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Submitted by:

Rida Mahmood 2016-CE-54

Tooba Naseer 2016-CE-72

Rabeya Hamood 2016-CE-81

Ayesha Jabbar 2016-CS-159

Supervised by:

Dr. Shiekh Faisal Rasheed

Department of Computer Science and Engineering

University of Engineering and Technology

Lahore Pakistan

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Internal Examiner	**External Examiner**
Signature:	Signature:
Name:	Name:
Designation:	Designation:
Chairman	**Dean**
Signature:	Signature:
Prof. Muhammad Ali Maud	Name:

Department of Computer Science and Engineering

University of Engineering and Technology

Lahore Pakistan

Declaration

I declare that the work contained in this thesis is my own, except where explicitly stated otherwise. In addition this work has not been submitted to obtain another degree or professional qualification.

Signed: _____

Date: _____

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Abbreviations

LAH	**L**ist **A**bbreviations **H**ere
FP	**F**inger **P**rints
BLE	**B**luetooth **L**ow **E**nergy
RSSI	**R**educed **S**ignal **S**trength **I**ndicator
GPS	**G**lobal **P**ositioning **S**ystem
TOA	**T**ime **O**f **A**rrival
TDOA	**T**ime **D**ifference **O**f **A**rrival
AOA	**A**ngle **O**f **A**rrival
IR	**I**nfrared **R**adiations
TOF	**T**ime **O**f **F**light
CNN	**C**onvolution **N**eural **N**etwork
ARM	**A**dvance **RISC** **M**achine
AP	**A**ccess **p**oint
LAN	**L**ocal **A**rea **N**etwork
dbm	**d**ecibles **p**er **m**inute
MACAddress	**M**edia **A**ccess **C**ontrol Address
ML	**M**achine **L**earning
CSV	**C**omma **S**eperated **V**alues
KNN	**k**- **N**earest **N**eighbours
RF	**R**andom **F**orest
ANN	**A**rtificial **N**eural **N**etworks
API	**A**pplication**P**rogram **I**nterface
SIFT	**S**cale **I**nvariant **F**eature **T**ransform
PCA-SIFT	**P**rincipal **C**omponent **A**nalysis **SIFT**

SURF	**S**peeded **U**p **R**obust **F**eature
LSH	**L**ocality **S**ensitive **H**ashing
SVM	**S**upport **V**ector **M**achine
NB	**N**aive **B**ayes
SDLC	**S**oftware **D**evelopment **L**ife **C**ycle
IR	**B**

Abstract

The Thesis Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too...

Chapter 1

Introduction

1.1 Introduction

1.1.1 Overview of Project

Outdoor and indoor localization is an integral component of IoT (Internet of Things) in this era of mobile computing. Indoor localization can open new horizons for ubiquitous applications targeting university departments, government small institutes, software houses, airports, shopping malls, museums etc. Our project will find the location of a specific person by using appropriate machine learning approach using BLE based Android application. This location will be used to provide guided tour of the indoor building (Computer Science and Engineering Department at UET, Lahore) we will use to validate our work.

This project will guide persons who are not much familiar with visiting place. It has an android application that will predict the indoor location of a person at room level and also gives information of current room location and nearby rooms in the form of text, images, audio and videos. In our case visiting place will be CSE dept at UET LHR. For room prediction, RSSI fingerprints of BLE beacons will be captured for training of model. After finding the location of the person, guidelines of that certain room/area will be provided to the user on user end Android application. Indoor positioning has numerous applications. We can use indoor positioning of people to guide them inside shopping malls, airports or museums.

Indoor positioning systems can be broadly classified into two main parts: Systems that need some infrastructure which are further categorized into those which needs ad-hoc deployment like BLE beacons and systems which takes profit of previously

installed infrastructure like WiFi fingerprinting technique. Those technologies which do not need any infrastructure deployment are based on magnetic field fingerprinting. Ad-hoc deployment can be initiate in new areas where there is need to save environment from magnetic rays or in those areas where WAPs are weak so we choose to detect indoor location using BLE beacons.Also, BLE based indoor localization is wireless, consumes low power because it works on battery and mostly available in smart mobile devices.

BLE can be used from two different approaches: trilateration [20] and fingerprinting [21], [22]. In tilateration relationship between the user's RSSI measurement and its distance to the BLE beacon station is considered. By estimating distances to multiple beacon stations, the user's location can be predicted using a least square algorithm. The fingerprinting approach is implemented in two phases: an ofliine phase and an online phase. The ofline phase is called the training phase. During this phase, fingerprint RSSI values are determined of every beacon from each device location. The online phase is known as the localization phase which is the actual prediction of the user's device location.

1.1.2 Background

Outdoor localization has been formalized by using satellite-based technologies i.e. GPS[3], BeiDou[12], GLONASS[12], and GALILEO[2]. It is hard for finding the indoor location by using conventional GPS technology because of no direct (Line of Sight)[9] in indoors, so we cannot use these technologies for indoor positioning. Up to date, the technologies used for indoor localization approach are: TOA (Time of Arrival), TDOA (Time Difference of Arrival), AOA (angle of arrival) but they have some limitations. TOA and TDOA require precise clock count and its synchronization and AOA-based systems require special antennas for their propagation. By keeping in view the evergreen trend of engaging users towards something is through mobile computing.So, there exists some systems which used magnetic rays, time of arival of specific signals, some used WiFi based localization and also deployed on Apple and Android smart phones but due to coherence and interference of different signals in determining the RSSI of fixed WAPs, crucial errors occurred. By analyzing these calculations, we are able to avoid multiiteration(which predict location of device by determining the distance between the AP and mobile device) and capture fingerprints from multiple mobile devices.

The indoor positioning system which we are using is communicating with hardware device so we require a technique which translates the signal into a location. There are three categories to transform this: proximity, geometric and scene analysis,.

Proximity methods create zones and assigns the users location when they enter that zone. Geometric method uses signal measurements from device locations and put them in geometrical equations to predict the location but scene analysis method measures the signal from different refence points by standing at one location and then predicts location by passing that fingerprint to trained model which is called fingerprinting technique. A fingerprint is a collection of signals received at a certain location in the scene, in this way they aim to make the fingerprint location specific, such fingerprints are often based on the RSSI values collected from beacons[11].

So, we are going to implement a system which employs suitable machine learning approach to find the location by using RSSI (Received Signal Strength Indicator) fingerprinting technique because there is less hinderance of other signals in using this technique.. This RSSI values will pass to the trained model (a model which is trained on a given set of input and output values by using appropriate machine learning algorithm) which gives the location of the user's mobile device.

1.2 Motivation

People/visitors who go to an unknown place find it difficult to traverse and wants to find places/people of interest easily. Such problems motivate us to provide ease and leverage facility to users so that they can see the information of a particular indoor environment on his mobile application automatically. BLE is available on nearly every smart device so no additional hardware required at user end. Hence by utilizing their indoor location determined using machine learning on BLE fingerprints, guided tours of smart campus to visitors can be provided and facilitating them. We are using latest technology of BLE beacons because they work on battery and consume less energy than Wi-Fi signals[13].

1.3 Objectives of the project

1.3.1 Industry Objectives

- Implement a system that takes into account the demands of university campus exploration.
- This project leads to visitors of any organization or store to save their time and effort by providing them textual and pictorial information of organization or store.
- Administrators seek advantage of their time by providing much information to their customers in less time which automatically increase the sales and

profit of their product.

1.3.2 Research Objectives

- To find the location of the user that will be connected to his Android app via Bluetooth technology[6].
- To monitor and provide guidelines to user who is connected to the BLE beacon via Bluetooth and mobile application, we need to find user location inside buildings.
- To understand the concept of Android application development which provide textual and pictorial information of particular area and its nearby areas to the user who is located in that indoor environment.

1.3.3 Academic Objectives

- This project enables us to understand the concepts of following subjects:
  a. Machine learning
  b. Networking
  c. Android development
  d. Front-end design
  e. Client server communication management
- To complete a whole real world project , utilizing concepts from computer networking, databases, machine learning, software development life cycle of SE , testing and mobile development.
- To develop the understanding and connection between the Android app and the hardware structure.
- To find the best Machine Learning algorithms which are used to train the model of fingerprints.
- To make an Android application which use as an interface to provide guidelines to the user who is located in a particular indoor environment.
- To ensure the use of latest technologies in implementing the project which helps technical persons and students to enhance their academic skills via learning new features

1.4 Scope of the project

In this project, android application runs on a users mobile device and and will capture BLE RSSI fingerprints. The fingerprints collected at the initial stage will be processed and used to train suitable machine learning model, after training of the ML based location prediction model, based on the room prediction relevant information of nearby rooms, facilities and personnel available will be prepared to be displayed to user at run time , the user will be guided to install our Android app on their phone, their mobile device will capture BLE fingerprint and the fingerprint will be sent to back end server where our trained model will predict their current location inside building in terms of room[7]. The relevant information will be delivered and shown on user mobile device providing guided tour. The placement of Bluetooth low energy beacons will be held in CSE dept at UET Lahore.

1.5 Target Audience

Targeted audience will be the:

- Visitors of the University campus
- New Students and Staff of the campus

1.6 Possible Applications of work

The possible application of work for our project are as follows:

- Software house information (Development, QA, Frontier)
- Airport assisting system
- University Campus smart information system
- Government small Institutes
- Medical departments exploration in hospitals

Chapter 2

Literature Review and Problem Statement

2.1 Description and scope of the related literature

This study aimed to focus on detailed analysis of existing literature related to our project that includes literature review of indoor and outdoor localization techniques, their performance, their contributions and their shortcomings.

In recent times, indoor localization can open new horizons for fascinating and useful applications targeting university campuses, government institutes, airports, shopping malls, museums etc. We can provide different kinds of information by using indoor location of the person. This will be extremely beneficial not only in university campus but also in airports and shopping malls. Shopping malls can use this kind of application by providing much information to their customers in less time which automatically increase the sales and profit of their product. But our purpose is that to provide the ease to the users who visit our department. Our project can be extensible to other areas where it can provide huge benefits to the businesses. But we are specifically focused on providing guidance to the visitors of our department. In this way our project will be used as a guidance tool.

Our project is innovative in the sense that we use indoor location of a person by providing him/her smart guided tour of our department but mostly existing systems uses indoor location of a person for different purposes like providing assistance to older age people. We are not interested in their purposes, but we have great interest in existing indoor localization techniques. So the scope of this literature review will cover all well-known existing indoor localization techniques.

But before going on detailed study of indoor localization, we have to study about outdoor localization in order to find how they work and why we cant use outdoor localization technique in indoor environment and then we delve into indoor localization techniques.

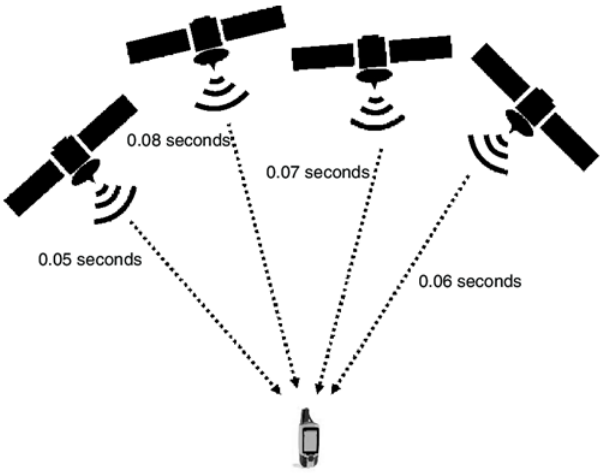
2.2 General findings and availability of the literature

As I stated, that mostly existing systems uses indoor location of a person for different purposes like providing assistance to older age people. But there exist a research[10] that presents a mobile campus tour application based on augmented reality in various universities and the features of application are the information about points of interest, location search and navigation, but it provides outdoor locations of large university campus using GPS, because it is not based on room level prediction and information about indoor locations. But the huge literature related to indoor localization presented various indoor techniques and analysis of their performance measures is available on internet in which we are interested.

2.3 GPS Outdoor Technology

GPS (which is known as Global Positioning System) is the satellite navigation system. It is used for outdoor localization. It tells us where you are on the earth. It retrieves information of time and position where you are on the earth in all weathers. GPS was developed by United States military in 1960 and it is used in next few decades.First of all, it is used for civilian purpose. Today, we use GPS in many technological devices such as GIS device, mobile phones and many watches. The area of application of GPS includes land, space, air and marine. The GPS system is made up of 5 ground stations and 24 satellites where each satellite placed in precise orbit at an altitude of 10,900 miles [4]. As we all know, we used GPS as outdoor locating services. It receives signals from at least three satellites and uses triangulation and trilateration technique which is used to calculate the position of the object. It calculates the distance of a receiver from each satellite where distance is calculated by time it takes for a radio wave to reach the receiver end. GPS can be used in any type of weather and it also provides timing information. Here is the illustration of how GPS works.

GPS does not work in indoor location because of no direct line of sight in indoor area. Here are some limitations:



- GPS signals carry waves at a frequency that is scattered by solid objects usually by buildings and walls.
- Actually, satellites sent the signals that are not easily penetrate all kinds of barriers.
- When signal enters into the building, then it gets distorted due to construction material such as wood, bricks, cements etc because it serve as hindrance to the satellite signal.[5]

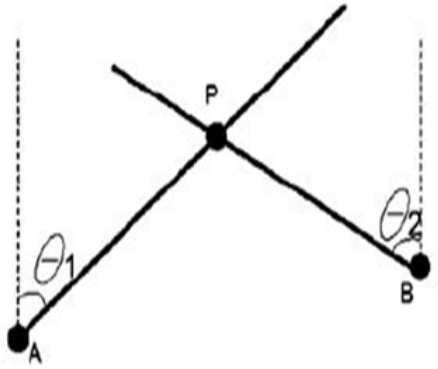
  Hence, we cant use outdoor localization technology like GPS in indoor environment.

2.4 Indoor Localization Techniques

Indoor localization techniques become popular day by day because it can provide ubiquitous location based services to people. Indoor positioning systems consist of a network of transmitters used for locating persons inside buildings. Here are the popular approaches:

2.4.1 Triangulation

Triangulation technique uses the geometric properties of triangles in order to find the position of the object. In triangulation, AOA (Angle of Arrival)[15] technique is used to measure the angle and distance relative to two or multiple fixed points through the intersection of direction lines between the fixed points and then this information is used to calculate the position of transmitters which in turn describes the actual location of object. In other words, position of target object is determined by the intersection of direction lines. Here is the illustration of this technique.



Drawbacks of Triangulation

This method achieves good results outdoors but it gives weak results inside the building because the radio signals emitted by transmitters get attenuated by several obstacles hence it gives poor estimation of distance calculated. Moreover hardware requires special antennas for signal propagation and hardware requirement for the coverage of large area tends to be expensive and complex[15]. When the area becomes large with multiple reference points, accuracy will decreases due to some errors in the estimation of distance calculated.

2.4.2 Trilateration

Trilateration is also used to estimate the position of object using geometric properties of triangles. The position of target object is determined by TOA (Time of Arrival) and TDOA (Time difference of arrival) [15]. TOA is used to estimate the position of target object by calculating the time taken by a signal to reach the receiver from transmitter. TDOA is the improved version of TOA that considers the difference in TOA at two different receivers and then finds the relative position of transmitter based on the difference which further used to estimate the location of target object. This results in higher accuracy.

Drawbacks of Trilateration

The cost and complexity of hardware is high and it does not give good enough estimates in indoor area because of the inherent error of the distance measure calculations, hence most results have several meters of error[12]. The accuracy is also affected by environmental conditions. In order to get good results both transmitter and receiver require precise clocks that should be synchronized.

2.4.3 Proximity

Proximity technique is also used to estimate the location of target object. It requires a grid of antennas with known locations. When mobile device is detected

by more than one antenna, then the antenna with the strongest signal is used to calculate its position. The position of target object (mobile device) is determined by using RSSI (Received Signal Strength Indication) to estimate the distance between mobile devices in order to get the position information of device.

Drawbacks of Proximity

Although proximity is applied on the systems using Bluetooth, IR but it requires calibration effort[15]. Also, we need larger spread of readers in order to achieve a reliable system but it increases system complexity and cost.

2.4.4 Fingerprinting technique (Our Selected Approach)

Fingerprinting technique is based on pattern matching technique. It is used to create signal strengths database that are based on the RSSI (Received Signal Strength Indication) values of various APs. These values are collected at different locations of an experimental area. These are called fingerprints, then by applying any machine learning approach we can train the model which further uses to predict the location of target user. Fingerprinting technique has a better positioning performance and accuracy as compared to the others and it doesnt require any software or hardware modifications at transmitters end.

Here are the **indoor positioning technologies** which uses mostly any of method described above to predict location:

1. Infrared (IR) positioning systems

This system consists of a network of IR sensors that are linked by wires and then connected to a centralized server. Early badge system uses IR sensors for determining the position of object or people who is wearing badge. Active Badge system uses IR sensors and TOA approach for estimating the location. Theses sensors are cheap and have good battery life. But the problem is that people have to wear the badge. This problem is solved by using IR thermal sensors[15] that uses the thermal rays emitted from human body for the prediction of location. Because we know that the temperature of human body is differs from room temperature.

Drawbacks of IR positioning systems

We need larger number of IR sensors to cover the large area which in turn increases system complexity and cost. Also these systems have limited accuracy. Thermal IR sensors also have major drawback that human body is not only the source of heat, there are also other heat sources like electronic devices and light bulbs that could affect the signals received from thermal IR sensors.

2. Ultrasonic positioning systems

This system contains ultrasonic sensors that emit ultrasonic signals which are used to estimate the location of object by measuring the TOF (Time of Flight) [8]. The distance between transmitters and receiver is calculated by TOF and then this information is used to estimate the target position.

Drawbacks of ultrasonic positioning systems This system is expensive and difficult to implement and maintain on larger area. Also, the ultrasound signals have low signal propagation speed when compared to speed of light[15]. It also affects by hindrances in indoor environment which in turn reduces its accuracy.

3. Image based indoor localization

It is a visual-based localization method. Early visual based methods require feature detection and matching that require huge computation and also it is affected by environmental conditions. There is a literature that implements this system by different approach. According to this research, firstly we need to build a database that contains collected images of experimental area. CNN (Convolution Neural Network) is used to train the model which is further used to predict the location of target object by inputting it the image of target location.[14]

Drawbacks of image based indoor localization

Clearly, use of camera might be obtrusive for some users. Also time consuming effort is required to build the dataset and it also has scalability issue. Also, if we take image from different point of view which is not present in database, it might be possible that it would be predicted wrongly which in turn results the low accuracy.

4. Zigbee and capacitive sensors

Zigbee sensors [11] are also used for indoor location but they are very expensive and have medium scalability. Capacitive sensors [11] are also used to estimate location by pressure sensing that detects the presence of a person but this system is very impractical to implement and deployment of sensors in floor is expensive.

5. Wi-Fi based indoor localization

In this, we can use either triangulation technique or fingerprinting technique for the estimation of the location of target user. But in triangulation, we require modification and special software to run on Wi-Fi base stations [11]. But fingerprinting technique with Wi-Fi is a good approach for indoor localization because, we didnt need any additional hardware for this system and we can use already deployed infrastructure.

Drawbacks of Wi-Fi based indoor localization

Its main drawback is that it consumes more power. There are some spots where Wi-Fi access points would be difficult to power. There are some areas where Wi-Fi signals are not accessible. [12]

6. BLE beacons based indoor localization (our approach)

After seeing the drawbacks of existing technologies, we decided to find the indoor location of a person using BLE beacons with fingerprinting technique, because it overcomes many drawbacks in existing systems, also they give better accuracy. BLE beacons are Bluetooth low energy beacons. Classic Bluetooth consumes more power than BLE beacons and transmits to long ranges. BLE beacons are small in size, light weight and cheaper then Wi-Fi. BLE consumes less power than Wi-Fi. BLE beacons are usually battery powered, which are more flexible and easier deployed than sensors used by existing systems. BLE signals have higher sample rate than Wi-Fi signals. BLE consumes much less power because it transmits data over the small range [1]. Bluetooth having version greater than 4.0 are BLE. BLE Beacon is a tiny device with a massively used for broadcasting of signals. It has unique ID (MAC Address). A BLE beacon has three major components: ARM computer, a Bluetooth connectivity module and batteries for powering the entire circuit. The antenna is attached to the CPU of ARM computer. It broadcasts electromagnetic waves with specific length and frequency. Here is the internal circuitry of BLE beacon.

Android phones with 4.3 and 4.3+ version support BLE [8], which makes it easy to implement.

Conclusion

As we can see there are many drawbacks in existing systems. In some systems, camera is required for indoor positioning which is obtrusive for some users. High

cost and effort is required for the deployment of indoor localization infrastructure. Triangulation and trilateration proximity techniques require modifications at hardware end (Wi-Fi work stations) for the purpose of these techniques to work. These techniques also didnt give satisfactory results in indoor environment due to the errors in distance measure calculations. Proximity technique also requires calibration effort and it is a costly technique to implement. Fingerprinting technique seems to be most suitable thats why in our proposed system we use this technique. Most of the other existing systems have medium or low accuracy. In image based indoor localization, time consuming effort is required to build data sets. Wi-Fi fingerprinting is relatively better than other systems because of finding position by using already deployed infrastructure. But its main drawback is that it consumes more power. There are some spots where Wi-Fi access points would be difficult to power. So, after analyzing the drawbacks of existing technologies, we find out that BLE beacons with fingerprinting approach is most suitable because of various reasons that I have described above.

2.5 Applications of GPS

There are many applications of GPS which are as follows:

- Machinery and Information Technology for Bio Mass Production
- Mobile Robot Sensors
- Traffic sensing Technologies
- Sensors and computing systems in Smart Clothing
- Radio Navigation Systems

Why we cant use outdoor localization technology in indoor environment?

2.6 Problem Statement

Whenever a visitor goes to university campus or visits a new place, he does not know about the specifications of that area i.e. what happens in that specific room or what courses have been taught in a particular and its nearby labs. So, we are developing a system which assists them in determining the textual and pictorial information of a particular area and its nearby locations. For this purpose, we first find the indoor location of a user by using BLE beacons and RSSI values, and then provide information to him automatically on his Android application.

Chapter 3

Dataset

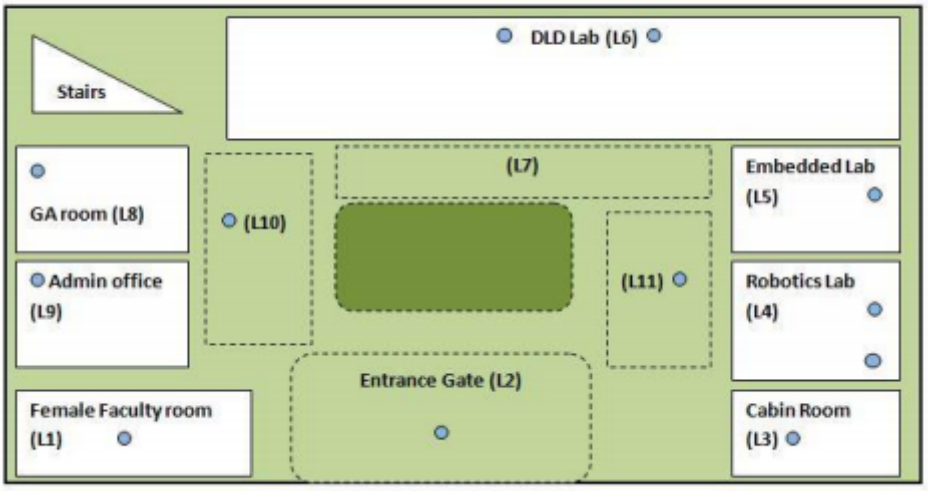
3.1 Dataset Description

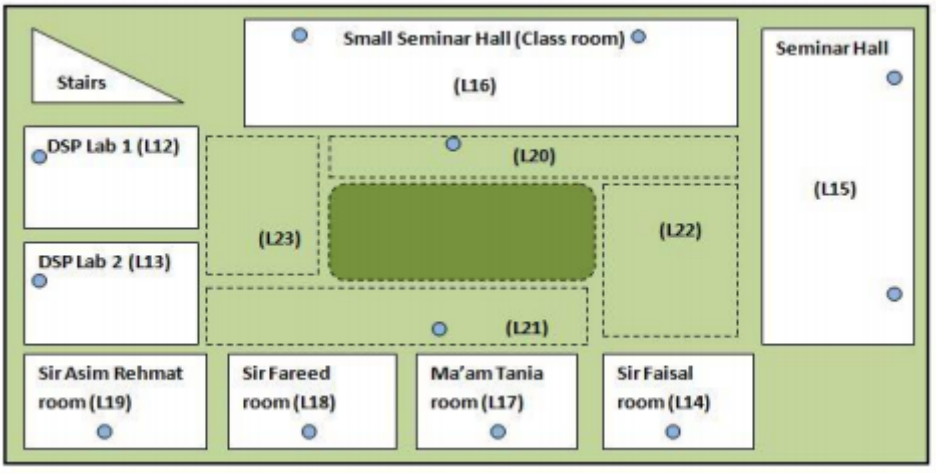
To determine the indoor location of the user, we need a trained model on specific dataset through which we can predict his location. In order to train our model, we gathered dataset which contains the fingerprints of BLE beacons in Computer Engineering Department. Each beacon has its own MAC address which is used for its identificati n. We have total 24 beacons, thats why we have 24 input features and each feature contains the RSSI values of specific beacon associated with that feature, and the output is the labeled name of the location. We have total 23 labels which mean we have total 23 classes hence it is a multiclassification problem. RSSI values ranges from -95dBm (low RSSI far off Access point) to -50dBm (demonstrating high RSSI close to Access point).

L1	RSSI 1	RSSI 2	RSSI 3	• •	RSSI M
L2	RSSI 1	RSSI 2	RSSI 3	• •	RSSI M
• •	• •	• •	• •	• •	• •
Ln	RSSI 1	RSSI 2	RSSI 3	• •	RSSI M

3.2 Experimental Area Description

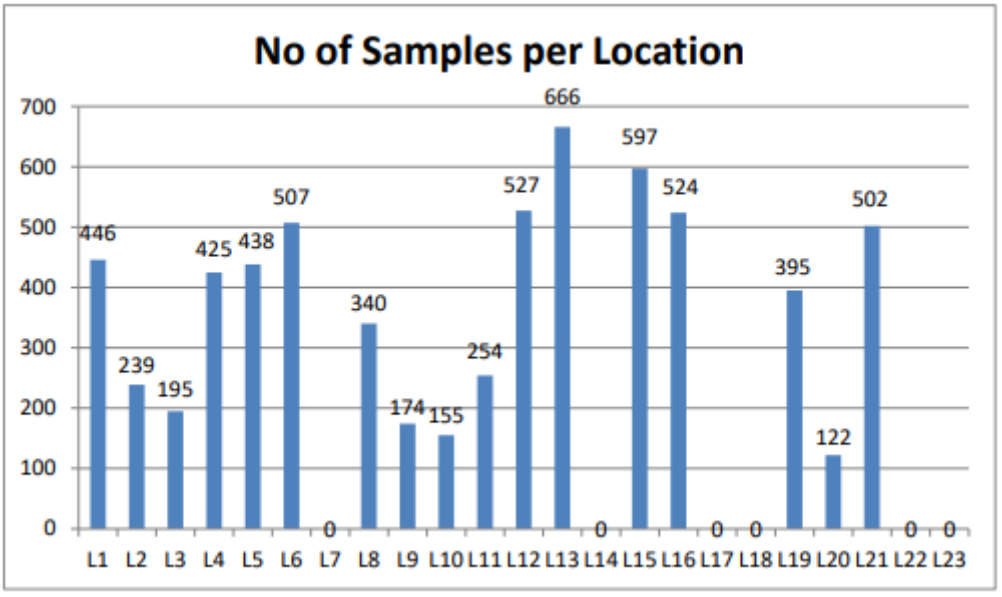
The experimental area that we covered is the Computer Engineering building of UET, LHR. We skip some rooms of that building because they are locked most of the time. The representation of the deployment of beacons in dept is shown in the following figures. Figure 2 represents the ground floor and Figure 3 represents 1st floor of the building. Small blue circle represent BLE beacon. Following figures only represents those rooms that we have considered in our experimental area. Each room is assigned a label as shown in the figures. Corridors are divided into 4 portions. Each portion is represented by a dotted box and assigned a label shown in the figures.





3.3 Collected Dataset

Our collected dataset contains 6500 samples of 18 locations of selected area out of 23 locations. Each location has its own fingerprint RSSI value with respect to certain beacon which depends on different environmental conditions such as distance of device location from the beacon or signal capturing strength of the device. So, we collect samples to predict different locations. The number of samples collected per location is shown in the following figure.



3.3.1 Preparation of data set

When we captured the data, numerous .csv files generated in which each .csv file contain one sample. We used 5 different cell phones for data capturing. Then we compile all the generated .csv files into single .csv file in specific format that we have shown in Figure 1. We discard all those RSSI values of surrounding BLE enable devices which are not from our BLE beacons.

3.3.2 Preprocessing of data

We have done pre-processing on our collected data set. In pre-processing, we have dropped all those rows that have null values in all of their input columns. During data collection some access points are visible, some not hence there were lot of missing values in data set. So, we replace missing values with -100dbm. The reason for replacing the missing values with -100dbm is because it shows extremely weak

signal means it is far off from access point. We have not done normalization on our data set because we didnt find it suitable for our collected dataset.

3.3.3 Performance Measures criterion for the comparison of algorithms

Accuracy is the measurement of model performance. It is calculated as the no of samples correctly classified/ total no of samples.

$$\text{Accuracy}(\%) = \frac{\text{Tp} + \text{Tn}}{\text{Tp} + \text{Tn} + \text{Ep} + \text{Fn}}$$

Precision tells about how accurate your model is out of those predicted positive, how many of them are true positive. Precision is a good measure to determine, when the costs of False Positive is high.

$$\text{Precision} = \frac{\text{Tp}}{\text{Tp} + \text{Fp}}$$

Recall actually calculates how many of the Actual Positives our model captures through labeling it as Positive (True Positive).

$$\text{Recall} = \frac{\text{Tp}}{\text{Tp} + \text{Fn}}$$

For calculation of precision and recall for multi-classification, we can calculate the precision and recall separately for each class. Then we calculate the average precision and recall of all classes and hence we will get the approximate calculation of precision and recall for them.

Chapter 4

Research Methodology and Implementation

4.1 Methodology

4.1.1 Introduction

After the literature review, we conclude that the most of the applications are based on outdoor localization such as GPS. This application only tells the outdoor locations on the maps. When we are out of the building, its only shows the boundaries of the buildings not the rooms. But we want to create an application which tells about the indoor location. This application is based on room level prediction. Its not only tells the room level prediction but also tells the entire information of the room.

The purpose of writing this chapter is to explain the methodology for making this indoor localization based application. We want to tell that which methods and approaches we used to develop this application. We will also explain that which ML (Machine Learning) algorithms are used, how to collect the data, how to analyze data for this application. We also describe the use cases, use case diagram and test cases of this application.

4.1.2 Research Methodology

From the literature review, we conclude that the concept of outdoor localization is introduced on the behalf of GPS. People can access anywhere when he is on the GPS which is installed on every smart phone. But people can only see the boundaries of the building not the rooms of the buildings. They did not know the

entire information of the building. They do not know the concept of indoor localization. People face the problem to know the entire information of the building. For example, when a student enters the University for Admission, he/she did not know the ways of the university. They have to face the problem where is Admin block? Where is library? Where is department? Furthermore, if people enter to the hospital, offices, buildings etc., than they did not know the indoor location of those places. To answer all of these questions, we want to develop the application which tells the indoor location of the building. It not only tells the room name but also tells the entire information of the room. If we talk about the building of the university, then it also tells us the room member name, its office hours etc. We provide this information in the form of texture, audios and pictures.

4.1.3 Proposed Work to develop the Android Application

Actually, we cannot refuse that many indoor applications also developed but they all used different technologies. Most of the indoor applications used Wi-Fi for predict the position of the person that tells the indoor location of that person. But we have to develop the system which tells the indoor location of the person which is based on BLE beacons. BLE beacon is the Bluetooth device which consumes less energy. It is light weight and cheaper than Wi-Fi signals. BLE beacons are usually battery powered, which are more flexible. It is easier to sense the signals. We dont have enough resources to make this application globally. Now, we make this application for our computer Engineering department, UET. To develop this system, we consider the number of points which tells the methods to develop the system that is as follows:

- First of all, we deploy the BLE beacons in our department. BLE beacons will be installed on the ceilings of rooms.
- We capture the RSSI fingerprints of BLE beacons at different position using data capturing. By using this application .csv le will be generated.
- Data will be pre-processed and trained by using machine learning algorithm such as KNN, ANN and random forest.
- After capturing and train the data, we integrate the data with our android application. For this purpose, we made two android applications. One is admin application and the other is user application.

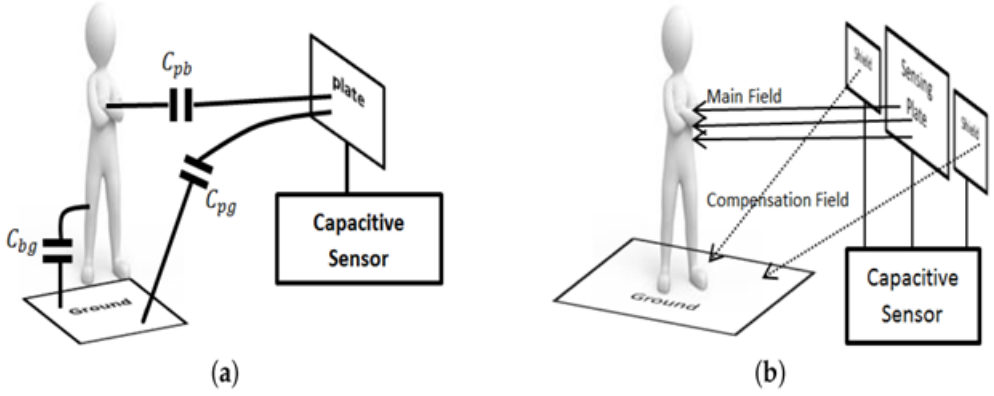
- We made the android admin app to add, edit and delete the data of rooms. We can also add, edit and delete the data of room members. Also, we can add, edit, delete office hours of the room members. We can also add pictures and audio of the room
- At the end, we made the android user application. First of all, we integrate the data using different API. We need to make the API to integrate the data.
- After integration of data, when user reach the room of our department, he/she can see the details of rooms, room members and also see the details of office hours of the room members in the form of texture, audios and pictures.

4.1.4 Related Work

Different Indoor applications are exit. But their functionality is different. One of the indoor applications is Image based indoor localization. The data set of this application is images, image features and annotations. Some of the images features are SIFT, PCA-SIFT and SURF. For capture the image, we have to use omni directional camera. It consists of three wheels tripod stand. But we capture the image from the laptop. System easily covered the wide area. After capture the image, the location of the image is also stored by using the interface. The annotation data consists of (x, y, z) coordinates. It also has the information of room name, floor and show case name for the image. For this Image based indoor localization, they use fast nearest neighbor algorithm that is ANN and LSH (Locality- Sensitive-Hashing). LSH is the nearest neighbor search technique which uses the hash function. It is noticed that LSH is the faster than other algorithms. Here are the some experimental results of this Image based indoor localization. By applying these algorithms, it shows the precision and processing time of each feature.

Feature	Feature extrac-tion	Correspondent point search	Total	Precision
SIFT	1.51s	1.60s	3.11s	91.9%
PCA-SIFT	1.63s	0.56s	2.19s	90.8%
SURF	0.22s	1.54s	1.77s	88.2%

Now we discuss about another application of capacitive sensors based on indoor localization. Capacitive sensing is that technique that tracking the conductive and non-conductive objects. This sensor is able to sense the 3D position of human and their interacting objects. By using this technique, we can find the indoor location of the person by using human-body detection technique. It uses capacitive transducers which operate in 3 modes. But in this case, we use only 2 modes known as shunt mode or transmit mode for the detection of the body. Another scientist introduced the load operation mode. In this mode, human body acts as a potential-plate that is shown in Fig (a). Capacitances used in load mode are Cpb (plate-body capacitor), Cbg (body-ground capacitor) and Cpg (plate-ground capacitor). It is more suitable for deployment. For develop capacitive sensors based application, load operation mode is used.



For develop this system, they also use some algorithms such K-NN (K-Nearest Neighbor), NB (Naive Byes), SVM (Support Vector Machine). To perform the experiment, they have a room in which they place sensor plates of 4cmX4cm. They deploy the sensors on the four sides of the room. After deploy the sensors, they used three algorithms as we explain above. These algorithms used to find the precision and recall of this indoor localization system. The precision and recall are given in table below:

Algorithm	Recall	Precision
1- Nearest Neighbor	52%	53%
56- Nearest Neighbor	51%	50%
Naive Byes	55%	55%
Support Vector Machine	56%	60%

They also perform this experiment with the room having sensor plates of 8cmX8cm. The results of precision and recall are different from the above results. They give

better result than the above. The precision and recall of 8cmX8cm sensor plates are given in table below:

Algorithm	Recall	Precision
1- Nearest Neighbor	45%	45%
56- Nearest Neighbor	65%	65%
Naive Byes	71%	75%
Support Vector Machine	69%	70%

They also perform this experiment with the room having sensor plates of 16cmX16cm. The results of precision and recall are also different from the above results. They give best result than all of the above. The precision and recall of 16cmX16cm sensor plates are given in table below:

Algorithm	Recall	Precision
1- Nearest Neighbor	60%	62%
56- Nearest Neighbor	70%	70%
Naive Byes	71%	74%
Support Vector Machine	69%	72%

Another most important technology, we discuss here. We have to discuss the indoor based localization using Wi-Fi. This application also tells the user to the position of the person where he stands. It also tells the indoor localization of the person. The patterns that connect the different access point of the Wi-Fi which is fixed to the various point and become unique. This pattern is called Wi-Fi finger printing. It consists of Received Signal Strength Indicator (RSSI) values and MAC Address data. RSSI values contain negative numbers. If RSSI values are closest to the zero (0) such as (-5) then It indicates that the signal strength is strong. The data set of this application consists of RSSI value and MAC address. The algorithms of machine learning also apply in this indoor based localization using Wi-Fi application. Due to the large data set. The fastest algorithm is used in this system. The algorithm which is used in this application is deep learning. Meanwhile, the machine learning algorithms such as k-NN, NB, SVM also used for this application. Their precision and recall also shown in table:

Algorithm	Recall	Precision
k- Nearest Neighbor	96.4%	96.4%
Naive Byes	67%	72%
Support Vector Machine	79%	62%
Deep Learning	99.3%	99.3%
Random Forest	99.5%	99.5%

4.1.5 Comparison of Existing Work

Here are the comparisons of some of them

System Type	Methodology	Weakness	Accuracy Achieved
Image based indoor localization	Convolution Neural Network(CNN)	-Time consuming effort required to built data set -Low accuracy	74.09%
By using Capacitive Sensors	Pressure sensing systems that detect presence	-Deployment of sensors in floor is expensive -Impractical	73.01%
By using Zigbee sensors	K- Nearest Neighbors(KNN)	-Expensive -Medium Scalability	76%
By using Wi-Fi	Deep Learning algorithms	-Consumes more power -Wi-Fi signals are not accessible to some areas	71%

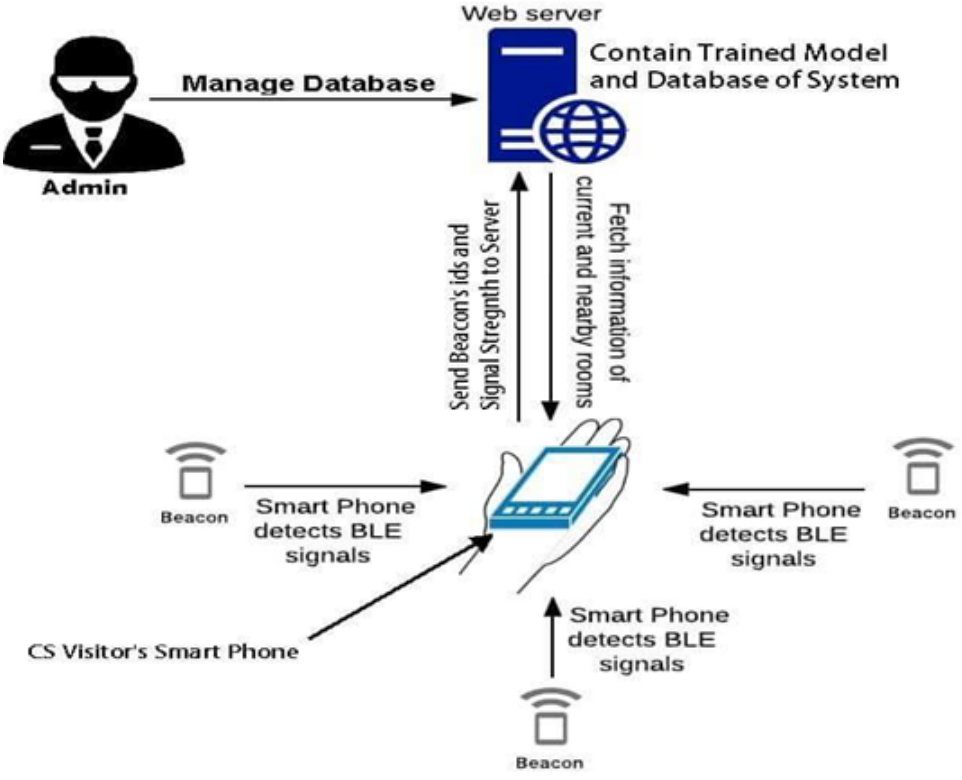
4.1.6 Limitations of Existing System

Here are some limitations of existing system which are as follows:

- In some systems, camera is required for indoor positioning which is not suitable for some users.
- High cost and effort is required for the deployment of indoor localization.
- Most of the existing systems have medium or low accuracy.
- In image based indoor localization, time consuming effort is required for built data sets.
- It consumes more power.
- There are some spots where Wi-Fi access points would be difficult to access.

4.1.7 Software Architecture

Here is our software architecture:



4.2 Software Development Life Cycle Used

To implement a project, one must have to follow some software development life cycle to deliver his project completely according to user requirements in time. By following a certain SDLC, a project developer feels so comfortable as he have specific tasks and time to implement project timely which meets the users point of view. In our project, there are lots of fluctuations time by time. So, we decided to follow AGILE model.

4.2.1 AGILE SDLC

Agile SDLC model is a combination of incremental and iterative process models deals with customer requirements satisfaction and process adaptability by rapid delivery of working product to the customer. This model breaks the whole project in small modules. Do proper testing after completion of each module. Then deliver this working module to the customer and important stakeholders to satisfy them.

If that module doesnt meet their point of views properly or to which customer point of view as he didnt explained in the document, then it has to be iterated to fulfill their new recommendations. And the other perspective is that if the customer wants to add some functionality in that particular module then a developer has to follow an incremental technique to add specific functionalities. To complete each deliverable module of the project, developer has to follow these steps

- Planning
- Requirements Analysis
- Design
- Coding
- Unit Testing and
- Acceptance Testing

Figure : Agile Methodology

4.2.2 Justification for AGILE SDLC

These steps will justify that our project is based on agile methodology:

- All the requirement specifications and the scope of the project is strictly defined in our documentation but by the time, it may require some amendments, so they will change by ourselves.
- Planning of time, design, implementation and testing is done.
- Hardware and software parts of our project are specified into a work breakdown structure.

- All the Modules of our project are divided in small pieces of time according to estimated time.
- In model training module, we first use Weka and then following TensorFlow to meet the requirements; hence we followed an incremental and iterative model.
- Do unit and acceptance testing after completion of each module.
- Budget plan for our project is defined
- We Add functionality of delay in Data Capturing application which capture data after some seconds when a user change his indoor location.
- Add restart functionality to restart scanning of Bluetooth devices once it stops which leads to incremental change in data capturing application.
- Roles and responsibilities of team members vary according to the prescribed task and time limit.

4.3 Requirement Analysis

The most important section of system requirement specification document is requirement analysis. To start any project, anyone needs to know his system requirements. This section includes all the software, hardware functional requirements of our system, user interfaces, database diagram, use case diagram, use case tests and test cases. Basically, we will discuss all the specifications of our system.

4.3.1 Hardware Functional Requirements

Deployment of BLE beacons

Deployment of BLE beacons on the ceiling is the requirement to capture fingerprints of BLE beacons with different mobile devices. At what angle and at what part of the ceiling these beacons should display, all we get it know before their deployment.

4.3.2 Software Functional Requirements

4.3.2.1 Data Capturing Application

Bluetooth scanning for nearby devices

A scanning function is made in data capturing application to scan BLE beacon for nearby mobile devices. Devices who present/locate near a certain BLE beacon are being scanned.

Capture RSSI values for nearby beacons BLE beacons Bluetooth range exists in a certain region and this region contain different mobile devices far and near to BLE beacon depending upon their indoor location. So, this function will capture RSSI fingerprints for all mobile devices which being scanned in that certain region.

Add delay factor to capture FPs

Once fingerprints of certain mobile device have been captured at a particular location and by determining the indoor location, we provide room information through our application to a users mobile device. The user may change his indoor location after a while. To provide updated room information to the user we are making a delay function which captures user fingerprints after a certain time (seconds) and provide him updated information according to his room location.

Automatic restart Bluetooth scanning for nearby devices once it stops

Automatic restart scanning function will scan for BLE beacon nearby mobile devices once scanning has been stops, because in this way our system will able to automatically find coming and going devices in a particular region and provide rooms information accordingly.

Generate .csv file for each BLE beacon

After capturing the fingerprints of all devices with a single BLE beacon which lie in that certain region, this function will generate .csv file and RSSI values of all devices in that file.

4.3.2.2 SmartGuide: Android Application

The functional requirements of our system for User are as follows:

Load trained model in Android app

There is need to load machine learning trained model in our Android application to predict the room location of a particular person.

Get the prediction of room from trained model

When a trained model receives .csv file of a particular BLE beacon, it gives the particular roomID of that beacon to a mobile device which is receiving higher RSSI value from that BLE beacon.

Allow user to know his indoor location

This function will enable users to see their indoor location i.e. in which room they are.

Fetch information of that particular room

This function will send RoomID of a particular BLE beacon to the database from which room information in image, texts and audio format can be fetched.

Provide information of the room to the user

After fetching the information of a particular room, this function becomes enable and displayed that information on user mobile screen.

Enable user to get information of nearby rooms

This function allow users to see their nearby (left, right, front and back) rooms and textual and pictorial information about that rooms.

The functional requirements of our system for Admin are as follows:

Allow admin to SignUp for our application

To use an Android application, in this case admin has to register on our application to add, update and delete records of certain data in our application.

Provide account activation functionality to the admin

Admin can login on another device; he has no restriction to use our application on a certain device. He may be login or logged out.

Admin has all the records of data

Admin has the ability to get all up-to-date records of data. Data can be of staff members, their visiting hours, room information, lab accessories and much more.

Store information to database in images, audios and text format of rooms and their nearby rooms

This function will store information about rooms in images, audios and text format in the database. Also, the information about nearby rooms of a certain room will also be stored by the admin in the database manually.

Allow admin to edit or update the information about rooms

When After sometime, the specifications and in formations about certain rooms and departments can be changed. So, this function will enable admin to update the information accordingly to provide up-to-date information to the user.

Admin has all those functionalities which a user has

Admin can see the information of a room and nearby rooms in any format provided in our application like user.

4.3.3 Non Functional Requirements

Reliability

Our project will be reliable .The users information will be kept confidential and there will be no worry of losing the information.

Usability

Our application will be usable for the users and easy to use.

Maintainability

This system will have the capability to adapt changes and amendments done in the database by the admin as the information of rooms will be updated or edited.

Security

Our Android application will work under potential risks. It will not be accessible by the malicious user or be crashed by external attacks.

Recoverability

In case of crash, our system information will recoverable

Safety

Optimize safety in the design, development, use and maintainability of the application.

Reusability

Our system will provide reusability factor to the visitors of the department.

Performance

To make a system which gives accurate and up-to-date information about rooms even a user change his indoor location after a while. This system will give results efficiently in small time.

4.3.4 Use Case Diagram

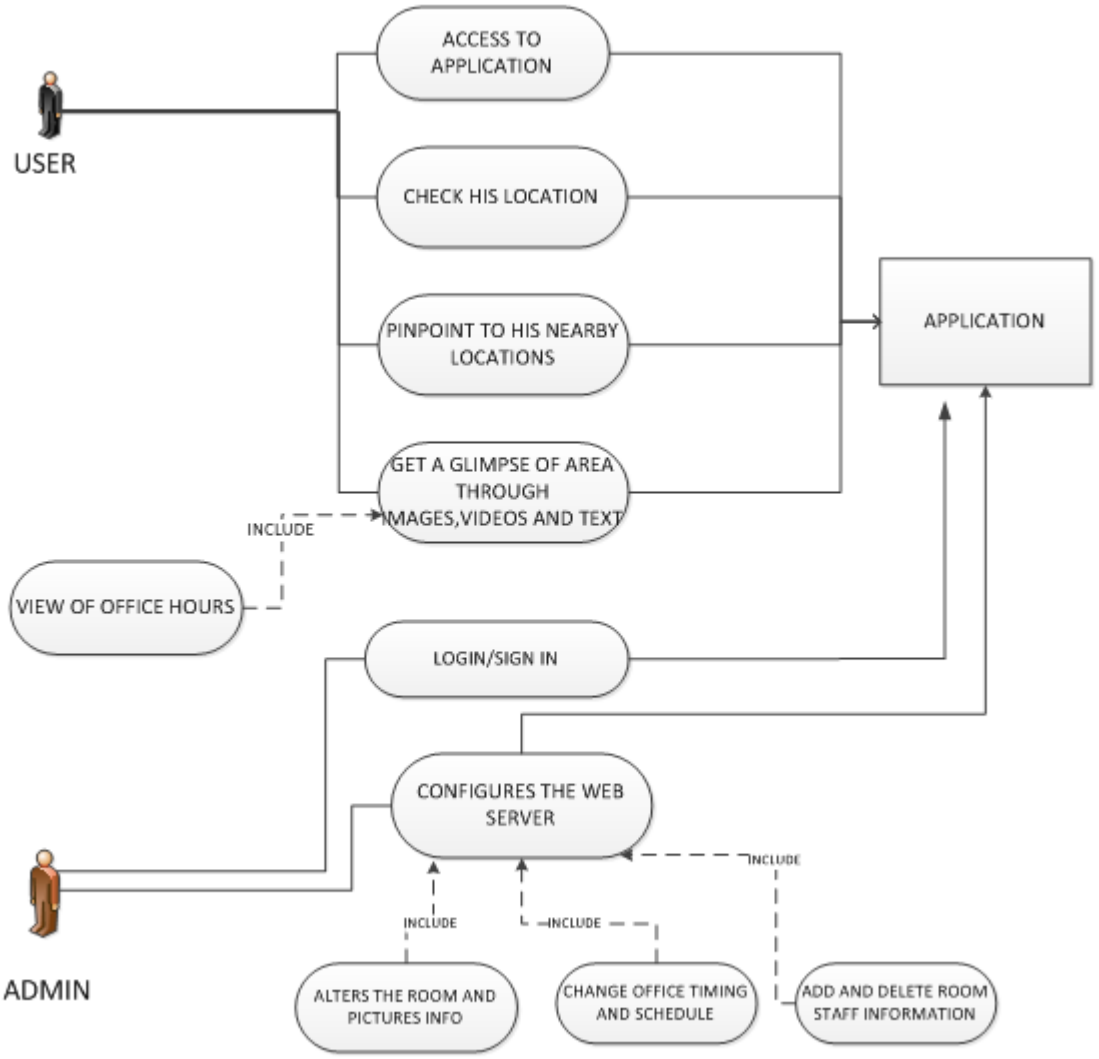


Figure : Use Case Diagram

4.3.5 Use Case Texts

Use Case Name	Access to the application
Actor	User
Description	User has to step into the application for the benefits of the app through his mobile phone.
Pre-conditions	1- The mobile must have Android OS. 2- The application must be downloaded on the phone.
Normal flow	1- The app will be downloaded through Google PlavStore. 2- User opens the app the front page appears showing "Welcome to CE Department".
Post-condition	Application will be opened and front page will show that this app will guide the user in CE department.

Figure : Use Case 1

Use Case Name	Checking the location and explore nearby places
Actor	User
Description	User can find out where he is standing right now and what the neighboring locations are.
Pre-conditions	1- Bluetooth connectivity must be turned on. 2- Bluetooth must be connected to beacon. 3- User must be in department premises.
Normal flow	1- After main page, another page appears with two buttons. 2- User can check his current location by clicking first button showing "My current location" which gives the user its current location. 3- Next button shows "Nearby Rooms/Labs" by clicking that user get to know about the surrounding rooms and labs around him.
Post-condition	1- User will able to know his location at that moment. 2- He will also know the neighboring rooms and labs.

Figure : Use Case 2

Use Case Name	Pictures, schedule and office timings of rooms & labs.
Actor	User
Description	The information of current and neighboring rooms and labs through pictures and texts with the extension of office timing of the teacher's room can be seen
Pre-conditions	User must know the location where he is standing and the nearby labs and rooms.
Normal flow	1- When the user clicks current location button, next screen gives 3 buttons. • One gives the pictures of the room. • Second gives the schedule and name of lab attendant if it is lab. • Third gives the office timing if the room belongs to any teacher. 2- When the user clicks the nearby rooms button, then the next screen shows rooms or labs nearby him and when the user clicks any of the room button he will be provided with the images, schedule and office timings.
Post-condition	User will be given the information i.e. pictures, schedule, office timing of his current position and the nearby rooms and labs.

Figure : Use Case 3

Use Case Name	Room/Lab staff information
Actor	User
Description	In this use case, User can have the knowledge of the working staff or the teacher's name in the room or lab
Pre-conditions	1- User should have the information of his current position by having the pictures, schedule and office timing of that room or lab. 2- He should have the pictures, schedule and office timing about the nearby rooms and labs.
Normal flow	1- When user is checking current location, another button is given which says "Staff Information" and by clicking that the user will know the teacher's name, his skills and which subjects he teaches. 2- When the user clicks nearby rooms/labs it will also give the staff information button and by clicking that user will know the teacher's skill and if it is lab then he will know which teachers are using this lab and for what subjects.
Post-condition	User will know the skills of teacher of specific room and what he teaches as well as he will know which teachers are teaching in specific lab.

Figure : Use Case 4

Use Case Name	Login/Sign in
Actor	Admin
Description	Admin have to make himself registered as an admin
Pre-conditions	Admin must have his login ID
Normal flow	1- Admin opens webserver. 2- Enter his login ID and password. 3- Click to "login as an admin"
Post-condition	Users have the access to webserver and he can alter the information in the webserver.

Figure : Use Case 5

Use Case Name	Alteration in rooms and labs information
Actor	Admin
Description	Admin can change the required information w.r.t changing environment i.e. change of any teacher, change of any lab etc.
Pre-conditions	Admin must have the authority to access the webserver of the application.
Normal flow	4- Admin access to the server where he can change picture or the text of specific room/lab. 5- Admin can also change the office timing of teacher's room and schedule of the labs.
Post-condition	Up to date information will be given to the user.

Figure : Use Case 6

Use Case Name	Amendments in room staff information
Actor	Admin
Description	If the teacher changes his lab, the admin has the authority to change his lab information and if lab attendant is changed then admin can modify it.
Pre-conditions	1- Admin has access to web server. 2- He should have up to date information.
Normal flow	1- Admin opens the server and checks for the specific teacher or staff. 2- Update/delete/insert the information.
Post-condition	Up to date information of the room staff will be provided.

Figure : Use Case 7

4.3.6 Test Cases

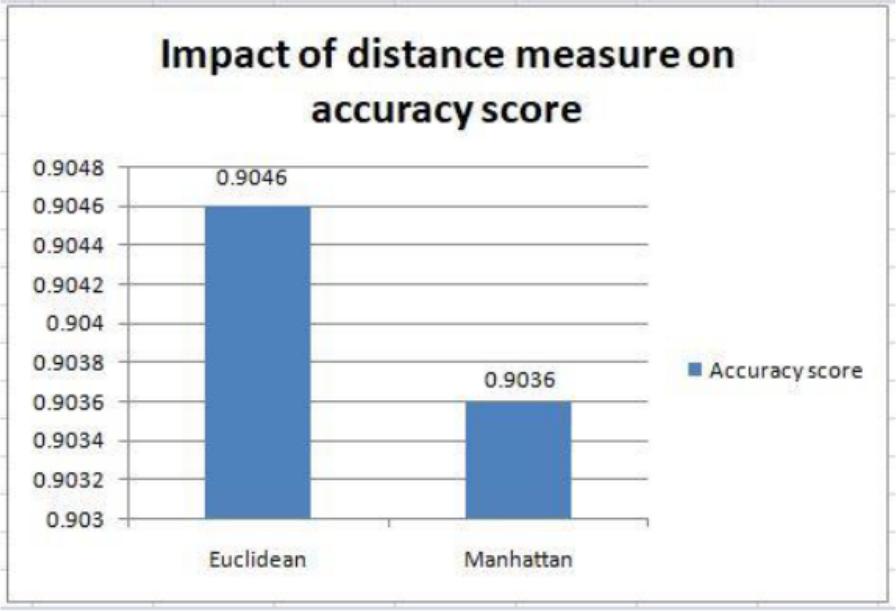
Feature Name	Test Case ID	Summary	Execution Steps	Expected Results
Bluetooth scanning and connecting with device	1	Validate that Bluetooth is connecting to the beacon.	1- Turn Bluetooth connectivity on 2- Scan Bluetooth 3- Connect to the beacon	You are connected to beacon 'X'
Automatic Bluetooth scan	2	Validate that Bluetooth is scanning automatically.	When the person moves Bluetooth scans itself.	You are connected to another beacon 'Y'
Predictions of rooms	3	Validate the predictions of room	1- Get the information of rooms 2- Train that model through tenserflow 3- Predict using weka	Your accuracy is '123%"
Send Room ID to Android App	4	Validate that data capturing app is	After predictions of room the room ID is send to	Room ID 2 is sent to Android app

		sending room ID to android app	android app	
User know his indoor location	5	Validate that user will know his location	1- Turn Bluetooth connectivity on 2- Connect to beacon 3- Open the application 4- Click on "your current location"	You are at this place
User is getting nearby locations information	6	Validate that user will know the information of his nearby rooms	1- Turn Bluetooth connectivity on 2- Connect to beacon 3- Open the application 4- Click on "Nearby Locations"	Your nearby rooms are a- Room 'X' b- Lab 'Y'
Login/Sign In by admin	7	Validate that Admin is getting access to webserver	1- Open the webserver 2- In the required area type admin login ID and password	1- Message appears "You are logged in as an admin". 2- Webserver will be opened for admin
Admin change the information	8	Validate that when admin amend anything it will appear	1- Open the webserver 2- Login to the webserver	Room No 'X' information is updated Or
			3- Update/Modify the database	'xyz' is shifted to room no '123'

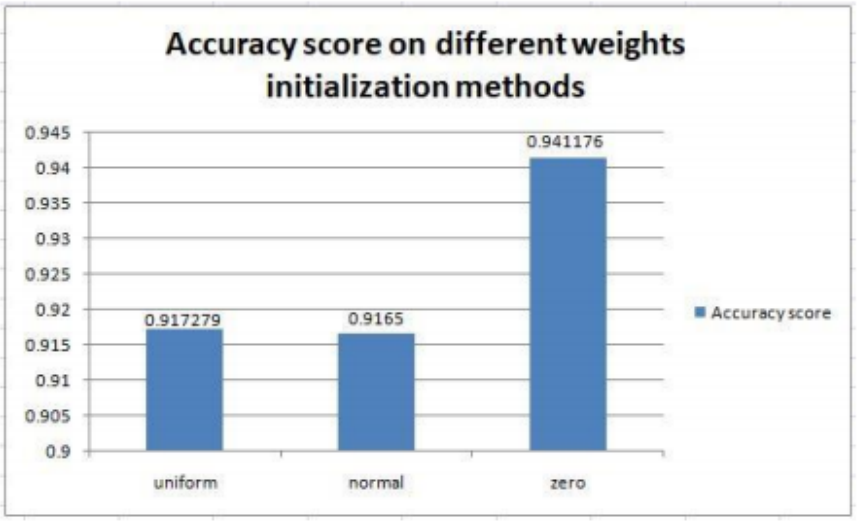
Chapter 5

Results and Discussions

As we have to predict the indoor location of the user, we gathered our dataset by capturing RSSI fingerprints using our data capturing application which we further use to train our machine learning model.To train our machine learning model, we use three different machine learning algorithms. Firstly knn, which we used for supervised machine learning problem i.e.multiclassification problem. After tuning hyper-parameters of knn, it gives us accuracy of 90.04 while measuring Euclidean distance and of 90.03 while measuring Manhattan distance as shown in the figure(a). The impact of different number of weights on accuracy score is shown in figure(b).

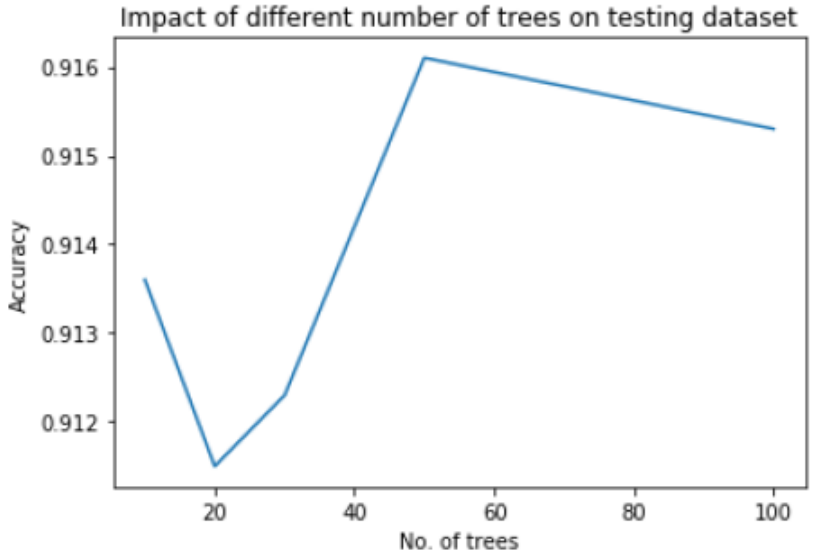


Figure(a)

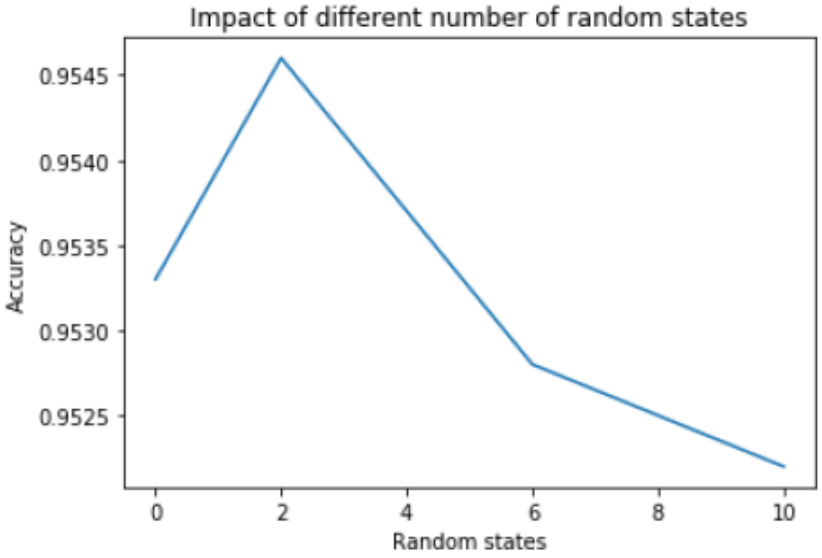


Figure(b)

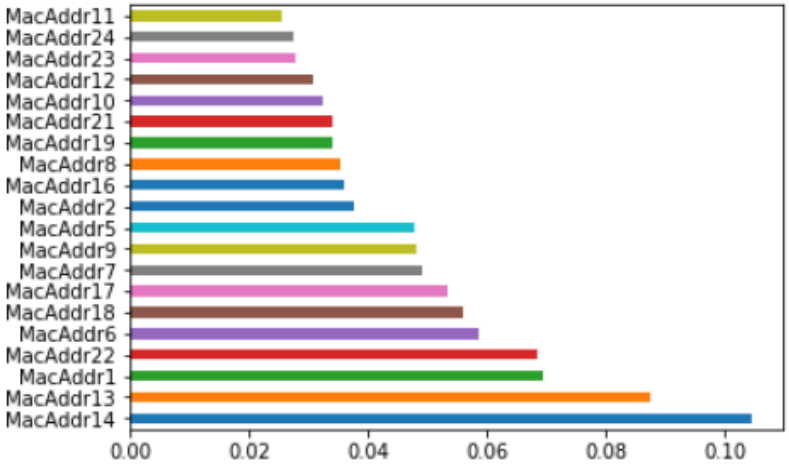
Secondly, we choose random forest algorithm which works on the principle of random creation of decision trees and gives the final prediction by polling the score of all decision trees for multiclassification problems. We tuned random forest algorithm on different hyper-parameters i.e. number of decision trees, maximum number of splits and nodes. The best combination of setting these parameters gives us the trainng accuracy of 95.33 and testing accuracy of 90.1. The imapct of different number of trees and random number of states is shown in the figures(c and d). The importance of each feature of our dataset is shown in figure(d).



Figure(c)

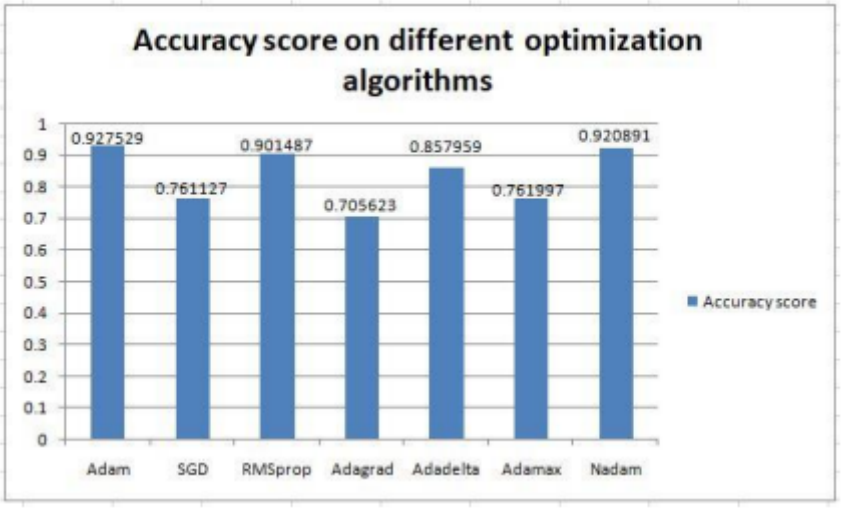


Figure(d)



Figure(e)

For the better prediction of the indoor location of the user, we thirdly use neural networks in which we use 2-layered neural network for our multi-classification problem.The input layer consists of input neurons. Those neurons transmit data to the next layer, which in turn sends the output neurons to the output layer. To implement this algorithm, we have to find the best values for parameters at which accuracy score is maximum. For this purpose, we use GridsearchCV function to test for all possible combinations. Here are the results of impact of optimizations algorithms on accuracy score.



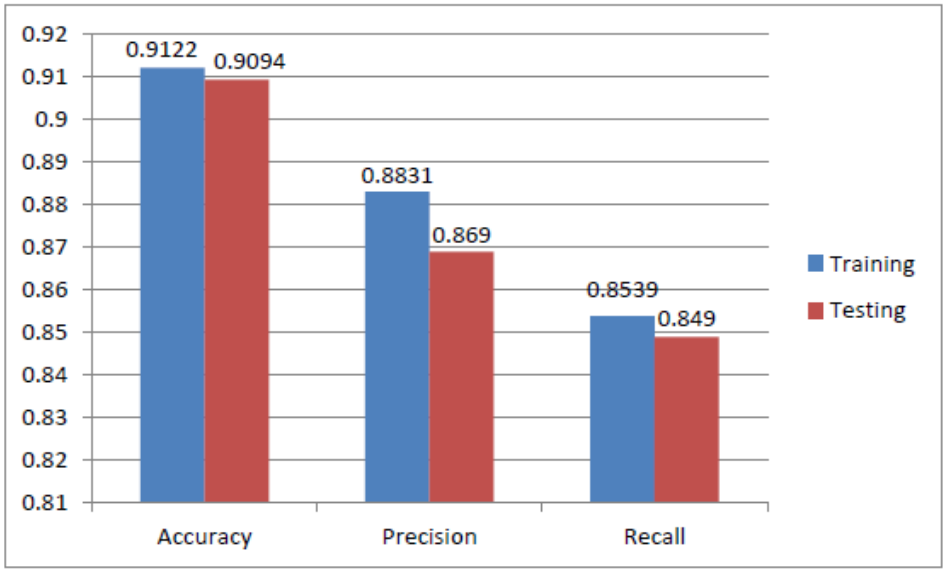
We also tune activation functions 'relu', 'tanh', 'sigmoid', linear. All of them gave same accuracy score.Hence, after checking the impact of choosing different values of parameters on accuracy score, we find out that best combination has following values:

- Batch size: 40
- Epochs: 250
- Optimization Algorithm: Adam
- Weight Initialization Methods: uniform
- Activation Function: relu for hidden layer and sigmoid for output layer
- Number of Neurons for hidden layer: 27

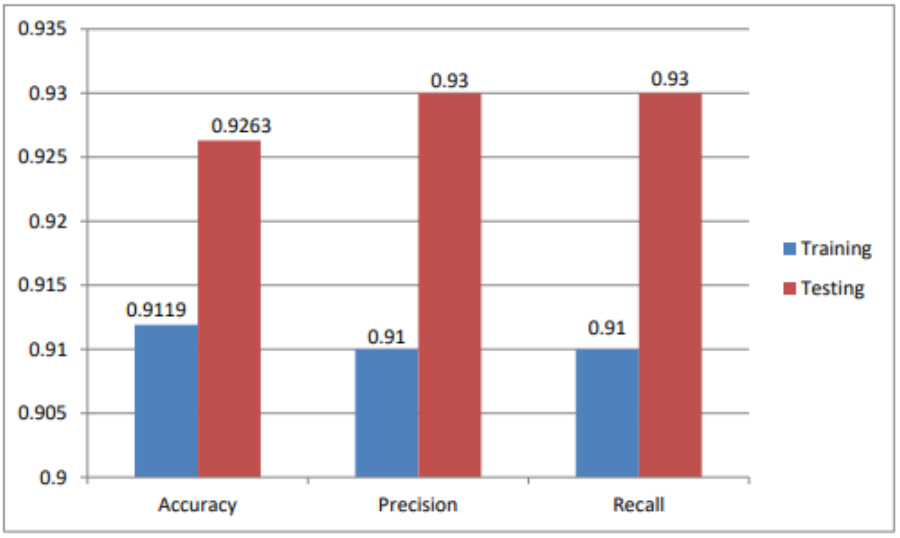
So,we conclude that on the basis of accuracy, precision and recall score for k-NN, Random forest and ANN. It is clear that ANN has highest accuracy, precision and recall score. Hence, ANN is our selected mode.

5.1 Graphs

The accuracy, precision and recall graph of knn is as follows:

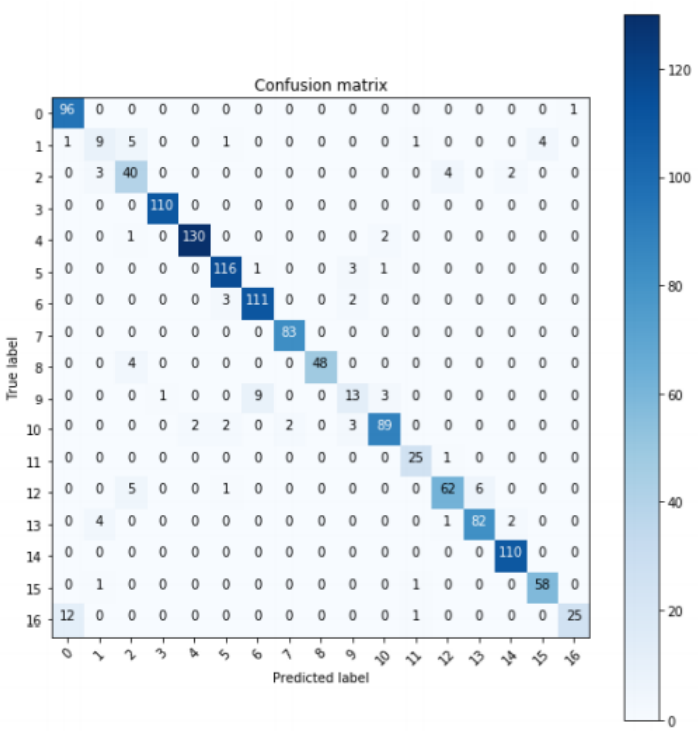


The accuracy, precision and recall graph of ann is as follows:



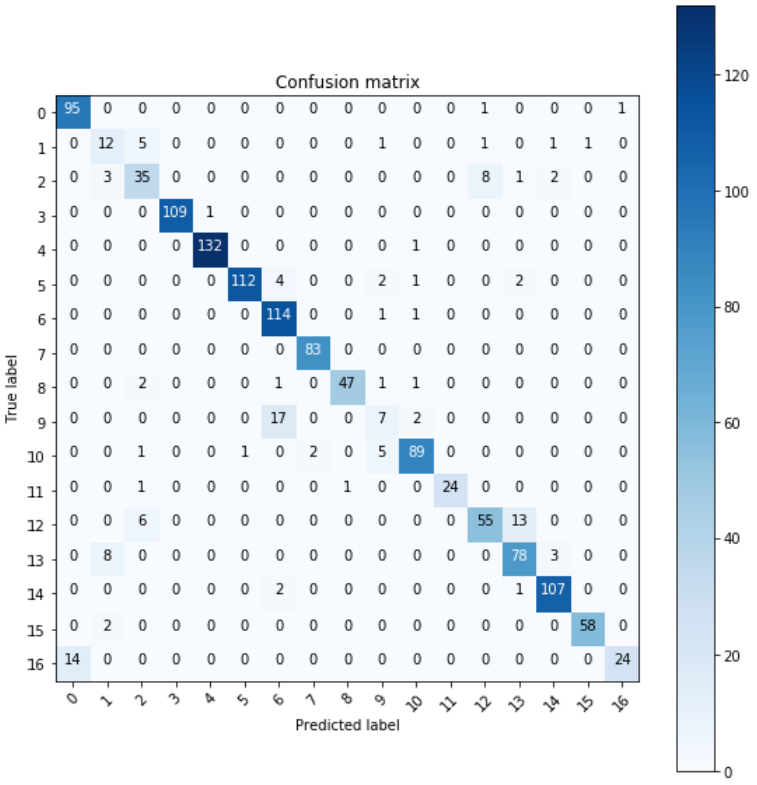
5.2 Confusion Matrix

For the better prediction of the algorithms, we draw confusion matrix of the algorithims. The confusion matrix for knn is shown in the Figure(a) . As it is a multi-classification problem, it is a little bit different from binary classification. For example: L1 row shows that out of total samples in test data where data is labeled as L1, 92 instances were correctly classify, while 4 samples were wrongly predicted as L9.



Figure(a)

The confusion matrix for ann algorithm is shown in the Figure(b). As we use label encoder, so it encode classes ranges from 0 to 16. Here is the actual sequence, it means L1 encode to 0, L10 encode to 1 and so on:


Confusion matrix
True label
Predicted label
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
120
100
80
60
40
20
0

Figure(b)

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