Be Aware -Application for Measuring Crowds Through Crowdsourcing Technique in Makkah Al-Mukarramh

Olfat M. Mirza, **Israa Alharbi, Sereen Khayyat, Rawa Aleidarous, Doaa Albishri, Wejdan Alzhrani**

Department of Computer Science, College of Computer and Information Systems,
Umm Al-Qura University, Makkah, Saudi Arabia

Abstract
The world health organization classified the emerging coronavirus (known as Covid-19) as a pandemic after confirming the extent of spread and scale. As a matter of fact, outbreaks of similar scale or even worse have been witnessed throughout history. Thus, the development of prevention strategies exists to protect against such calamaties. One of the widely proven measures that controls the spread of any contagious diseases is social distancing. As a result, this paper will demonstrate the concept of an application "Be Aware" on enabling the implementation of this preventive measure. In particular "Be aware" evaluates the extent of congestion in public places using current time data. The proposed project will use Global Positioning System (GPS), and Application Programming Interface (API), to ensure information accuracy, and the API use Crowdsourcing to collect Real-Time Data (RTD) from the selected places. One line

Keywords:
Global Positioning System, Application Programming Interface, Real Time Data, Crowdsourcing and Makkah.

1. Introduction

From Social distancing is key to halting the spread of any health pandemic for example Covid-19 which is an infectious disease caused by a newly discovered coronavirus [1]. Social distancing is a method in public health aimed at stopping infected people from coming into close contact with healthy people in order to minimize disease transmission opportunities [1]. Social distancing is especially important for children, old people, people with cancer, and others with weakened immune systems. From the dangerous returns of the coronavirus outbreak, schools and universities have been closed, exams and events have been postponed, regular health information services are limited, and social contact with friends and the wider family is highly discouraged because of congestion, which is a key factor in the speed of the infection spreading and the possibility of getting infected is very high.

At this time of the global crisis, the objective of this research centered around making the community safer. So the main motivation is how can technology benefit the world? how can it help in dealing with the pandemic? how will technology improve the risk of crowding out? These thoughts pushed us to think about using technology to help to deal with the global crisis (covid-19).

From here came the idea of applying Be Aware application (app), we choose this name to express the awareness or consciousness about the congestion in public places among society members.

Consequently, this work will be focused more on measuring congestion in public places by Be Aware app and can be applied in many scenarios that support various consideration such as avoiding crowds in the times of pandemics (i.e., Covid-19), or due to health risk factors (i.e., weakend immunity), or simply just to avoid long waiting and queuing time. The search was conducted on Makkah city to help the vulnerable people in avoiding the crowded places especially in Hajj, which is the most crowded event in the year for Muslims, all Muslims from around the world come to perform the rituals of Hajj at the same time form different background, health issues, and cultures.

This paper will try to answer six research questions. The first and fundamental question is how to measure congestion in public places using mobile application? Also, how does the congestion to reduce the pandemic spread? what is the technique used or based on? why this technique is used? how such a technique will be applied? what is the technical tools support be aware application? these questions have been asked to help in the research direction and providing a path through the research and the writing process.

The development method used in the project is the iterative waterfall which is a model based on combine classical waterfall and iterative software developments, classical or pure waterfall is a sequential approach depend on the sequence of phases, each phase must be separate. One of the risks when using classical waterfall does not allow get back to the previous phase to fix the error and it will cost us a lot. The iterative waterfall is chosen because this approach is preceding phase which can be used to get back to previous phases to correct the error by feedback

Manuscript received February 5, 2022
Manuscript revised February 20, 2022
https://doi.org/10.22937/IJCSNS.2022.22.2.26

path if need it [2] [3]. The iterative waterfall development method phases are planning phase, analysis phase, design phase, implementation phase and testing phase. We have chosen this approach because we need to work by the scheduled plan for every phase and document at each phase in a formal way. Furthermore, it is widely adopted approach, simple and understandable.

After the introduction in Section 1, background related to the topic is discussed in Section 2. Next, Section 3 explains literature review which will touch on some previous studies related to calculating congestion in public places. In Section 4, the existing systems will be presented with several applications that similar to our application. In addition, Section 5 methodology will present the feasibility study that was conducted during the research, the system requirements and discusses the proposed solutions that contribute to helping reducing congestion in public places. Then, Section 6 present the use case diagrams and their explanation. Section 7 discusses major model of our system with details. Section 8 discusses the implementation of the proposed app. Section 9 present some type of testing of our app. Also, Section 10 details future work and finally, Section 11 presents the conclusion [4].

2. Background

The congestion is considered a big problem in current time, with an impact in many social and economic aspects, and the objective of this project is to measure congestion in public places and reduce it. Technology has always helped us to get easier life, so we work to adopt modern techniques and concepts to reduce congestion e.g., machine learning, crowdsourcing, real data time. The challenge is how to get accurate data in real-time and define the boundaries of public place then measure the extent of congestion in the places.

A. Crowdsourcing

Crowdsourcing is that the practice of engaging a ‘crowd’ or group for a typical goal — often innovation, problem-solving, or efficiency. Crowdsourcing can happen on many alternative levels and across various industries. Because of the growing connectivity, it's now easier than ever for people to collectively contribute — whether with ideas, time, expertise, or funds — to a project or cause [5]. Another definition of crowdsourcing means to collect data from a large number of people to get a better solution to a problem [5]. One of the powerful uses of crowdsourcing is crowd management, some researchers used crowdsourcing to improve the performance of an automatic crowd flow estimate method developed in the video and image processing laboratory at Purdue University, the research aims to estimate the crowd flow as accurately as possible in real-time [6]. There are other uses of this concept, for example, crowdsourcing has been utilized by non-profit organizations to develop their products (e.g. Wikipedia) [7], beyond that using Mobile crowdsourcing (MCS) as a crucial developing paradigm for enabling smart cities that combines the knowledge of dynamic crowds with mobile devices to enable decentralized ubiquitous services and applications [8]. Another one-off uses of crowdsourcing is in health surveillance, for example, Freifeld and colleagues worked on many applications of crowdsourcing that have been used for community diseases surveillance and epidemic outbreaks, such as HealthMap, which is a map displaying information for disease outbreaks in real-time, data sources, taken from "online news, eyewitness reports, expert-curated discussions and validated official reports"[9]. Also, crowdsourcing is currently being used for the reporting of crimes and the public's engagement in their possible resolution, sometimes without relying on government law enforcement organizations [10].

B. GPS

Global position system GPS is an electronic system that uses navigational satellites to locate an object such as a vehicle, person, etc. [11]. We will use GPS to determine locations of a large number of cellphone users, implemented by real-time data RTD which means information that is delivered immediately after collection, and there is no delay in the timeliness of the information provided [12]. RTD is often used for navigation or tracking that it uses to analyze traffic to improve the accuracy of crowds within public places predictions. It is about many users collecting, contributing, and verifying data. e.g., whenever a driver uses Google Maps to navigate, they are sending geolocation data to Google every minute.

C. API

Application Programming Interface API is simply the point of contact between a specific development environment and developers, in order to allow these developers to benefit from the services of this environment without the need to build everything from scratch; Developers don't need to know how an API is implemented [13]. In general, the goal of the API is to hide the details of encapsulation and highlight the way the code is used. There are several advantages that increase the desire of developers to use APIs, such as:

- Automation: with APIs, computers instead of people can manage the work. Through APIs, agencies can update workflows to form them quicker and more productive. More scope: with an API an application layer is often created which might be want to distribute information and services to new audiences which might be personalized to make custom user experiences [14].

- Efficiency: when access is provided to an API, the content generated may be published automatically and

is on the market for each channel. It allows it to be shared and distributed more easily [15].

- Integration: APIs allow content to be embedded from any site or application more easily. This guarantees more fluid information delivery and an integrated user experience.
- Personalization: through APIs, any user or company can customize the content and services that they use foremost.
- Adaptation: needs change over time and APIs help to anticipate changes.

When working with this technology, data migration is supported better, and therefore the information is reviewed more closely. In short, APIs make service provision more flexible.

3. Related Work

Feldman et al. presented Hajj Crowd Management, the researchers mentioned Hajj season is one of the huge gatherings in the world and employment modern technologies helped us to crowd manage it and control a gathering in Hajj season. The researcher used modern methods and technologies which are Wireless, Computer Vision, Spatial Computing, Data Analytics, Mobile Applications, Immersive Technologies, and Crowd Modelling and Simulation. this paper focuses on the utilization of technologies for improving crowd management during the Hajj season [15]

Sheikh et al. discussed an important topic that poses a great challenge is observing the crowd during the Hajj. In this paper, a specific crowd control framework called iCrowd is proposed. This frame provides a digital display of the crowd in near real time. It collects, identifies, elicits, analyzes, stores and retrieves real-time location information for each of the pilgrims (pre-registered participants) to determine and display the numbers of crowds (pilgrims) [16].

Minho Shin et al. presented location Privacy for Mobile Crowd Sensing, the researcher mentioned that the Crowd-sensing's concept is crowdsourcing of sensor data from mobile devices, and it is contributed to clarifying the initial picture of the workflow mechanism to move forward to realization project's idea. Moreover, it discussed an important issue that almost hinders preserving user privacy [17].

The author Kumarage mentioned how collecting data travel time, the researcher found many ways to collect data such ad from motion sensors or cameras, or Bluetooth sensors, pressure sensors, etc. This research focuses on travel time information obtained from Google Distance Matrix API based on method crowdsourcing. Most application maps such as google map used the travel time to suggest the best path and fastest it in real-time [18].

Van Bui et al. presented the detection GPS-Based Indoor/Outdoor using Machine Learning techniques paper, the researchers describe that the GPS signal is weakened in an indoor environment (inside buildings). GPS signal in an outdoor environment is stronger but tall buildings and mountains weaken and can even block GPS signals [19].

Martín et al. discussed how to use Wi-Fi Fingerprinting data for Indoor Positioning, the researchers presented a Wi-Fi RSS (Received Signal Strength) database created to foster and ease research works that address the problem of lack of robustness to short and long-time signal changes [20].

Abuarafah et al. discussed Real-time Crowd Monitoring by Infrared Thermal Video Sequences, the academics discussed a novel technique for crowd density and behavior estimation in real-time has been proposed. The proposed technique employs a far-infrared FLIR camera. The technique used is able to process the thermal camera output such as video sequences in real-time and produce an estimation of the crowd density [21].

4. Existing Systems

Through our research in applications, we found several applications those were similar to our application and help to identify how does congestion works in different practical places as shows in Table 1. These applications are Google Maps to measure traffic congestion, Crowdless to measure supermarket congestion, WaitlessCY to measure congestion in specific regions, and Al-Mutawf to measure congestion in various rituals of Hajj. We compared our application with other applications in following table based on some features added that support the implementation of the project's objectives.

Features	Google Maps	Crowdless	WaitLessCY	Al-Mutawf	Be aware
Provides precise, real-time data on crowdedness of public places	No	No	No	No	Yes
Provides notification service if the place is not crowded during a certain time	No	No	No	No	Yes
Provides information about the place	Yes	Yes	Yes	No	Yes
Allows users to add and save their favorite places	Yes	Yes	No	No	Yes
Suggest other places if the place is crowded	No	No	No	No	Yes
Provides a service for locating the closest places	Yes	No	No	No	Yes

Table 1: Differences between applications based on some features.

5. Methodology

A. Feasibility study

The data is collected through a questionnaire to find out the extent to which people need to know the crowding rates in public places to reduce and avoid crowding. An online survey has been created and distributed for our targeted sample to measure the impact of crowding in public places on the community in their lives. Also, to take an advantage to have good planning when going out and helping to save time and avoid risks. The survey was design as multiple choices and received about 338 responses that helped the research to summarize the requirement.

The most important questions that were asked in the survey:

1) Does congestion impact their daily life?, 2) Could crowding inside public places be a reason of any of the problems in your work/school life?, 3) What the extent of the effect that crowding in public places affects the spread of infectious diseases and exacerbation of health problems?, 4) Are you keep saving your time and take care of planning before going out?, 5) Does crowding affects your plans when going out to a specific place?, 6) Have you ever used a certain method to show you an estimate of the percentage of crowding in a particular public place?

Most of the responses based on the survey showed that:

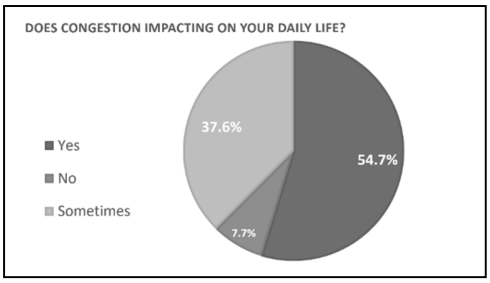

Fig. 1 Does congestion impact their daily life?

• Fig.1 shows 54.7% of user think the congestion impacting their lives.

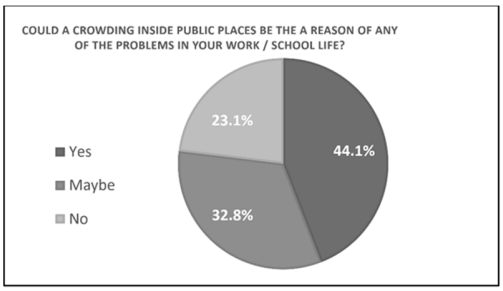

Fig. 2 Could crowding inside public places be a reason of any of the problems in your work/school life?

• Fig.2 shows 44.1% of users think that crowding is causing problems in their work/school life.

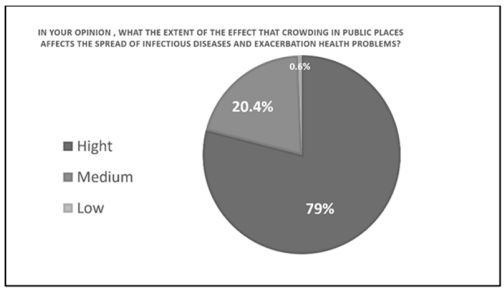

Fig. 3 What the extent of the effect that crowding in public places affects the spread of infectious diseases and exacerbation of health problems?

• Fig.3 shows 79% of users believe that crowding in public places greatly affects the spread of infectious diseases.

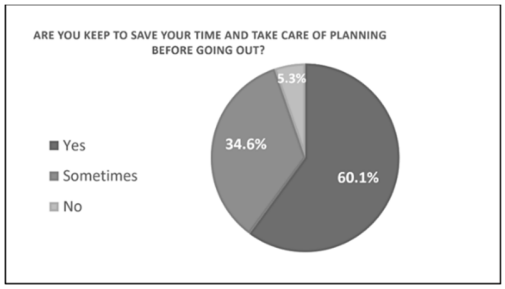

Fig. 4 Are you keep saving your time and take care of planning before going out?

• Fig.4 shows 60.1% of the users are keep saving their time and take care of planning before going out.

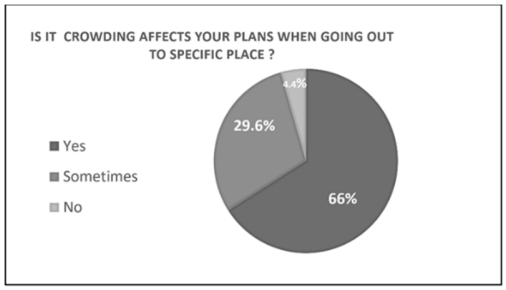

Fig. 5 Is it crowding affects your plans when going out to a specific place?

•Fig.5 shows 66% of users believe the crowding affects their plans when going out.

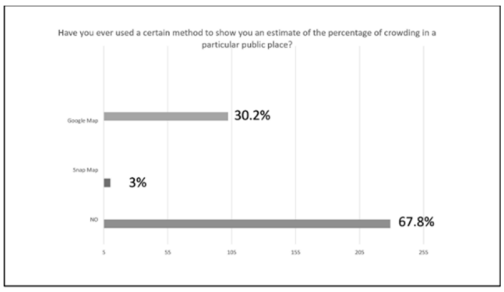

Fig. 6 Have you ever used a certain method to show you an estimate of the percentage of crowding in a particular public place?

• Fig.6 shows 67.8% of users have not used any method to show an estimate of the percentage of crowding in a particular public place.

Through the questionnaire, we reached the extent to which people need an application to help them avoid crowding. Most of the answers were that crowding affects their lives and increase the spread of diseases.

B. System Requirement

The system requirements are description of functionalities and features of the system. Also, it can explain the characteristics that needs to use in certain hardware or software and involves functional and non-functional requirements.

1) Functional requirements:

User requirements:

- The user shall create an account.
- The user shall use the application by their account.
- The user permit GPS to access its location.
- The user can find out how extended crowd within the public places.
- The user can search about detailed information of specific places.
- The user can view suggestion places when the chosen place crowed.
- The users can view their list of favorite places.
- The user can be informed when place is uncrowded.
- The user can find the nearest places.

2) Non-functional requirements:

- Look and feel requirements: the application shall display extent of crowd by color and percentage and the application should have a graphical interface.
- Usability requirements: the application shall be easy to learn and use for novice users, the use should be able to search for any public places, the application will send a notification, the application should show a helping guide and the application should send alert messages when it has error occurs.
- Security requirements: the application should have permission to GPS information access control from user, and the user information will be secure and protected.

C. Proposed Solutions

Be Aware application uses real data time (RDT) to determine the extent of crowded public places given a window period that reflects the current time depending on user GPS technology and real time APIs which display five states for the crowding in the map that appears to the user as percentage and color of fullness, which is (Low, below average, Average, Above average, High) to aim for the user's convenience and reduces the congestion in Saudi Arabia. The Application provide several services which are:

1. Search for the extent of crowd: Provides precise, real-time data on crowdedness of public places such as supermarket, café you can see it in the map as colored pointers refers to extent of crowd or choose specific place and see the extent crowd in pop up window. It also provides forecast data of the crowd during the days of the week in the form of a graph.
2. Display place information: Provides information about the selected location such as (place name, rating, location of the specified places, phone number of places, and website link).
3. Add Favorite's places: The user can specify favorite places for quick access to it and view it in favorite list.
4. Send notification: send a notification to inform the user that the place who wants to go is not crowded.
5. Display nearest places: Displays to user all the nearest places by type, all places that have same type are displayed in the map.
6. Suggesting places: view suggested places of similar type to the user when the chosen place is crowded.

6. Use Case Diagram

Use case Diagram is mostly used to model interactions between a system and external actors (users or other systems), use case diagram can summarize the details of your system's users (also known as actors) and their interactions with the system [22].

Our system has four actors which are (Users, GPS, API, Database) and eleven use cases are (Sign-In, Sign-Up, Determine the location, Display the nearest places, Find-out how extended crowd places, Display information about places, add favorite places, view previous notifications, View list of favorite places) shown in figure 7.

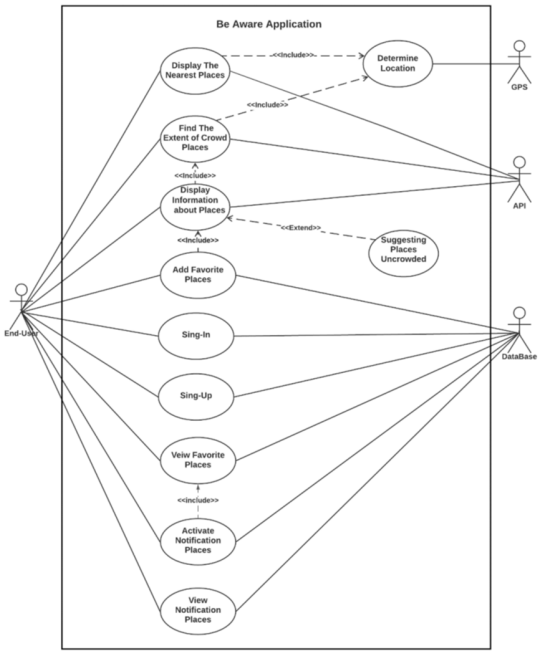

Fig. 7 Be Aware Use Case Diagram.

7. System architecture

Major Model represents the major components of a system. There are six main components of our system which are mobile application (Be aware), GPS, User, Firebase, Best time API, Google API shows in figure 8.

1. User authenticates whit creating a new account (sign-up) or login (sign-in) to use the app.
2. The app will notify the user for taking permission to use the current user location where the user must allow the app to access his/her location.
3. There are six main services of the app. It can be used if the user accepts the GPS permission:

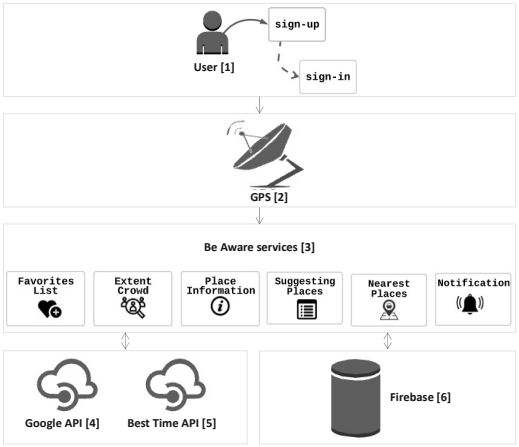

Fig. 8 System Architecture.

Extent crowd: Provides precise, real-time data on the crowdedness of public places.

Place information: Provides information about the selected location.

Favorite's list: Specify favorite places for quick access to the user and view the favorite places list.

Notification: Send a notification to inform the user that the place is not crowded.

Nearest Places: Displays to the user all the nearest places by type, all places that have the same type are displayed in the map.

Suggesting places: View suggested places of a similar type to the user when the chosen place is crowded.

4. Google API, the app used two APIs from Google: Map and Places. Map API will be used to get the map of Makkah city to locate the places and clarify the locations. Places API will be used to find detailed information about each place (name, rating, location of the specified places, phone number, and website link). Also, provides search for public places and locating the nearby places from the user location.
5. Best time API will be used to get the information about extent crowded places such as Bin Dawood supermarket.
6. Firebase will be used to store/retrieve user information, favorite places, and notifications.

8. Implementation

To implement the application, there are several software tools have been used: Android Studio, Firebase, APIs. we will explain them in detail:

Android Studio:

It is the Integrated and unified Development Environment (IDE) for Android app development it is a fast and feature-rich emulator where you can develop for all Android devices and extensive testing tools and frameworks [23].

Database:

Firebase platform (Cloud Firestore) is a platform developed by Google which is a database that allows creating more powerful and secure applications. It has been used because it's a flexible and scalable mobile, web, and server development database from Firebase and Google Cloud. Also provides a Firebase real-time Database, where keeps data in-sync across client apps through real-time listeners and offers offline support for mobile and web so you can create responsive apps that run regardless of network latency or internet connection [23]. Firebase has been connected to the application by **Firebase class** which is containing references of firebase to check if the account already exists in the Database by email.

API:

You might wonder what is API? API allows the application to access data and interact with external software components. Be Aware application used several APIs to accomplish the app aim, such as Google API and BestTime API.

Google Cloud Platform:

Is a suite of public cloud computing services offered by Google. The platform includes a range of hosted services for compute, storage and application development that run on Google hardware. Google Cloud Platform services can be accessed by software developers, cloud administrators [24].

Using API keys:

Fig 9 API key.

In Fig.9, Once you create an account and subscribe to Google Cloud Platform; an API key is given which is a simple encrypted string that identifies an application without any principal. They are useful for accessing public data and are used to associate API requests with our project [25].

Also, we need to enable two API from Google Cloud as follows:

1. **Maps SDK for Android**

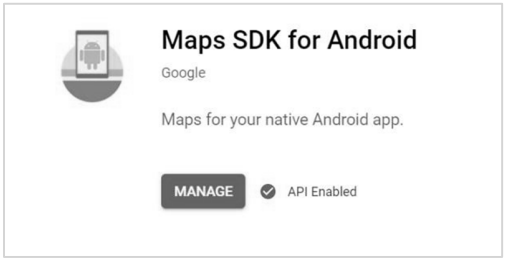

Fig. 10 Enable Maps SDK.

Fig 10 shows Maps SDK for Android to add maps based on Google Maps data to our application with the Maps SDK for Android. The SDK automatically handles access to Google Maps servers, map display, and response to user gestures such as clicks and drags [26].

2. **Places API**

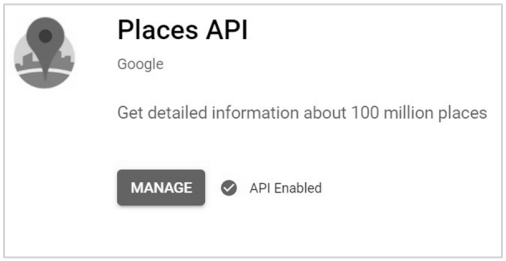

Fig. 11 Enable API key.

Figure 6.14, Places API to Get data from the same database used by Google Maps to show place details [2], which also was used to accomplish nearby places and suggestion services.

BestTime:

BestTime API is a web (API) service that forecasts how busy a public business (e.g., restaurant, gym, etc) will be at any given hour of the week.

API Key:

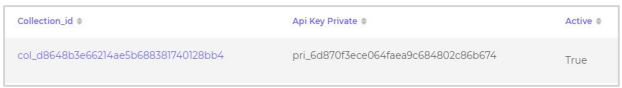

Fig. 12 BestTime API key.

Fig. 12 shows the BestTime API written by JSON formula, so it includes all requests to the server by using JSON-encoded POST and return JSON-encoded responses. To access data must have a key. BestTime API uses API keys

to allow access to the API. So, we generate API keys at the API keys Management [27].

Theirs is two types of data provided by BestTime, forecast data and live forecasted data [27].

1- Forecast data:

Forecast data is data that was collected and analyzed depending on the business of the week. The Data in the forecasts represent an approximate how busy a business will be in a relative number. Each hour of the week is rated on a five-point scale (Low, below average, average, above average, high) [28].

Below shows the Forecast responses attributes:

• **Analysis** list

List with an analysis object for each day of the week, the list contains days object and are sorted on day of the week: day_int 0 (Monday) to 6 (Sunday).

• **Hour_analysis** list

List with hour objects, containing details per hour.

• **Intensity_nr** int

Hour intensity_nr indicates how busy the venue is on a scale of 5, ranging from -2 to 2. When the venue is closed at the given hour it indicates 999.

• **Intensity_txt** string

Hour intensity_txt indicates how busy the venue is on a scale of 5. The intensity is either (-2 Low, -1 Below average, 0 Average, 1 Above average, or 2 High). When the venue is 999 closed at the given hour it indicates Closed.

2- Live data:

Is Real-time information with live data. includes how active the place currently is, how much more, or less busy it is compared to the historical average for that hour. Is expressed as a percentage. The percentage is relative to the typical visitor peak for the busyness for the week. The percentage could even be higher than 100% when it is currently more crowded than the forecasted peak of the week [28].

In the following the Live data responses attributes:

• **Analysis** object

Object with live analysis details.

• **Venue_live_busyness** int

Live busyness at the venue for current, based on the weekly forecast. Ranging from 0 to 200 percent. In most cases, the live percentage will be 100% or lower. However, if the value is above 100% it means it is busier than the highest forecasted peak of the week. E.g. 200% meaning it is two times busier than the normal forecasted peak of the week.

• **Venue_live_busyness_available** boolean

Indicates if there is live data available for this venue at this moment.

• **Venue_live_forecasted_delta** int

Indicates the difference of the current live busyness versus the forecasted busyness for this hour, in percentage. A negative number indicates that is less busy than normal, while a positive number indicates that it is more busy than normal. Ranging from - 100 to 100.

After receiving the congestion data (Forecast, Live), the congestion state is determined according to the following: 0-20 for Low status, 21-40 for Below average status, 41-60 for Average status, 61-80 for Above average status, 81-200 for High status and other than that for Closed place.

9. Testing

The application has been verified to discover any bugs or things that don't meet the project requirements and ensuring that the project work as expected, it has been verified by doing several kinds of tests which are unit testing, integration testing, and system testing that include usability testing. Testing is executing a system in order to identify any gaps, errors, or missing requirements contrary to the actual requirements.

The testing process has two distinct goals: First, to demonstrate to the developer and the customer that the software meets its requirements. Second, to discover situations in which the behavior of the software is incorrect, undesirable, or does not conform to its specification. The specification of a system to identify equivalence partitions was used, this called 'black-box testing'. Here, you don't need any knowledge of how the system works. Black Box Testing is a software testing method in which testers evaluate the functionality of the software under test without looking at the internal code structure.

The first test that was implemented is Unit testing is a type of software testing where individual units or components of the software are tested. The purpose of a unit test is to ensure that the module or program performs its function as defined in the program specification [29]. The sound test was Integration testing is a type of testing where a set of modules or programs must work together without error. They ensure that the interfaces and linkages between different parts of the system work properly [29]. The purpose of this level of testing is to expose defects in the

interaction between these software modules when they are integrated [30]. There are four approaches to integration testing: user interface testing, use scenario testing, data flow testing, and system interface testing [30]. This project concentrates to use scenario testing, it is done by moving through each use scenario to ensure that it works correctly. The third provided test was Usability testing is one of system testing refers to evaluating a product or service by testing it with target users, to measure the software if it is useful and usable. The testing is used with prototypes or systems that are completed and waiting for installation. The goal is to identify any usability problems, determine the participant's satisfaction with the product, and collect feedback from the target users to fix problems before launching the software. We conducted usability testing by first defining the tasks that will be evaluated by the target users, then selecting the test participants, conducting the test, and finally analyzing and documenting the findings. [29] [31]

After doing the testing and conducting the survey and analyzing its results, we found that the application works well and won the admiration of the users, but the semantics of the application need to be clearer and the users mentioned a suggestion to create a Version for the iPhone, this idea we mentioned in the future plan of our application.

10. Future Work

In the future, we are thinking about applying our improvement plan to make the application more adequate than it is and to include more utilities that reduce the congestion in public places. Our plan starts with measuring the congestion in other public places on a wider field, also collecting data from more than one source and use Kalman filter to make the information more accurate, other solutions to make data extent more accurate through creating our API that gets real data time in specific places by the sensor inside the public places, furthermore expansion and inclusion of most stores and important centers in the neighborhoods of Makkah, expanding the field of congestion measurement throughout the Kingdom of Saudi Arabia, and implement an IOS version of the application.

11. Conclusion

In this work, we represent an idea of how to use crowd-sourced data to estimate the extent of congestion in public places. There are several opinions about how to measure congestion and what is the best technique to use. We are as application developers, prefer to use the APIs technique, which is one of the optimum ways used to test congestion using crowdsourcing techniques because they are using many ways to collect data, also the data collected from anonymous cellphones provide security for the user's information. Basically, the work was built on android application; where linked it with several APIs to fetching data and then processing that data to estimate the extent of places congestion and display detail information for it, in addition to provided many other services that help achieving the desired goals. This paper has not only provided a mobile application, but took a look at other technologies that used to collect real-time data, each of them has negative side and positive side. On the other hand depends what can be used on your knowledge, abilities and the type of project will be worked on.

References

[1] World Health Organization, Coronavirus, viewed 8 June 2021(https://www.who.int/health-topics/coronavirus#tab=tab_1)

[2] Sommerville, I.: *Software* Engineering, Nine Edition, Addison Wesley, New York. (2011)

[3] Gharajeh, M.: *Waterative Model: An Integration of the Waterfall and Iterative Software Development Paradigms*, Tabriz, Iran. (2019)

[4] Pearce, K.: *What is social distancing and how can it slow the spread of COVID-19*, Johns Hopkins University, March 2020. (https://splg.org/wp-content/uploads/2020/03/what-is-social-distancing-and-how-can-it-slow-the-spread-of-COVID-19-johns-hopkins.pdf)

[5] Wazny, K.: *Applications of crowdsourcing in health: an overview*, vol 8, (2018) (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5840433)

[6] Delp, E., Torres, L.: *Automatic crowd flow estimation enhanced by crowdsourcing*, UPC University and Purdue University (2014), (https://upcommons.upc.edu/)

[7] *Taeihagh, Araz.: Crowdsourcing, Sharing Economies, and Development*, *Journal of Developing Societies. 33 (2), (2017).*

[8] Kong, X., Liu, X., Jedari, B., Li, M., Wan, L. Xia, F: *Mobile Crowdsourcing in Smart Cities: Technologies, Applications, and Future Challenges*, IEEE iInternet of thing journal, Vol. 6, No. 5, (2019)

[9] HealthMap, *About HealthMap*, (2007), viewed 7 October 2020, (https://healthmap.org/about/)

[10] Arolas, E.: *Using crowdsourcing for a safer society: When the crowd rules*, European Journal of Criminology (2020)

[11] Collinsdictionary, Definition of 'GPS', viewed 20 September 2020,(https://www.collinsdictionary.com/dictionary/english/gps).

[12] Rai, R.: Socket. IO Real-Time Web Application Development, First Edition, Packt publishing, Birmingham (2013).

[13] IBM Cloud Education, what is an Application Programming Interface (API), IBM, (2020) (What is an Application Programming Interface (API) | IBM)

[14] Android Developers, Meet Android Studio, (2019) viewed 9 November 2020,(https://developer.android.com/studio/intro)

[15] Felemban, E., Rehman, F., Biabani, S., Ahmad, A., Naseer, A., Abdul-majid, A., Hussain, O., Qamar, A., Falemban, R. , Zanjir, F.: *Digital Revolution for Hajj Crowd Management:A Technology Survey*, vol. 8, (2020)

[16] Saeed, S., Abid, A., Waraich, E., Atta, SH., Sheikh, A., Felemban, E.: *iCrowd - A Framework for Monitoring of identifiable Crowd*. International Conference on Innovations in Information Technology (2016)

[17] Shin, M. Cornelius, C., Kapadia, A., Kotz, D., Triandopoulos, N.: *Location Privacy for Mobile Crowd Sensing through Population*

Mapping, MDPI Sydney, Australiaa, vol. 15, pp. 15285-15310, (2015)

[18] Kumarage, S.: *Use of Crowdsourced Travel Time Data in Traffic* Engineering Applications," University of Moratuwa, Sri Lanka, (2018)

[19] Bui, V., Tuan Le, N., , Luan Vu, T., Nguyen, V., Jang, Y.: *GPSBased Indoor/Outdoor Detection Scheme Using Machine Learning Techniques,* Kookmin University, Seoul, Korea, vol. 10, no. 2, p.500, (2020)

[20] Mendoza-Silva, D., Richter, P., Torres-Sospedra, J. Lohan, E., Huerta, J.: *Long-Term WiFi Fingerprinting Dataset for Research on Robust Indoor Positioning,* Data, vol. 3, no. 1, p. 3, (2018)

[21] Abuarafah, A., Khozium, M., AbdRabou, E.: *Real-time Crowd Monitoring using Infrared Thermal Video Sequences*, Umm Al-Qura University, Makkah, Saudi Arabia, pp. 1545-1003, (2012)

[22] lucidchart,2021, UML Use Case Diagram Tutorial, viewed 16 April 2021, (https://www.lucidchart.com/pages/uml-use-case-diagram)

[23] Firebase. (n.d.). Firebase Products viewed 9 November 2020, (https://firebase.google.com/products).

[24] Google Cloud, Google Maps Platform, viewed 15 November 2020, (https://cloud.google.com/maps-platform/maps).

[25] Google Cloud, Google Maps Platform, viewed 15 November 2020, (https://cloud.google.com/maps-platform/maps).

[26] Google Cloud, Places, viewed 15 November 2020, (https://cloud.google.com/maps-platform/places).

[27] besttime.app. ,BestTime.app , introduction, viewed 11 November 2020, (https://documentation.besttime.app).

[28] besttime.app. ,BestTime.app ,Forecast popular times of public businesses, viewed 11 November 2020,(https://besttime.app/).

[29] P. Ltd., 2018, Software Testing, viewed 25 March 2021 (https://www.tutorialspoint.com/software_testing/software_testing_tutorial.pdf)

[30] Wiley, J., Sons, System Analyses and Design,2012 (https://www.saigontech.edu.vn/faculty/huynq/SAD/Systems_Analysis_Design_UML_5th%20ed.pdf)

Usability.gov,2021, Usability Testing, viewed 25 March 2021,(https://www.usability.gov/how-to-and tools/methods/usability-testing.html)