Realtime Location Queries With Firebase - Geohashing

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Submitted to - Prof. Anu Yadav

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Project submitted for the paper 'Advanced Algorithm Design'

Certificate of Originality

The work embodied in this report entitled **Real Time Location Queries With Firebase-Geohashing** has been carried out by **Ashutosh Jha** for the paper ‘Advanced Algorithm Design’. I declare that the work and language included in this project report is free from any kind of plagiarism.

Ashutosh Jha

Abstract

The objective of the project was to apply theoretical as well as practical knowledge of Advanced Algorithm Design to build an android application for where one can perform real time location queries on firebase, also known as Geohashing.

Geohashing is a geocoding method used to encode geographic coordinates (latitude and longitude) into a short string of digits and letters. The more characters in the string, the more precise the location. Using this algorithm, we have performed real time location queries on a set of predefined restaurants data for various locations like Sonipat, Delhi, Bhiwadi etc.

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Abbreviations and terms

Android	An open source platform designed for mobile devices
OS	Operating system
SDK	Software development kit
JRE	Java Runtime Environment
IDE	Integrated development environment
GUI	Graphical user interface
Android Emulator	Container for running Android OS along with applications
XML	Extensible Markup Language
RAM	Random Access Memory
IT	Information Technology
GHz	GigaHertz
API	Application Programming Interface
ICT	Information and Communication Technology
UI	User Interface
URL	Universal Resource Locator
HD	Hard Disk
CPU	Central Processing Unit

1) INTRODUCTION

a) Background of Project

Geohashing is a geocoding method used to encode geographic coordinates (latitude and longitude) into a short string of digits and letters. The more characters in the string, the more precise the location.

GeoFire is an open-source library that allows users to store and query a set of items based on their geographic location. GeoFire uses Firebase for data storage, allowing query results to be updated in real time as they change. GeoFire does more than just measure the distance between locations; it selectively loads only the data near certain locations, keeping the applications light and responsive, even with extremely large datasets.

b) Problem Statement

Querying for nearby places is an almost essential feature to many web and mobile applications. Typically when searching for nearby locations, we would need to create a range of latitude and longitude coordinates that could be used to capture a list of restaurants, stores, etc. However, Firebase Realtime Database queries can only perform range filtering on a single field. This means that we are unable to query on both latitude and longitude as separate fields.

c) Goals

The main goal of the project was to apply geofire in our android application so that it can perform location based queries in real time and filter out restaurant data.

2) ANALYSIS OF ACTIVITY DONE

a) Duration

Project	**Canteen App**
Start Date	16 February 2021
End Date	29 April 2021

b) Project Schedule

i) Time Schedule

During the semester long project the time for implementing various features are given below:

S.No	**Task name**	**Duration**
1)	Study and Analysis	15 days
2)	UI Design	8 days
3)	Database design	5 days
4)	Responsive Design	7 days
5)	Android	4 days
6)	Firebase	5 days

ii) Project Phases

It is very important to follow up phases as the pre requirements for every next phase is the completion of the previous one. The project was divided broadly into 4 phases

1) Designing Layouts
2) Implementing the classes and functions

3) Hosting on Firebase and setting required methods
4) Integrating Geofire

3) SYSTEM ANALYSIS

a) System Analysis

Analysis can be defined as breaking up of any whole so as to find out their nature, function etc. It defines design as to make preliminary sketches of; to sketch a pattern or outline for plan. To plan and carry out especially by artistic arrangement or in a skillful wall. System analysis and design can be characterized as a set of techniques and processes, a community of interests, a culture and an intellectual orientation.

It is the most creative and challenging phase of the system life cycle. The output of this phase is a description of the recommended alternative solution. The steps involved during system analysis process are:

1) Understanding application
2) Planning
3) Scheduling
4) Forming theory background
5) Developing the solution
6) Performing the test analysis
7) Recommending alternative solutions
8) Launching the proposed solution

System analysis can include looking at end-user implementation of a software package or product and involves gathering requirements for the system. In System Analysis more emphasis is given to understanding the details of an existing system or a proposed one and then deciding whether the proposed system is desirable or not and whether the existing system needs improvements. Thus, system analysis is the process of investigating a system, identifying problems, and using the information to recommend improvements to the system. The project should address a real world interface design and be implementable. Feasibility Study is a major process in System Analysis. It helps in determining whether the project will yield a desired output with realistic and economic use of available resources.

b) Requirement Analysis

Requirements analysis is critical to the success of a systems or software project. The requirements should be documented, actionable, measurable, testable, traceable, related to identified business needs or opportunities, and defined to a level of detail sufficient for system design.

i) Functional Requirements

In a development process, functional requirement provides the developer with a blueprint of how the application and its component will behave or function. The functional requirements describe what the application system should do. The functional requirements of the application are as follows:

General

G1	All the data shall be hosted on Firebase for data processing and storage.
G2	A surface app page shall provide a user with all user system functionality.
G3	A responsive UI shall provide the user with filtering data functionality.

Android Application

A1	The app should upload restaurant data to firebase
A2	The app should generate firebase keys
A3	The app should use Geofire library
A4	The app must create a geofire node in firebase for every restaurant
A5	The app must provide a responsive UI to filter out results

A6	The must must filter out results once a centre and radius is defined by the user
A7	The app must retrieve restaurant data once the UI thread is running.
A8	The app should respond to changes in Firebase data in real time

ii) Non-functional Requirements

Non-functional requirements are not concerned with the functions of the system. Instead, they look at the criteria to which the application is expected to conform to. Non-functional requirements can include things like response time and reliability. Some of the Non-functional requirement for the applications are:

(1) The android application should be compatible with android devices with SDK greater than 25.
(2) All the components of the application should be fully loaded within reliable time without downgrading performance.
(3) Should be user friendly and content should be readable by all types of users.
(4) Should take minimal time, effort, resources or cost to create the android application.
(5) Should provide the correct information about all the modules.
(6) Should consider the Response times
(7) Android applications should strictly follow Material Design guidelines
(8) The data should get retrieved from the server even in all types of network connectivity
(9) All the communications between server and app should have a secure endpoint

iii) Usability Requirements

The android applications can be accessed by users on their android devices, given they install the desired apks.

iv) Efficiency Requirement

Mean Time to Repair (MTTR) - Even if the system fails, the system will be recovered back up within an hour or less.

v) Accuracy

The system should accurately provide real time information taking into consideration various concurrency issues. The system shall provide 100% access reliability.

vi) Safety Requirements

The system uses SSL (secured socket layer) in all transactions that include any confidential information.

vii) Performance Requirement

The information is refreshed at regular intervals depending upon whether some updates have occurred or not. The system shall respond to the user in not less than two seconds from the time of the request submittal. The system shall be allowed to take more time when doing large processing jobs. Responses to view information shall take no longer than 5 seconds to appear on the screen.

viii) Maintainability and Portability Requirements

Changes (new parts in addition, password changes, and database changes) must be verified once per day at least.

ix) Feasibility Study

After studying and analyzing all the existing or required functionalities of the system, the next task is to do the feasibility study for the project. The project is feasible – given unlimited resources and infinite time.

Feasibility study includes consideration of all the possible ways to provide a solution to the given problem. The proposed solution should satisfy all the user requirements and should be flexible enough so that future changes can be easily done based on the future upcoming requirements.

1) Economic Feasibility

This is a very important aspect to be considered while developing a project. I decided the technology based on the minimum possible cost factor. All hardware and software cost has to be borne by me.

2) Technical Feasibility

This included the study of function, performance and constraints that may affect the ability to achieve an acceptable system. For this feasibility study, I studied complete functionality to be provided in the system and checked if everything was possible using different types of frontend and backend platforms.

3) Operational Feasibility

No doubt the proposed system is fully GUI based that is very user friendly and all inputs to be taken are all self-explanatory even to a layman.

c) Technical Requirements

i) Hardware Requirements

- Minimum 35 MB Hard Disk space for installation of apk.
- Android Minimum API - 25

- Recommended 2 GB RAM
- Network card

ii) Software Requirements

- Application system : Android Studio, Android SDK
- Language : Java, XML, Android Framework

d) Input Design

Input design is part of overall system design that requires special attention. For designing input data, the data entered should be easy and free from errors. The input forms and dialog boxes in applications are designed using the controls available. Validation is made for each and every data that is entered. Help information is provided for the users.

Input design is the process of converting the user originated inputs to a computer based format. The collection of input data is considered to be the most expensive part of the system design. Since the input has to be planned in such a manner so as to get relevant information, extreme care is taken to obtain pertinent information. The application gives an interface for registering and validating users and the data entered by users are converted to suitable models and uploaded to firebase for further use.

e) Output Design

Output design of the applications generally refers to the results and information that are generated by the system for many end-users; output is the main reason for developing the system and the basis on which they evaluate the usefulness of the application. The output is designed in such a way that it is attractive, convenient and informative. As the outputs are the most important sources of information to the users, better design should improve the system's relationships with us and also will help in decision making. The application presents the information in an interactive, user friendly manner.

4) IMPLEMENTATION

a) Implementation Tools

The various implementation tools are listed below:

- Operating System - Windows 10
- Development environment - Java, XML, Android SDK
- IDE - Android Studio 4.1.1

b) Tools Used

i) Android framework

Android is one of the Open source platforms. It is created by Google and owned by Open Handset Alliance. It is designed with the goal “accelerate innovation in mobile”. As such android has taken over a field of mobile innovation. It is definitely a free and open platform that differs hardware from software that runs on it. It results in much more devices running the same application. Also it gives the possibility of a friendlier environment for developers and consumers. Android is a complete software package for a mobile device. Since the beginning the android team offers the developing kit (tools and frameworks) for creating mobile applications quick and easily as possible. In some cases you do not especially need an android phone but you are very welcome to have one. It can work right out of the box, but of course users can customize it for their particular needs. For manufacturers it is a ready and free solution for their devices. Except specific drivers, the android community provides everything else to create their devices.

ii) Firebase

Firebase is a mobile and web application development platform developed by Firebase, Inc. in 2011, then acquired by Google in 2014. As of November 2020, the Firebase platform has 18 products, which are used by 1.5 million apps. I have used it for hosting purposes. I have used the following features in the app :

(1) Realtime Database

The Firebase Realtime Database is a cloud-hosted database. Data is stored as JSON and synchronized in realtime to every connected client. The data is stored and sync data with their NoSQL cloud database. Data is synced across all clients in real time, and remains available when the app goes offline.

iii) GeoFire

GeoFire is an open-source library for Java that allows users to store and query a set of keys based on their geographic location. At its heart, GeoFire simply stores locations with string keys. Its main benefit however, is the possibility of querying keys within a given geographic area - all in realtime.

GeoFire uses the Firebase Realtime Database database for data storage, allowing query results to be updated in real time as they change. GeoFire selectively loads only the data near certain locations, keeping the applications light and responsive, even with extremely large datasets.

- Geohashes use Base-32 alphabet encoding (characters can be 0 to 9 and A to Z, excl "A", "I", "L" and "O”).
- Imagine the world is divided into a grid with 32 cells. The first character in a geohash identifies the initial location as one of the 32 cells.
- This cell will also contain 32 cells, and each one of these will contain 32 cells (and so on repeatedly).
- Adding characters to the geohash sub-divides a cell, effectively zooming in to a more detailed area.

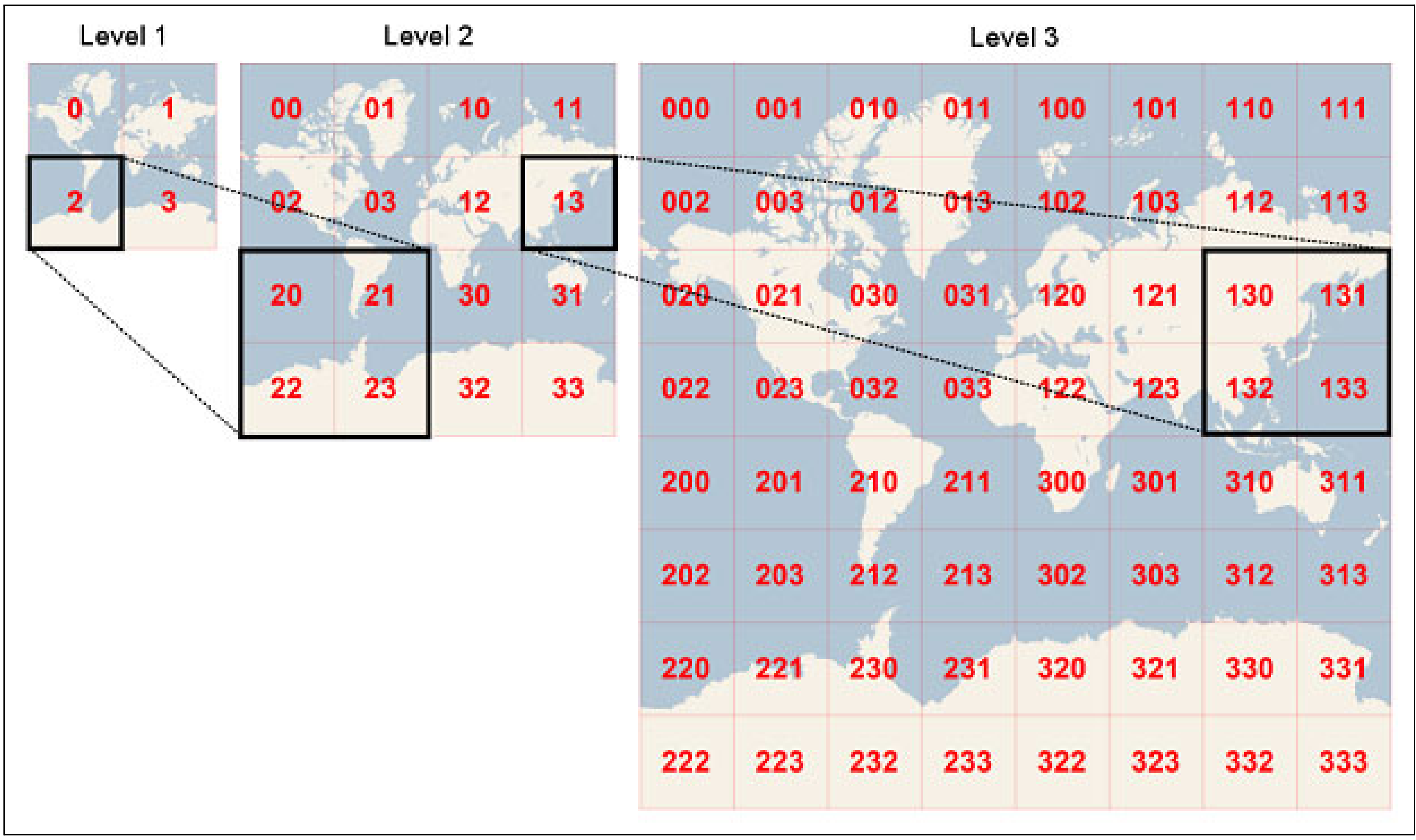


Image explaining the how the geofire library divides the world into grids

- The precision factor determines the size of the cell.
- A precision factor of one creates a cell 5,000km high and 5,000km wide
- A precision factor of six creates a cell 0.61km high and 1.22km wide
- A precision factor of nine creates a cell 4.77m high and 4.77m wide (cells are not always square).

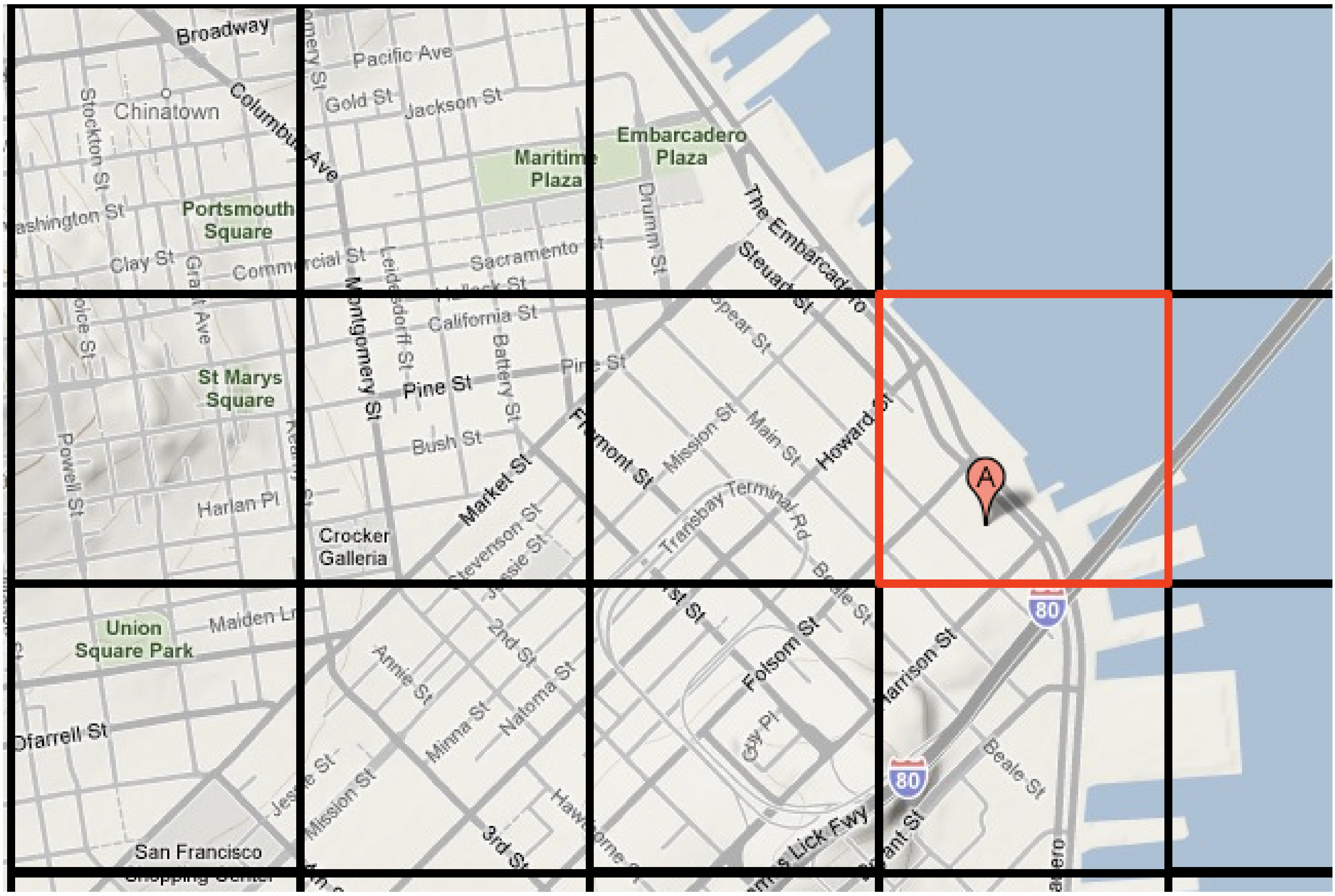


Image explaining how the location are more accurate when the string lengths are greater

c) System Implementation

System implementation is the important stage of a project when the theoretical design is tuned into practical system. The main stages in the system implementation are as follows:

1. Planning
2. Training
3. System testing
4. Changeover planning

d) System Maintenance

Software maintenance is far more than finding mistakes. Provision must be made for environment changes, which may affect either the computer, or other parts of the computer based systems. Such activity is normally called maintenance. It includes both the improvement of the system functions and the corrections of faults, which arise during the operation of a new system. It may involve the continuing involvement of a large proportion of computer department resources. The main task may be to adapt existing systems in a changing environment. Backup for the entire database files are taken and stored in cloud systems so that it is possible to restore the system at the earliest. If there is a breakdown or collapse, then the system gives provision to restore database files. Storing data in a separate secondary device leads to an effective and efficient maintenance of the system.

5) DEVELOPMENT

a) Designing Layouts

Layout defines the structure for a user interface in your app, such as in an activity. All elements in the layout are built using a hierarchy of View and ViewGroup objects. A View usually draws something the user can see and interact with. Whereas a ViewGroup is an invisible container that defines the layout structure for View and ViewGroup objects.

The View objects are usually called "widgets" and can be one of many subclasses, such as Button or TextView. The ViewGroup objects are usually called "layouts" and can be one of many types that provide a different layout structure, such as LinearLayout or ConstraintLayout.

You can declare a layout in two ways:

- **Declare UI elements in XML**: Android provides a straightforward XML vocabulary that corresponds to the View classes and subclasses, such as those for widgets and layouts.
- **Instantiate layout elements at runtime** : App can create View and ViewGroup objects (and manipulate their properties) programmatically.

Declaring your UI in XML allows you to separate the presentation of your app from the code that controls its behavior. Using XML files also makes it easy to provide different layouts for different screen sizes and orientations. So, the main elements used in our project were:-

1) Parent Views- Linear View, Relative View and Constraint view for holding widgets and child elements
2) Child Elements
   - Buttons:- Whenever user clicks it, then it performs a specific action
   - EditText:- To take user Input
   - CardView:- Show information inside cards that have a consistent look across the platform

- GridLayout:- a Layout manager that lays out a container's components in a rectangular grid. The container is divided into equal-sized rectangles, and one component is placed in each rectangle. Used along with a card view.
- TextView
- ImageView etc.

3) Sub-child elements- Combination of the above child elements

b) Implementing the classes and functions

We used various classes and methods in our project which is beyond the scope of this report. The main methods and classes used were:-

a) setOnClickListener- It helps us to link a listener with certain attributes. setOnClickListener is a method in Android basically used with buttons, image buttons etc.
b) addOnSucessListeners
c) addOnFailureListener
d) Toast - For displaying user a message
e) Intent- For taking user to other activities
f) DatabaseReference- for referring to the firebase database (restaurants data) according to the document ID etc.

c) Hosting on Firebase and setting required methods

Firebase gives us functionality like databases and crash reporting so we can move quickly and focus on the users. Firebase is built on Google infrastructure and scales automatically, for even the largest apps. The steps involved were:

- We need to set up a Firebase Account and create a new project.
- Then provide the necessary details and provide the apps SHA-1 fingerprint.
- Add the firebase configuration files and plugins.
- Add firebase SDK to the app
- In the database section, select Realtime database and the region we wish to store our data. Then make a collection and accordingly document. Each document has a specific ID. In our case, it is the user’s UID (Unique

Identification Number). We use DatabaseReference to refer to documents and their subchilds.

6) Testing

Testing is a method of assessing the functionality of a program. Testing is a set of processes aimed at investigating, evaluating and ascertaining the completeness and quality of a project. Testing refers to the process of implementing all or part of the system with the intent of finding errors. It is performed in order to find the bugs or errors in the system and minimize it. In general, testing is finding out how well something works .Testing is more than just debugging.

a) Unit Testing

Each division class of every page or layout is tested in the android device. Inspecting XML, and modifying style and layout in real-time.

b) System Testing

After completing the overall application design and development it is tested for error. We have also validated output errors with detailed debugging and have taken necessary actions.

c) Performance Testing

Performance testing is designed to test the run-time performance of software within the context of an integrated system. Performance testing occurs throughout all steps in the testing process. Even at the unit level, the performance of an individual module may be assessed as white-box tests are conducted.

d) Test Cases

The various test cases for the android application are :

Test Case ID.	1
Test Case Name	Loading Firebase Data
Test Case Description	This test case tests the firebase database

	retrieval process
Dependency or Prerequisite	Connection to the Database
Steps	1. User opens the app. 2. After splash screen, the user is diverted to home screen 3. In the home screen, the user is presented with a shimmer layout, a layout for loading data. 4. After the retrieval process is done, the shimmer layout becomes invisible and restaurant data is shown
Expected Result	Successful retrieval of firebase data.
Estimated Time	Depends upon the network (approx. 5 seconds)

Test Case ID.	2
Test Case Name	Adding Restaurants
Test Case Description	This test case tests whether a user is able to create restaurant data or not.
Dependency or Prerequisite	Connected to Database
Steps	1. User needs to click on the add restaurant option in the navigation view. 2. Upon clicking, the user is sent to add restaurant fragment 3. Type the necessary details and click Done. 4. After clicking on done, the user is

	presented with a loading dialog and a synchronous task runs in background and the data is uploaded to firebase as soon as sync thread is finished
Expected Result	Successfully able to create restaurant data.
Estimated Time	Less than 5 sec depending on the network speed

Test Case ID.	3
Test Case Name	Filtering Results
Test Case Description	This test case tests whether the filtering of data is taking place or not.
Dependency or Prerequisite	Connected to Database and Google Maps API
Steps	1. Application displays a restaurant data on home screen 2. Upon clicking on Filter option on app bar, user is asked for the center and filter radius 3. Upon clicking on Filter, the data is filtered
Expected Result	Successfully able to filter data.
Estimated Time	Less than 5 sec.

7) System Features

a) Geohashing

i) Description and Priority

I have implemented geohashing in the android application. GeoFire stores data in its own format and its own location within the Firebase database. This allows existing data format and security rules to remain unchanged and for us to add GeoFire as an easy solution for geo queries without modifying the existing data. The location data for each restaurant is stored using GeoFire, using the restaurant IDs as GeoFire keys. GeoFire then allows easy querying of restaurant IDs (the keys).

A GeoFire object is used to read and write geo location data to the Firebase database and to create queries. To create a new GeoFire instance we need to attach it to a Firebase database reference. In GeoFire we can set and query locations by string keys. To set a location for a key we simply call the setLocation method. The method is passed a key as a string and the location as a GeoLocation object containing the location's latitude and longitude:

GeoFire allows us to query all keys within a geographic area using GeoQuery objects. As the locations for keys change, the query is updated in real time and fires events letting us know if any relevant keys have moved. GeoQuery parameters can be updated later to change the size and center of the queried area. There are five kinds of "key" events that can occur with a geo query:

1) Key Entered: The location of a key now matches the query criteria.
2) Key Exited: The location of a key no longer matches the query criteria.
3) Key Moved: The location of a key changed but the location still matches the query criteria.
4) Query Ready: All current data has been loaded from the server and all initial events have been fired.
5) Query Error: There was an error while performing this query, e.g. a violation of security rules.

Key entered events will be fired for all keys initially matching the query as well as any time afterwards that a key enters the query. Key moved and key exited events are guaranteed to be preceded by a key entered event.

The GeoQuery search area is changed with setCenter and setRadius methods as soon as the user gives these criteria. Key exited and key entered events will be fired for keys moving in and out of the old and new search area, respectively. No key moved events will be fired; however, key moved events might occur independently. The Backend services used are:-

1) Google Places API
2) Google Maps SDK

Methods used are:-

1) setLocation();
2) getLocation();
3) getInstance();
4) removeLocation(); etc,

The limit for handling multiple users is 200,000 and after that it is done through first come first basis. Simultaneous responses sent from a single database is 100,000/second.

ii) Stimulus / Response Sequences

- User clicks on the app
- Home screen will be followed by splash screen
- Restaurant data is loaded on the home screen
- User clicks on the Filter option in app bar
- User sets the centre and radius
- User clicks on Filter and data is filtered

iii) Functional Requirements

REQ-1 : Cellular Service provider for connecting the phone to the internet

8) SUMMARY

In this Project, a prototype of the application was developed. The application was able to connect to the server and retrieve information from the server. It can be installed and functions on several devices at the same time.

The prototype is working on an android platform and made on the base of Java framework. It uses Firebase to store and to receive information. The information is stored on Firebase and can be accessed any time. Google Maps SDK and Google Places API were successfully implemented and the application is able to filter out location based query results

9) References

a) Udacity Android Developer Program (https://udacity.com)

b) Android Developers (https://developer.android.com)

c) Dawidowicz, Paula 2010 Literature Reviews Made Easy: A Quick Guide to Success. IAP.

d) Gargenta, Marko 2011 Learning Android. O'Reilly Media, Inc.

e) StackOverflow (https://stackoverflow.com)

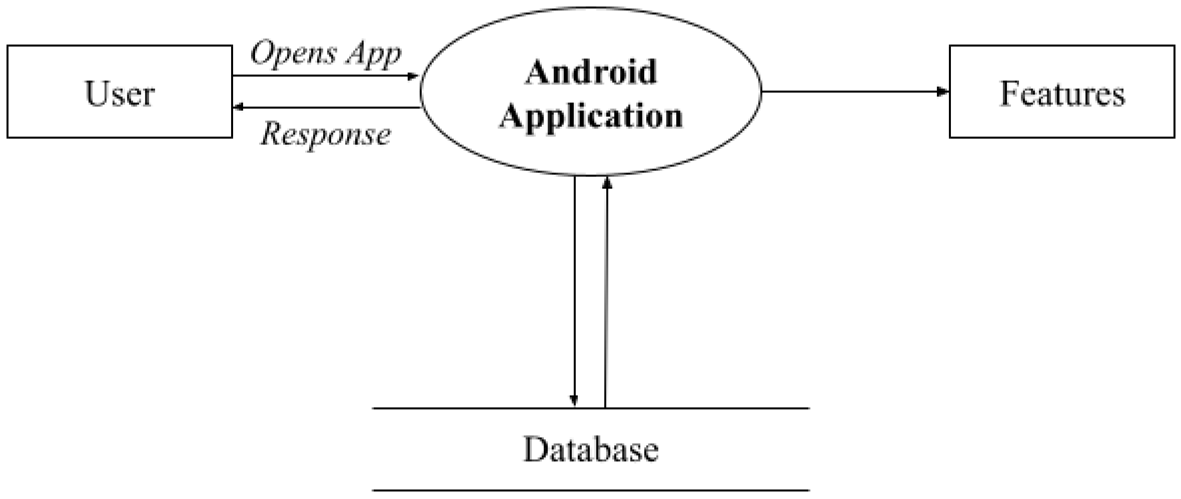
f) Material Design for Android (https://material.io)

g) Firebase Docs (https://firebase.google.com/docs)

h) Maps SDK for Android (https://cloud.google.com/maps-platform)

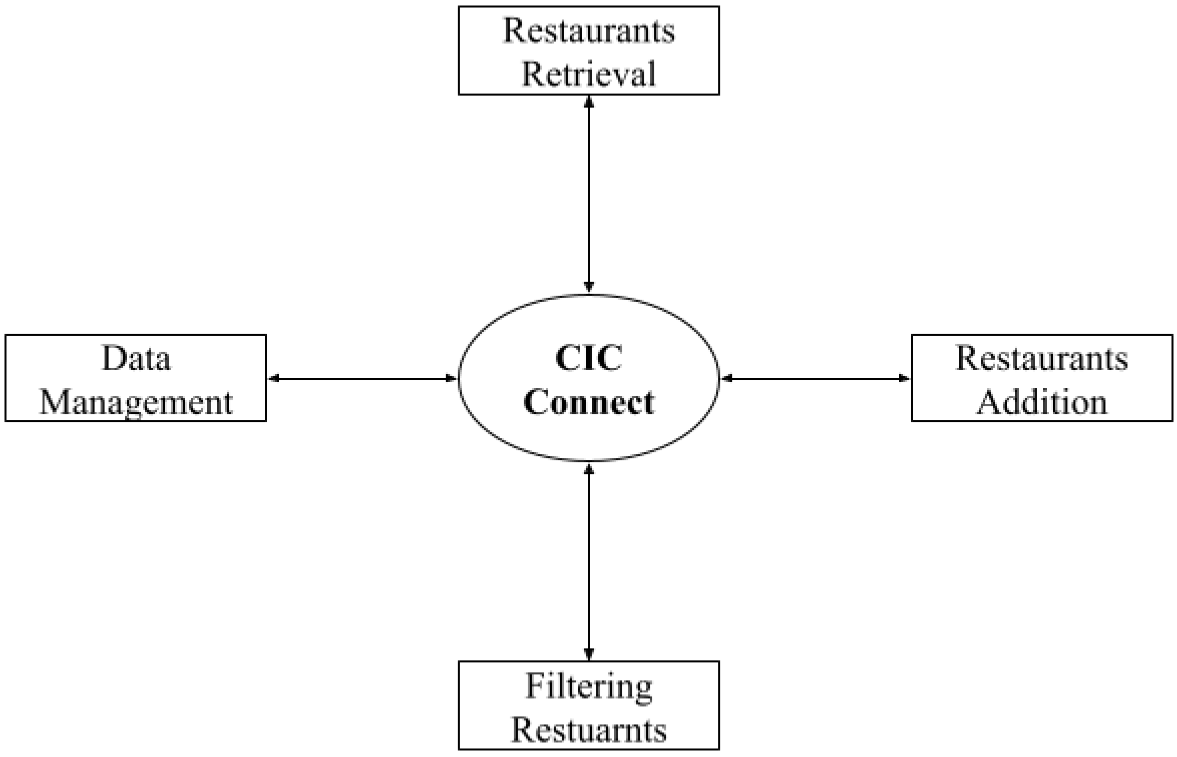
i) Github (https://github.com)

10) Appendix A : Context Diagram (Data Flow Diagram Level-0)

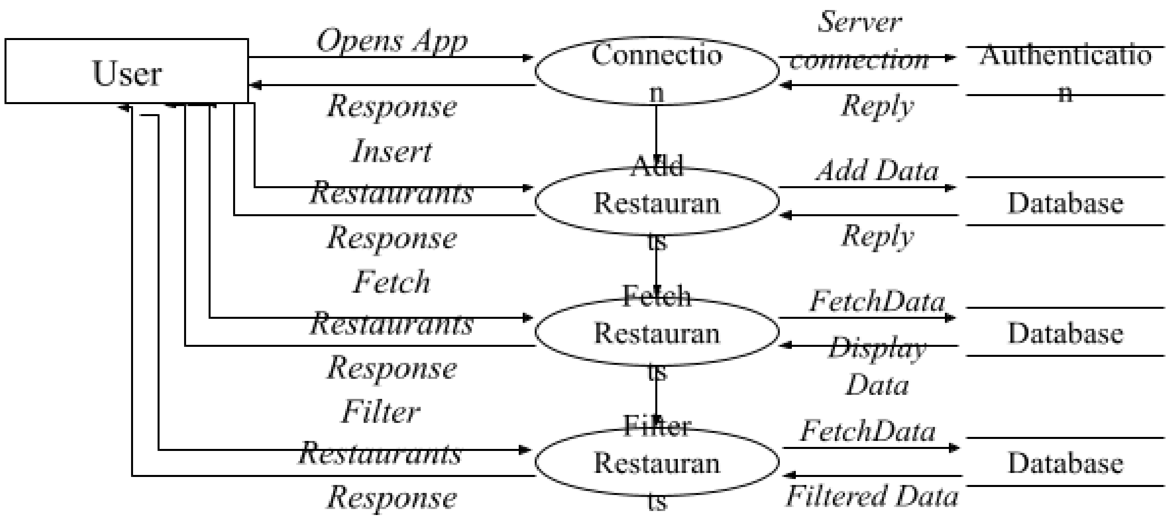


11) Appendix B : DATA FLOW DIAGRAMS

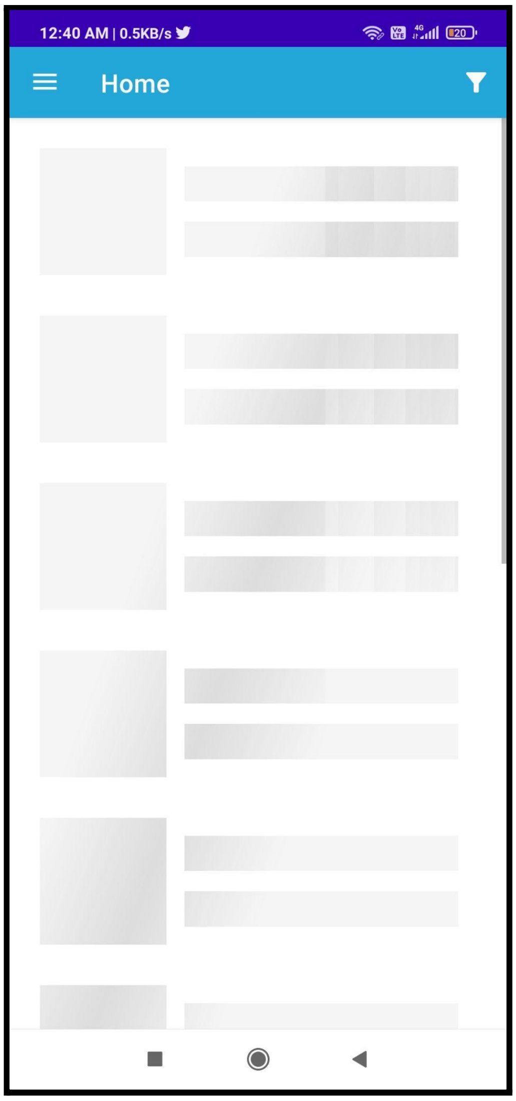
a) Data Flow Diagram Level-1

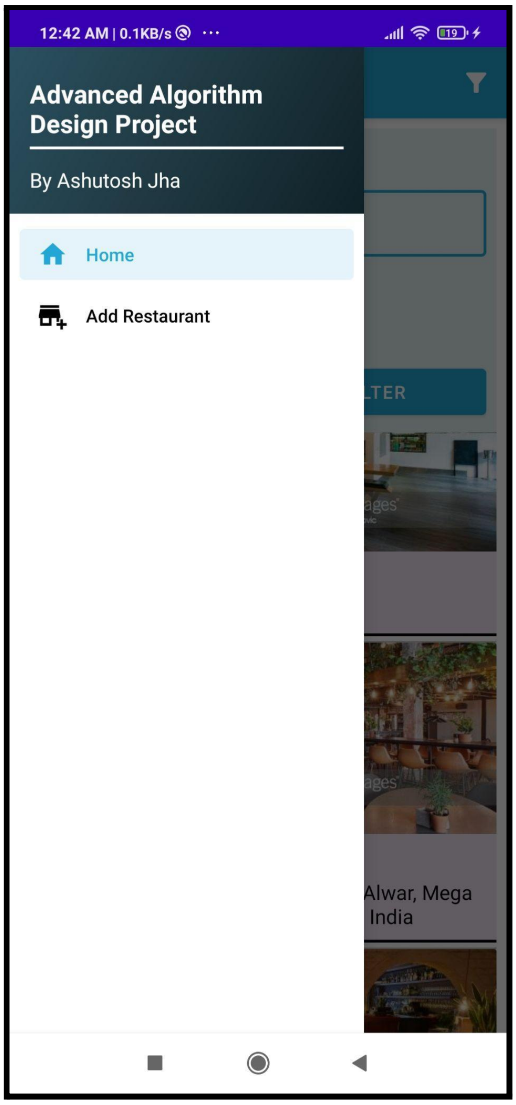


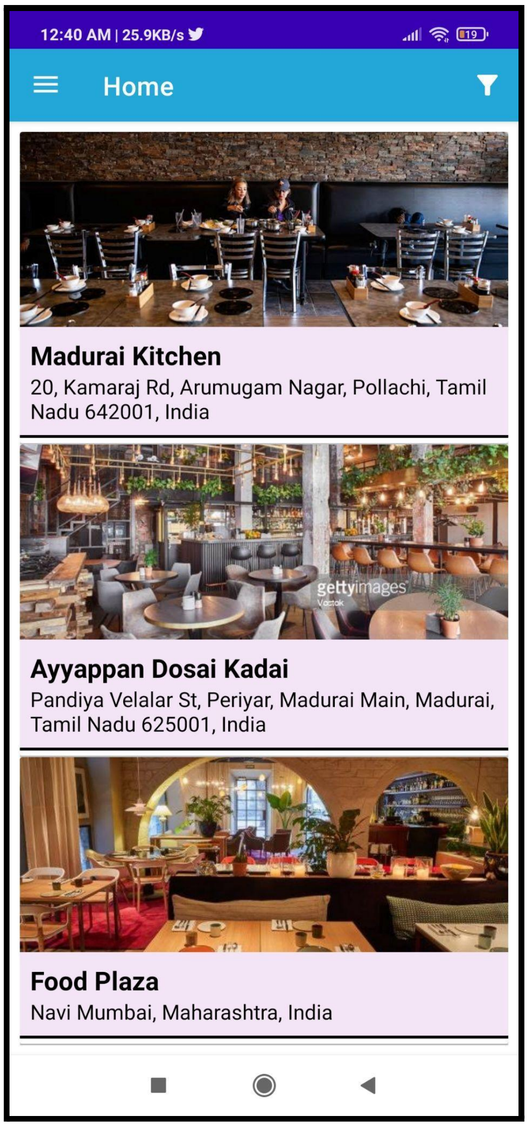
b) Data Flow Diagram Level-2



12) Appendix C : SCREENSHOTS





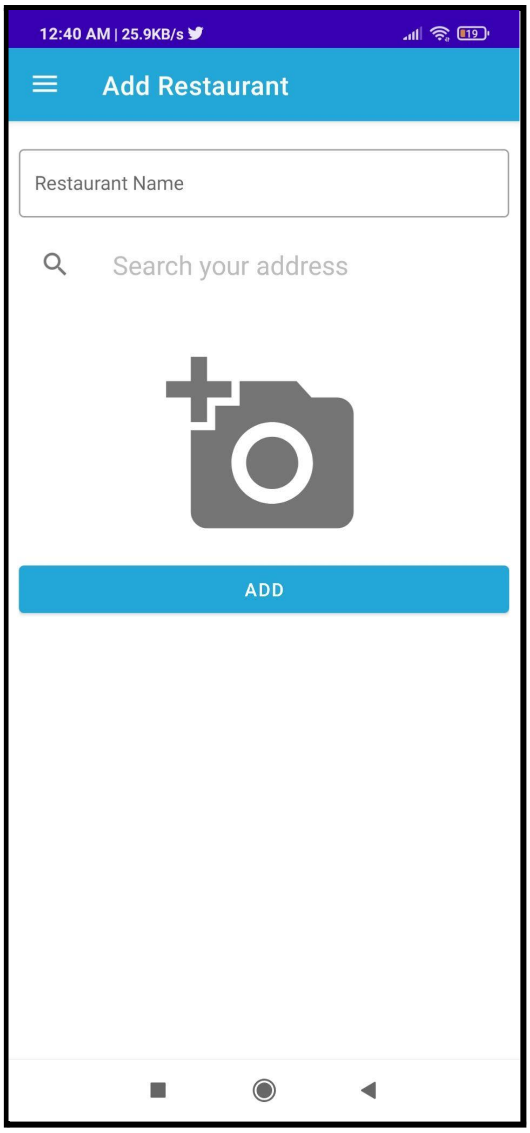

12:40 AM | 25.9KB/s

Home

Madurai Kitchen
20, Kamaraj Rd, Arumugam Nagar, Pollachi, Tamil Nadu 642001, India

Ayyappan Dosai Kadai
Pandiya Velalar St, Periyar, Madurai Main, Madurai, Tamil Nadu 625001, India

Food Plaza
Navi Mumbai, Maharashtra, India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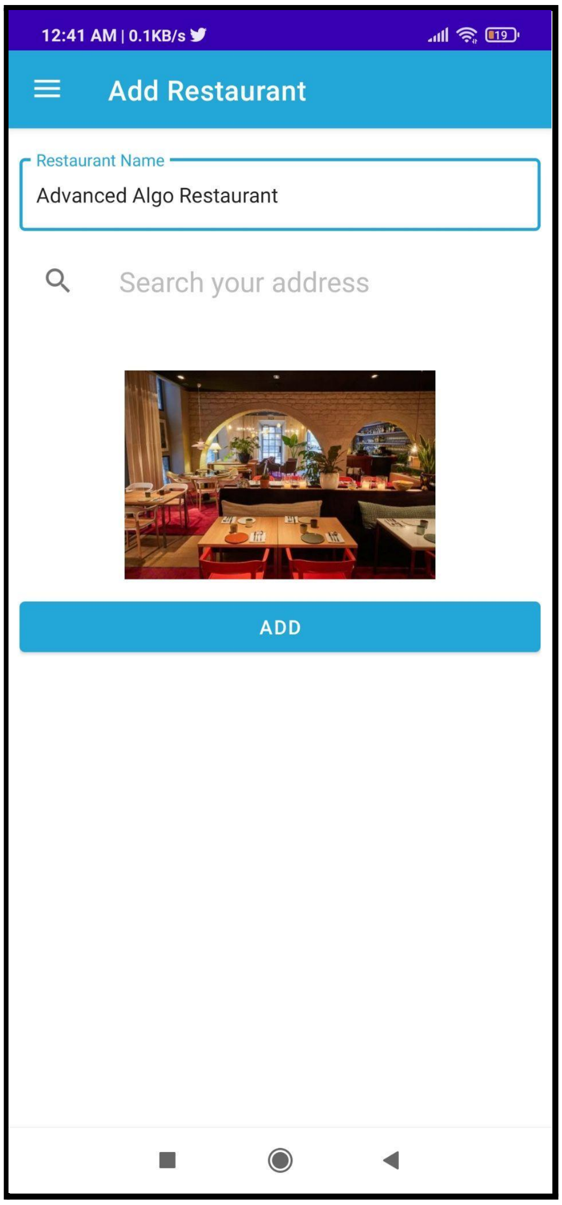
Add Restaurant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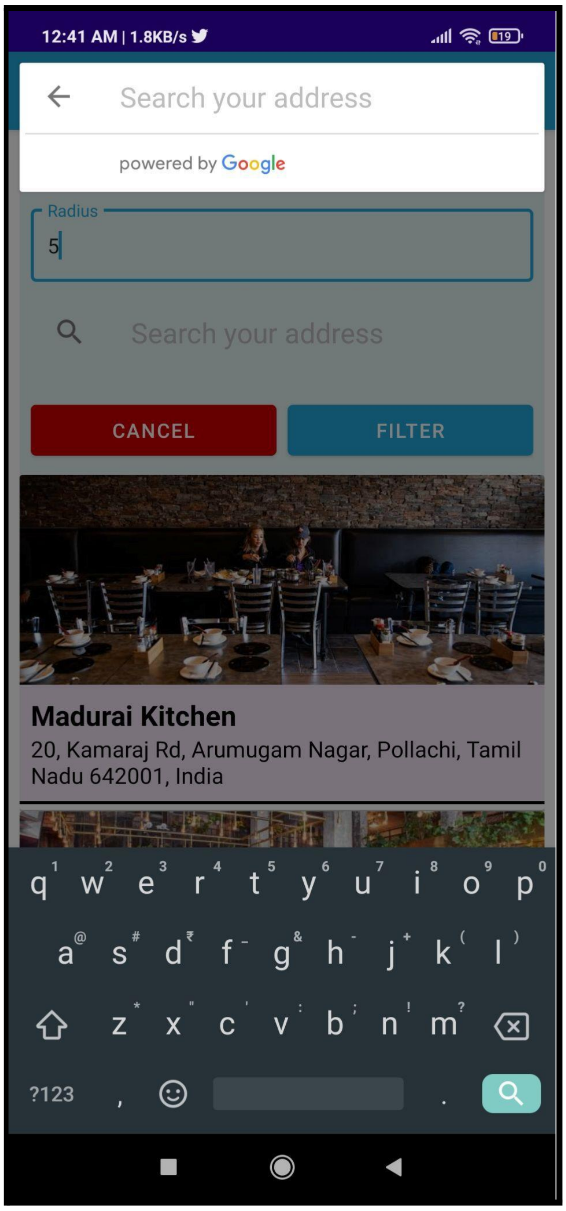
Add Restaurant

Restaurant Name
Advanced Algo Restaurant

Search your address

ADD


12:41 AM | 1.8KB/s

Search your address

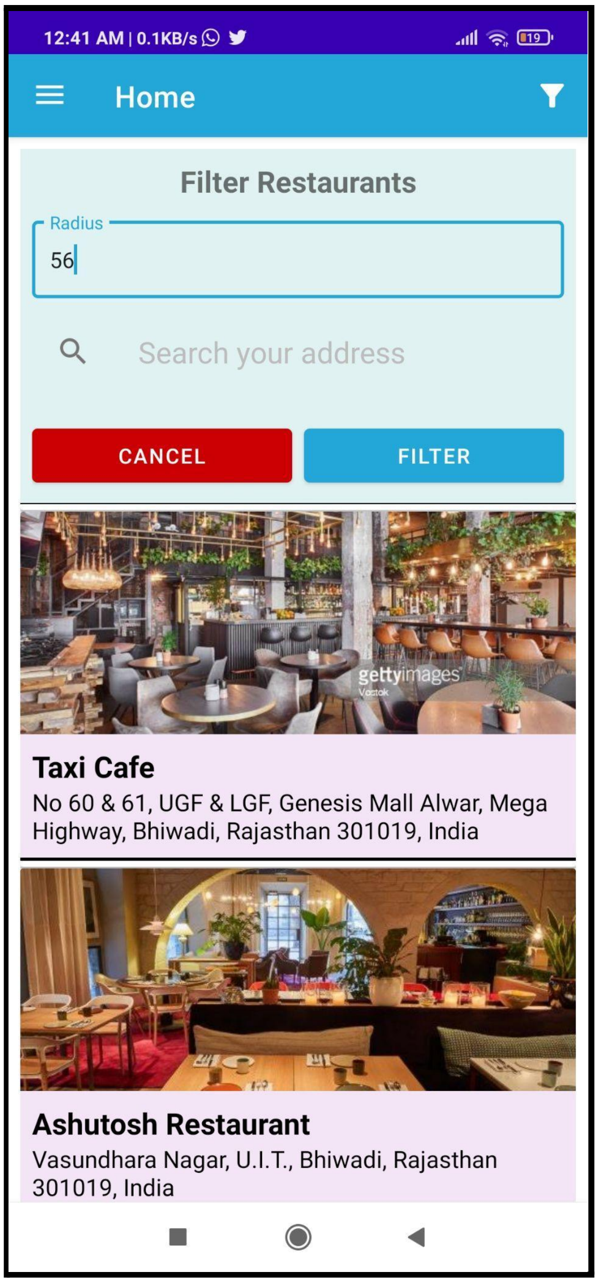
powered by Google

Radius
5

Search your address

CANCEL FILTER

Madurai Kitchen
20, Kamaraj Rd, Arumugam Nagar, Pollachi, Tamil Nadu 642001, India



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Home

Filter Restaurants

Radius

56

Search your address

CANCEL

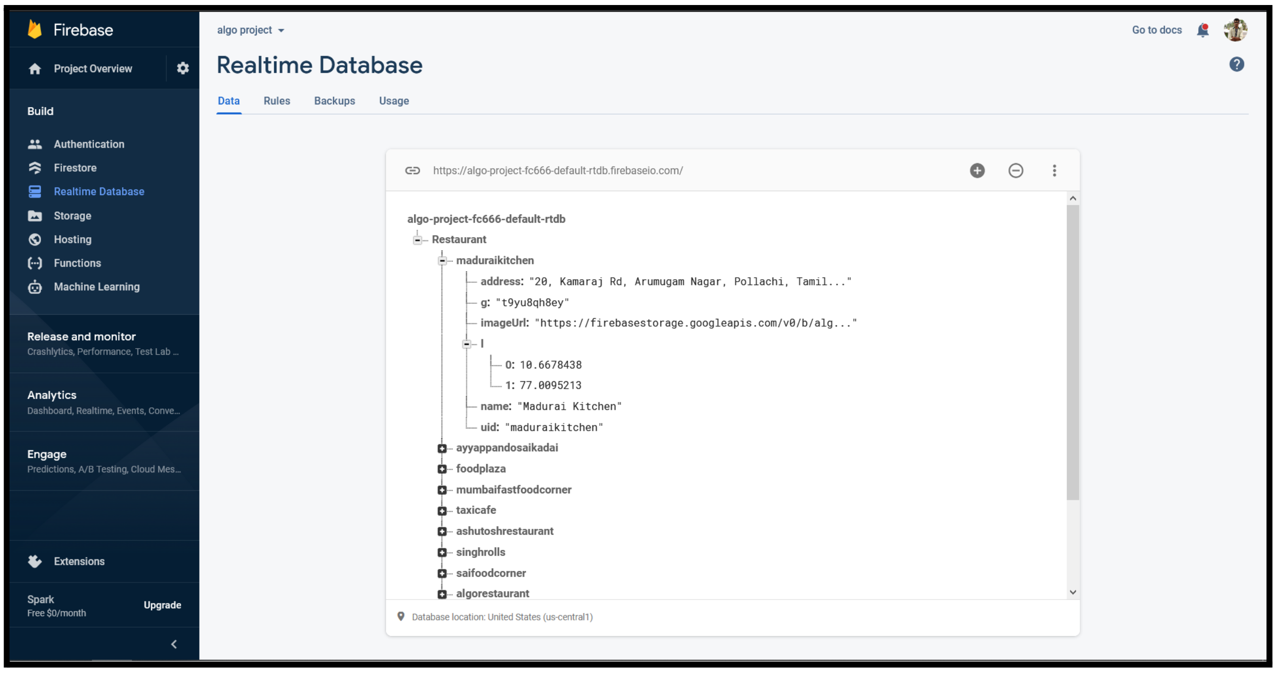
FILTER

Taxi Cafe

No 60 & 61, UGF & LGF, Genesis Mall Alwar, Mega Highway, Bhiwadi, Rajasthan 301019, India

Ashutosh Restaurant

Vasundhara Nagar, U.I.T., Bhiwadi, Rajasthan 301019, India



```
algo-project-fc666-default-rtdb
  Restaurant
    maduraikitchen
      address: "20, Kamaraj Rd, Arumugam Nagar, Pollachi, Tamil..."
      g: "t9yu8qh8ey"
      imageUrl: "https://firebasestorage.googleapis.com/v0/b/alg..."
      l
        0: 10.6678438
        1: 77.0095213
      name: "Madurai Kitchen"
      uid: "maduraikitchen"
    ayyappandosaikadai
    foodplaza
    mumbaifastfoodcorner
    taxicafe
    ashutoshrestaurant
    singhrolls
    saifoodcorner
    algorestaurant
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