navigate outdoors?

	Very frequently (daily)	Frequently (4-5 times a week)	Often (2-3 times a week)	Sometimes (5-6 times a month)	Rarely (2-3 times a year)	Never
Google maps/ bing maps/ other smartphone map application						
'yelp' on smartphone						
Paper maps						
Others:						

7. How often do you use the following to help you navigate indoors?

	Very frequently (daily)	Frequently (4-5 times a week)	Often (2-3 times a week)	Sometimes (5-6 times a month)	Rarely (2-3 times a year)	Never
Google indoor maps/ apple ibeacon/ other smartphone map application						
Paper maps						
Others:						

Appendix F - Participant Payment Receipt

My signature below confirms that I received a sum of $10 (CDN) cash from Anitha Kumar as an honorarium payment for participating in the "Find A Spot: using Heat Maps to represent indoor space availability" research project.

I understand this honorarium is taxable income and it is my responsibility to claim it on my income tax as Dalhousie University will not be issuing a T4A for this payment.

Name (please print): ________________________________

Signature: ________________________________

Date: ________________________________

Appendix G – Social Sciences & Humanities Research Ethics Board Letter of Approval

DALHOUSIE UNIVERSITY
Research Services

Social Sciences & Humanities Research Ethics Board
Letter of Approval

June 24, 2016

Anitha Kumar
Computer Science\Computer Science

Dear Anitha,

REB #: 2016-3860
Project Title: Find A Spot: using Heat Map to represent indoor space availability

Effective Date: June 24, 2016
Expiry Date: June 24, 2017

The Social Sciences & Humanities Research Ethics Board has reviewed your application for research involving humans and found the proposed research to be in accordance with the Tri-Council Policy Statement on *Ethical Conduct for Research Involving Humans.* This approval will be in effect for 12 months as indicated above. This approval is subject to the conditions listed below which constitute your on-going responsibilities with respect to the ethical conduct of this research.

Sincerely,

Dr. Karen Beazley, Chair

Appendix H – Demographics of the Participants

PARTICIPANT ID	AGE	GENDER	Department
P1	26	M	MACS
P2	26	M	MACS
P3	27	F	MCS
P4	25	M	MCS
P5	28	M	MCS
P6	23	M	MACS
P7	31	M	MCS
P8	20	M	CS
P9	24	F	MACS
P10	25	M	MACS
P11	27	M	MACS
P12	22	M	MACS
P13	24	M	MCS
P14	32	M	PhD CS
P15	23	F	MCS
P16	22	M	Chem Eng.
P17	26	F	MCS
P18	21	M	CS
P19	27	F	CS
P20	25	M	MCS
P21	27	M	MACS
P22	24	M	MEng.
P23	24	M	CS
P24	26	M	CS

Appendix I – Observation Data

ID: Participant ID
I1: Interface without landmarks
I2: Interface with landmarks
SQ: Single-Quiet scenario
SA: Single-Any scenario
GQ: Group-Quiet scenario
GA: Group-Any scenario

ID		I1				I2			
		SQ	SA	GQ	GA	SQ	SA	GQ	GA
P1	Choice of seats	Red round table	Cushion near window	Cabin	4-cushion chairs	Chair near stairs	Cushion near conference room	4-cushion chairs	Joined chairs
	Desired seat was occupied	No	No	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	No	No	No	No	No	No	No	No
P2	Choice of seats	Chair near washroom	Chair near stairs	Cabin	Joined chairs	Cushion near conference room	Cushion near window	Cabin	Cabin
	Desired seat was occupied	No	No	Yes	No	No	No	Yes	Yes
	Looked at the device while walking to the navigated spot	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
P3	Choice of seats	Cabin	Chair near elevator	Joined chairs	Joined chairs	Cushion near window	Chair near elevator	-	Chairs near conference room
	Desired seat was occupied	No	No	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	yes	no	No	no	No	yes	Yes	yes
P4	Choice of seats	Chair near stairs	Computer chair	Red round table	Chairs near washroom	Chair near conference room	Computer chair	Chairs near conference room	Chairs near washroom
	Desired seat was occupied	No	No	No	no	no	no	No	No
	Looked at the	Yes	Yes	Yes	yes	yes	yes	Yes	yes

	device while walking to the navigated spot								
P5	Choice of seats	Cushion near window	Red round table	-	Joined chairs	Cushion near window	Cushion near window	Red round table	Chairs near conferen ce room
	Desired seat was occupied	No	No	No	no	No	No	No	No
	Looked at the device while walking to the navigated spot	No	No	No	no	no	no	yes	no
P6	Choice of seats	Chair near washroo m	Chair near elevator	Joined chairs	Chairs near conference room	Chair near elevator	Cushion near window	Chairs near elevator	Joined chairs
	Desired seat was occupied	No	no	No	No	No	No	No	no
	Looked at the device while walking to the navigated spot	Yes	yes	Yes	yes	Yes	Yes	Yes	yes
P7	Choice of seats	Chair near elevator	Chair near elevator	4-cushions near conferen ce room	Joined chairs	Chair near conferen ce room	Cushion near window	Joined chairs	4-cushions near conferen ce room
	Desired seat was occupied	No	No	No	no	No	No	No	no
	Looked at the device while walking to the navigated spot	Yes	Yes	Yes	yes	Yes	Yes	Yes	Yes
P8	Choice of seats	Chair near stairs	Cushion near window	Joined chairs	Red round table	Chair near stairs	Cushion near window	4- cushion near conference room	Joined chairs
	Desired seat was occupied	No	No	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	Yes	Yes	Yes	Yes	No	No	No	No
P9	Choice of seats	Cushion near window	Red round table	4-cushion near conferen ce room	Joined chairs	Chair near stairs	Cushion near conference room	Joined chairs	-
	Desired seat was occupied	No	No	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	No	No	No	No	No	No	No	No

P10	Choice of seats	Chair near washroom	Cushion near window	Joined chairs	Joined chairs	Chairs near washroom	Cushion near window	Joined chairs	Joined chairs
	Desired seat was occupied	No	Yes	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	No	No	No	No	Yes	Yes	No	Yes
P11	Choice of seats	Cushion near window	Cushion near window	Joined chairs	Red round table	Cushion near window	Cushion near window	Joined chairs	Red round table
	Desired seat was occupied	No	No	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	No	No	No	No	No	No	No	No
P12	Choice of seats	Cushion near window	Cushion near window	Joined chairs	Joined chairs	Cushion near window	Cushion near window	Red round table	Red round table
	Desired seat was occupied	No	No	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	No	No	No	No	No	No	No	No
P13	Choice of seats	Chair by the corner near the window behind the big circular seat near the wall	Cushion near the window on the right corner of the first row from the map	Last set of table near the book shelf at the bottom of the floor.	Last set of table near the book shelf at the bottom of the floor.	Chair near the window on the right corner of the first row from the map	Cushion near the book shelves on the top behind the first row of seats	Last set of table near the book shelf at the bottom of the floor.	Last set of table near the book shelf at the bottom of the floor.
	Desired seat was occupied	No	No	No	No	No	**No**	No	No
	Looked at the device while walking to the navigated spot	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
P14	Choice of seats	Chair near the window on the right corner of the first row from the map	Chair by the corner near the window behind the big circular seat near the wall	Cushions near the conference hall	Set of tables near the room 302	Chairs near the conference hall	Chair near the window on the right corner of the first row from the map	Cushions near the conference hall	Last set of table near the book shelf at the bottom of the floor.
	Desired seat was occupied	No	No	No	No	No	No	No	No

	Looked at the device while walking to the navigated spot	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
P15	Choice of seats	Chair near the window on the right corner of the first row from the map	Table beside the cubicle and near the washroom	Red circular seat	Table beside the cubicle and near the washroom	Chair near the window on the right corner of the first row from the map	Chair near the window on the right corner of the first row from the map	Table beside the cubicle and near the washroom	Table beside the cubicle and near the washroo m
	Desired seat was occupied	No	No	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	Yes	Yes	**Yes**	Yes	Yes	Yes	Yes	Yes
P16	Choice of seats	Orange seat near the top right corner of the floor near window	Cushion near the book shelves on the top behind the first row of seats	Big circular seat	Big circular seat	Chair near the window on the right corner of the first row from the map	Chair near the window on the right corner of the first row from the map	Big circular seat	Big circular seat
	Desired seat was occupied	**No**	**No**	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	Yes	Yes	Yes	Yes	No	Yes	yes	yes
P17	Choice of seats	Chair by the corner near the window behind the big circular seat near the wall	Computer seat near the washrooms	Last set of table near the book shelf at the bottom of the floor.	Big circular seat	Cushion near window	Cushion near window	Cabin	Joined chairs near elevator
	Desired seat was occupied	No	no	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	Yes	yes	yes	yes	Yes	Yes	Yes	Yes
P18	Choice of seats	Cushion near window	Cushion near window	Cabin	Joined chairs near stairs	Cushion near widow	Cushion near window	Joined chairs near elevator	Joined chairs near elevator
	Desired seat	No	No	No	No	No	No	No	No

	was occupied								
	Looked at the device while walking to the navigated spot	Yes	No	No	Yes	Yes	Yes	Yes	Yes
P19	Choice of seats	Chair by the corner near the window behind the big circular seat near the wall	Chair near the window on the right corner of the first row from the map	Last set of table near the book shelf at the bottom of the floor.	Last set of table near the book shelf at the bottom of the floor.	Chair near the window on the left corner of the first row from the map	Chair near the window on the left corner of the first row from the map	Last set of table near the book shelf at the bottom of the floor.	Chairs on the top row near the window
	Desired seat was occupied	No	No	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	Yes	Yes	Yes	Yes	No	No	No	Yes
P20	Choice of seats	Chair near the top left corner near the bigger seats	Chair near the window on the first row from the map	Cushions near the conferen ce hall	Cubicle near the women washroom	Chair near the top left corner	Red circle seat	Last set of table near the book shelf at the bottom of the floor.	Cushions near the conferen ce hall
	Desired seat was occupied	No	No	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
P21	Choice of seats	Chair near the window on the first row from the map	Table beside the CD rack towards the bottom end of the floor.	Table beside the cubicle towards the bottom end of the floor map	Table beside the cubicle towards the bottom end of the floor map	Table beside the cubicle and near the washroo m	Chair near the window on the first row from the map	Table beside the cubicle near the washroom	Table beside the cubicle near the washroo m
	Desired seat was occupied	No	No	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
P22	Choice of seats	Chair by the corner near the window	Chair near the top left corner near the bigger seats	table beside the CD rack and the	Table beside the cubicle towards the bottom end of the floor	Chair near the window on the right	Chair near the window on the first row from	Join chairs to the table beside the cubicle near the	Join chairs to the Table near the washroo

		behind the big circular seat near the wall		cubicle towards the left bottom corner of the floor	map	corner of the first row from the map Near the wall	the map	desktops	m
	Desired seat was occupied	No	No	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
P23	Choice of seats	Chair near the window on the right corner of the first row from the map Near the wall	Chair near the window on the right corner of the first row from the map	Table beside the cubicle towards the bottom end of the floor map	Table beside room 302, beside the book shelf	Chair by the corner near the window behind the big circular seat near the wall	Chair near the window on the first row from the map	Chairs near the railing towards the bottom end of the floor map.	Table beside the cubicle towards the bottom end of the floor map
	Desired seat was occupied	No	No	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	No	No	Yes	Yes	No	No	Yes	No
P24	Choice of seats	Chair by the corner near the window behind the big circular seat near the wall	Chair near the window on the first row from the map	Join chairs and use the table beside the CD rack.	Table near the washroom	Chair near the window on the left corner of the first row from the map	Chair near the window on the first row from the map	Table beside room 302, beside the book shelf	Join chairs and use the table beside the CD rack.
	Desired seat was occupied	No	No	No	No	No	No	No	No
	Looked at the device while walking to the navigated spot	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes