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UTM's Groundbreaking COVID-19 Tracker for Strategic Pandemic Preparedness (UTMCCTA)

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***Abstract*—COVID-19 (novel coronavirus disease) is one of the most lethal viruses of this decade. Infected people with mild to moderate respiratory issues might have slight side effects due to the virus. However, senior individuals and individuals with serious medical problems like cardiovascular disease, serious lung disease, diabetes, or cancer, on the other hand, are considerably more likely to develop serious illnesses. Because the virus spreads via physical touch as well as through air droplets, it's critical to maintain tracking of everyone on the UTM campus, including UTM students and employees who come into contact during working hours. As a result, the UTM COVID-19 Contact Tracing System (UTMCCTA) was developed to address this problem. UTMCCTA is an automatic system that tracks contacts and notifies them if someone on their contact list tests positive for COVID-19. This program includes two user interfaces: one is a mobile app that UTM students use to automatically scan for nearby contacts, and the other is an online website that UTM Health Authorities and administrators will utilize. UTM health officials can look up a user and change their COVID-19 status from negative to positive, and vice versa. This will immediately notify any users with whom the infected person has been in touch. Furthermore, users can actively contribute to UTM's strategic preparedness by manually entering their daily commute location. This data enhances our capacity to respond proactively. Moreover, when a user contacts another user, their contact location and time are stored in the database. This information is solely accessible to the administrator, who may evaluate it and issue a locational hotspot notice to all users enrolled in the system. This innovative approach ensures that UTM is at the forefront of pandemic preparedness and response.**

***Keywords*—Coronavirus, contact tracing, Flutter, web, mobile**

I. INTRODUCTION

COVID-19 (novel coronavirus disease) is one of the most lethal viruses of this decade. Recognizing the need for not just containment but also strategic pandemic preparedness, we have developed the UTM COVID-19 Contact Tracing System (UTMCCTA). Infected people with mild to moderate respiratory issues might have slight side effects due to the virus. However, senior individuals and individuals with serious medical problems like cardiovascular disease, serious lung disease, diabetes, or cancer, on the other hand, are considerably more likely to develop serious illnesses. Because the virus spreads via physical touch as well as through air droplets, it's critical to maintain tracking of everyone on the UTM campus, including UTM students and employees who come into contact during working hours. UTMCCTA is an automatic system that tracks contacts and notifies them if someone on their contact list tests positive for COVID-19. This program includes two user interfaces: one is a mobile app that UTM students use to automatically scan for nearby contacts, and the other is an online website that UTM Health Authorities and administrators will utilize. UTM health officials can look up a user and change their COVID-19 status from negative to positive, and vice versa. This will immediately notify any users with whom the infected person has been in touch. Furthermore, users can actively contribute to UTM's strategic preparedness by manually entering their daily commute location. This data enhances our capacity to respond proactively. Moreover, when a user contacts another user, their contact location and time are stored in the database. This information is solely accessible to the administrator, who may evaluate it and issue a locational hotspot notice to all users enrolled in the system. This innovative approach ensures that UTM is at the forefront of pandemic preparedness and response.

Our university has many students living on and off-campus, as well as employees and cleaners who come to campus every day for their respective jobs. Students also visit school offices or other administrative offices from time to time for a variety of reasons. Most notably, when face-to-face classes start, students from all over Malaysia, as well as overseas students from all over the world, will start to arrive on campus, therefore UTM has to make available for digitalized system to track who these students have encounter if one of them becomes contagious with COVID-19. As a result, to limit the spread of COVID-19 on the UTM campus, a computerized contact tracing system is necessary. This will also help to prevent fear and keep students and workers informed about what is going on campus.

II. Related work

Previously during pandemic, the standard operating procedure for entering a premise in UTM is to scan QR codes with UTM SMART or MySejahtera applications, but if a student becomes infected, he or she must go through a laborious procedure to identify all the persons with whom he or she has been in contact in the last few days. However, it is useless since, according to the World Health Organization (WHO), COVID symptoms appear after 5 to 6 days or a maximum of 14 days incubation period, thus a person cannot identify every single individual with whom he or she has been into contact during the previous 14 days [1-2]. As a result, a mobile application is required to automatically scan for contacts, eliminating the requirement for students to scan QR codes regularly. It is also a difficult job for our campus health experts to monitor and record the identities of everyone with whom the sick person has had contact. As a result, a web-based application is required to conveniently search an infected user's contacts and deliver automatic notifications.

The current COVID-19 prevention and scanning system in UTM is based on the MySejahtera application developed by the Malaysian government and a manual contact tracing method that happens inside the UTM clinic. MySejahtera is a Malaysian government app designed to prevent the rise of the new Coronavirus or COVID-19. UTM Digital had to register for the MySejahtera Check-In function for each office and food court on campus. After successful registration, a QR code was issued for each premise, which those premises had to print and place in front of the premise for visitors, students, or employees to scan. Three distinct types of QR codes are now accessible on campus. Color-coded QR codes are available for campus staff, students, and visitors. The QR code for campus employees is blue, the QR code for students is pink, and the QR code for visitors is white.

A comprehensive systematic review on digital contract tracing technology has been done in [3,4,5]. However, we focus our comparison based on the official contact tracing applications from different countries. Our emphasis is on the functionalities suitable for contact tracing software, rather than on the technologies themselves. Table I, shows a detailed analysis of several contact tracing mobile applications including above mentioned MySejahtera and their features. From the comparison of TraceTogether [6], NZ Covid Tracer [7], Ireland Covid Contact Tracer [8] and also MySejahtera [9]. The comparison shows that the existing systems still lack better user data management, locational hotspot notifications, automatic exposure notification alerts if a person tests positive in the user's contact list, background operations in the mobile applications for the longer tracing period, automatically gathering two user's contact location and provide user a log of locations they have visited manually. Further investigation also has been done into how the contract tracing work [10,11] and the technical concept involving global positioning [12].

TABLE I. Comparison of Existing System

Application Feature	Applications			
	Trace together	***NZ COVID tracer***	***Ireland COVID Contact Tracer***	***My Sejahtera***
Technology Used	Uses Bluetooth (GATT, BLE), GPS, BlueTrace Algorithm, WIFI or Cell, SQLite database.	Uses QR Scanner, Bluetooth (BLE), Google nearby connections, GPS, WIFI or Cell, Cloud Database.	Uses Bluetooth (BLE), GPS, Google nearby connections API, WIFI, or Cell. unknown database, Random IDs.	Uses GPS, QR Scanner, COVID case count API, WIFI or Cell, Firebase database.
Contact tracing method	Traces nearby contacts using Bluetooth (GATT, BLE)	Uses Bluetooth to scan for contacts	Uses Bluetooth to transmit Random IDs and GPS to alert users if there is any nearby COVID-positive user	Does not do contact tracing
Locational data	No location data is recorded	Uses QR code scan for location entry, has a manual entry for users when there are no QR posters	Not specified	Uses QR code scan for location entry
Data management	Delete contacts older than 25 days	Deletes contacts older than 60 days	Not Specified	Not Specified
Background Operation	Does not run in the background, needs to keep the app open to	Not specified	Not Specified	Does not run in the background

Application Feature	Applications			
	Trace together	***NZ COVID tracer***	***Ireland COVID Contact Tracer***	***My Sejahtera***
	working			
Ease of Use	Does not turn on Bluetooth automatically, needs to turn on GPS (Trace together website, 2020).	Not specified	Automatically turns on Bluetooth. Needs to turn on GPS (Our Health Service, 2020)	Does not use Bluetooth technology
Contact with users	Contacts with a user if someone from their contact list is tested positive for COVID-19	Sends notification and Contacts with a user if someone from their contact list tested positive for COVID-19	Sends a notification informing the user about potential exposure and contacts with a user if someone from their contact list is tested positive for COVID-19	Sends general health notification, and puts the premise and all users in the premise under quarantine if a COVID-19 tested positive user visits that location
Location hotspot alert	Not Specified	Not Specified	Not Specified	Has hotspot search feature up to one kilometer

III. Methodology

Methodology for developing UTMCCTA is comprised of the proses model used for the development and the phases in the development. The phases comprised of user requirements, architecture design, implementation and lastly the testing for UTMCCTA. RUP is a process model which is largely utilized in the development of web-based applications. It is also frequently used for online apps, webpages, and mobile applications. RUP provides several benefits and tools that may be utilized during the software development process. It divides the development process into four stages: business modeling or inception, analysis, and design or elaboration, execution or construction, testing, and delivery, or transition. Each of these iterations may have multiple iterations or phases of its own.

For UTMCCTA the business context, which comprises the success drivers, and initial system planning was defined in this phase. To supplement the business case, a simplified use case model, project timeline, and project summary were developed. Another major objective of this phase is to obtain consensus from stakeholders. There are two iterations in the inception phas, two more iterations in elaboration phase, three iterations in construction phase and two more iterations in transition phase.

A. Inception phase

Iteration One: The problem foundation for UTMCCTA has been identified in this iteration, along with the system's scope, system's objective, importance, and approach. In addition, for UTMCCTA, this phase included a listing of all activities based on the methodology chosen. Finally, an interview with the selected stakeholders was performed, as well as a user survey and interview, to better understand the needs.

Iteration Two: During this iteration, comparisons between existing systems inside UTM were made. Along with that, several mobile system comparisons have been performed to improve the system.

B. Elaboration phase

Iteration One: In this iteration, the Software Requirement Specification (SRS) and Software Design Description (SDD) for UTMCCTA have been completed. In this iteration, test cases for the planned UTMCCTA system were also built.

Iteration Two: The review procedure for SRS, SDD, and STD, has taken place in this iteration.

C. Construction phase

This is the stage where most of the code for UTMCCTA was done. Multiple construction iterations were generated in bigger programs to split usage cases into manageable pieces, resulting in tangible prototypes. There are three iterations in the building process.

Iteration One: In this iteration, the creation of the database collections has been done, as well as the establishment of connections with the IDE and system.

Iteration Two: The front-end development for the mobile application and web application was finished in this iteration following the UI design.

Iteration Three: The review procedure for the system's front end and the back end has been completed in this iteration.

D. Transition phase

The goal of this phase was to transition the UTMCCTA system from the development stage to the testing stage. Blackbox testing has been done using the test cases that were generated during the Elaboration phase. There were two iterations in the transition phase.

Iteration One: Black box testing was performed in this iteration following the test cases specified in the Software Testing Document (STD). Following that, internal and beta testing was conducted with a small group of users.

Iteration Two: Following iteration one, the entire report was prepared, and the review procedure was carried out.

IV. User Requirements and Architecture Design

From the user survey and interview with the stakeholder, there were functional requirements and non-functional requirements were identified. Among them the key functional requirements for UTMCCTA were, to submit a form with user data by the user during the registration, submit a health status declaration form by the user during registration, Allow the user to start and stop the contact tracing, Give the user option to manually keep a log of visited location, the user should receive a contact exposure alert each time contact from their traced contact list gets diagnosed with COVID-19, the user should receive a locational hotspot alert form the admin, the UTM health authority can access the user's Fig. 1 shows the use case diagram for UTMCCTA which represent its functional requirements.

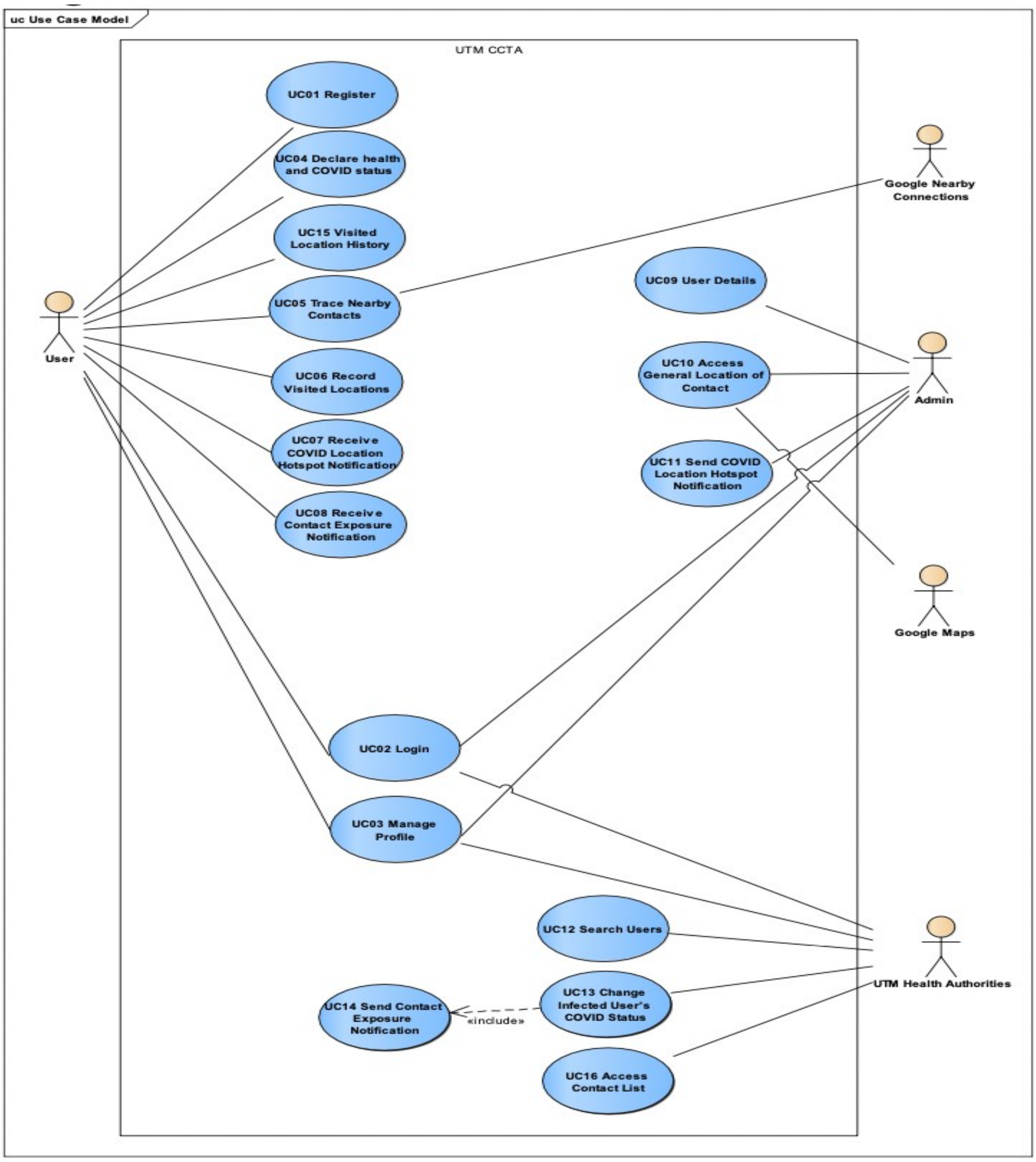

Fig. 1 Use Case Diagram of UTMCCTA

A three-layered architecture design was used to create the UTMCCTA. For both mobile and web systems, there are three main layers: the application layer, which contains all the system's UI elements. The business layer contains all the business logic and model classes for storing data from the database. The system interfaces with the Google connections API and Google Maps API at the business layer. The data is then passed to the data access layer via various handlers. The third layer of the UTMCCTA system is the data access layer. This layer contains all the Firebase queries and connects to the Firebase client SDK directly. Fig. 2 shows the architectural design of the UTMCCTA application.

V. Implementation

Implementation for UTMCCTA describes the development of the components designed in the architecture. Flutter, Firebase, and various APIs were used to implement the system designs created during the RUP elaboration phase. The Blackbox testing method was chosen as the primary testing method, and after the implementation is complete, the web and mobile applications went through a series of test cases to find and eliminate system problems and errors. Some of the main features and how they were described as follows.

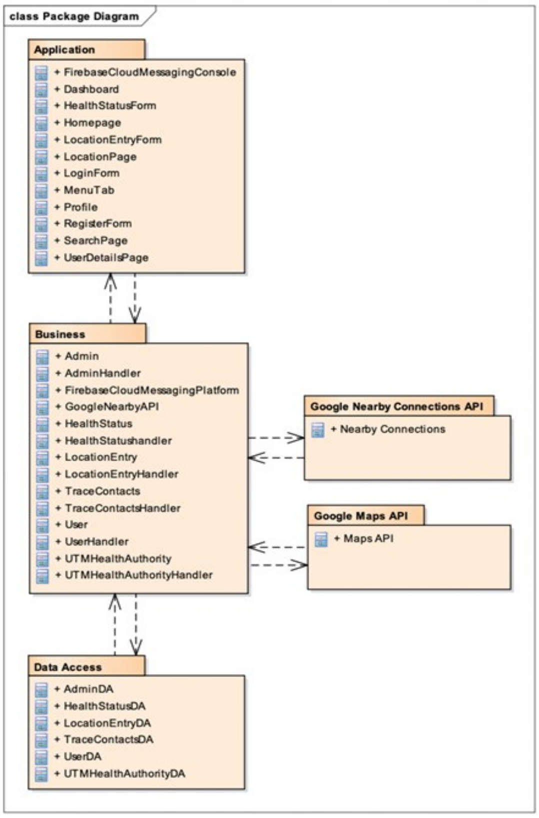

Fig. 2. Use Case Diagram of UTMCCTA

A. *Trace Nearby Contact Modules*

Contact tracing starts when the user taps on the “Start Tracing” button on the home screen of the mobile application. The home screen communicates with the Google Nearby API class in the system, and this class has all the business logic for the whole contact tracing to work as shown in Fig. 3.

```
onPressed: () async {
       if (!(await
Geolocator.isLocationServiceEnabled())) {
       // show alert to turn on GPS
       } else {
       _api.createState().adverise();
       _api.createState().discovery();
       startServiceInPlatform();
       }
},
```

Fig. 3. Code Excerpt for Tracing Nearby Contacts Method

The Google Nearby API class also communicates with both Trace Contacts Data access layer and as well as Google Nearby API from the Google cloud platform. The discovery and advertising methods shown in Fig. 4 shows user’s device into discovery mode and advertise the user’s device’s Bluetooth address through an encrypted channel so that other nearby devices with the UTMCCTA app installed can discover the user’s device and exchange data

After discovering a device and getting its user’s data from Firestore “Users” collection it saves these data alongside contacted geolocation and time in the “TraceContacts” collection under the advertised user id. This class also has a method to remove contacts from the “TraceContacts” collection if the contact is older than a certain threshold which is set to 14 days for UTMCCTA. The threshold is set at the init state of the user's home screen as shown in Fig. 5.

```
void discovery() async {
    try {
      bool d = await Nearby()

.startDiscovery(_traceContactsDA.loggedInUserID(
), strategy,
              onEndpointFound: (id, name,
serviceId) async {
        print('I saw id:$id with name:$name');

        Position position = await
Geolocator.getCurrentPosition(
            desiredAccuracy:
LocationAccuracy.high);
```

Fig. 4. Code Excerpt for Trace Contact Discovery Method

```
void removeOldContactListFromDB(int threshold)
async {
    await _traceContactsDA.getCurrentUser();
    // get time and date
    DateTime timeNow = DateTime.now();


_traceContactsDA.traceContactsCollection().snaps
hots().listen((snapshot) {
      for (var doc in snapshot.docs) {
        if
(doc.data().containsKey('contactTime')) {
          DateTime contactTime =
(doc.data()['contactTime'] as Timestamp)
              .toDate(); // get last contact
time
          // if time since contact is greater
than threshold than remove the contact from list
          if
(timeNow.difference(contactTime).inDays >
threshold) {
            doc.reference.delete();
          }      );
```

Fig. 5. Remove 14 days Old Contact Method

B. Access General Location of Contacts

Access General Location of Contact module is to keep an eye on the COVID dispersion around campus. Only UTM Admin has access to this. The Google map in the web application has been used by a UTM Admin to analyze the COVID-positive user's interaction. If a COVID Positive user interacts with someone after being diagnosed and their information has been entered into the database, their interaction location and phone number will be marked on the map as a marker. The administrator can quickly view the person's name and phone number by clicking on the marker. Fig. 6 shows how the markers on the map get the data. The UTM admin can also use this map to detect potential COVID hotspots, because if a Positive user continues to interact with people, a cluster of markers will appear in a specific area. The admin can then notify all UTMCCTA users by sending them a location hotspot notification via the web application and Firebase Cloud Messaging platform. Fig. 6 shows how a new marker is added to the map.

```
getMapMarkerData() {
    _locationEntryDA
        .getUsersLatLang()
        .where('contactCovidStatus',
isEqualTo: true)
        .get()
        .then((docs) {
      if (docs.docs.isNotEmpty) {
        for (int i = 0; i <
docs.docs.length; i++) {
          initMarker(docs.docs[i].data(),
docs.docs[i].id);
        }
      }
    });
  }
```

Fig. 6. Get User Location to Generate Maps Marker

C. Receive Contact Exposure Alert Module

To receive a contact exposure alert in both the background and foreground, native Kotlin programming in the UTMCCTA is necessary. By default, Flutter applications cannot receive a notification while running in the foreground, which means that when a user is actively using the app, they will not be able to receive a notification; however, when the app is closed or the phone is locked without much code, the app will receive any type of notification. First and foremost, for the app to allow any type of notification to be displayed in the foreground, a high priority or important channel must be established. We can then receive notifications even when the app is in the foreground by utilizing the Flutter Local Notification package.

D. Mobile and Web Based Interface

In this section the important mobile interfaces highlight the location entry interface and how the location entries will be presented to the user in the mobile application. Fig. 7 shows the mobile user interface for location entry. For the web based interface, Fig. 8 shows for admin and UTM health authority. Fig. 8 shows the location details based on admin view.

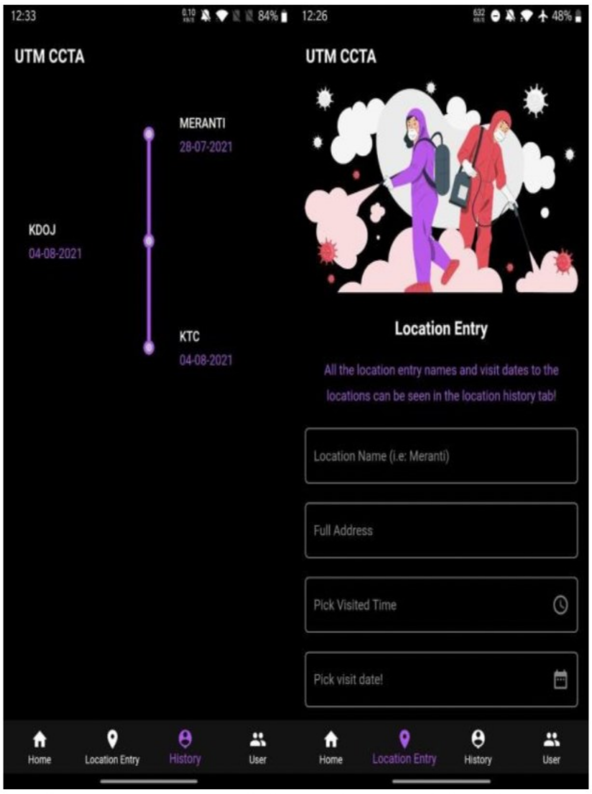

Fig. 7. Location Entry Mobile Interface for Users

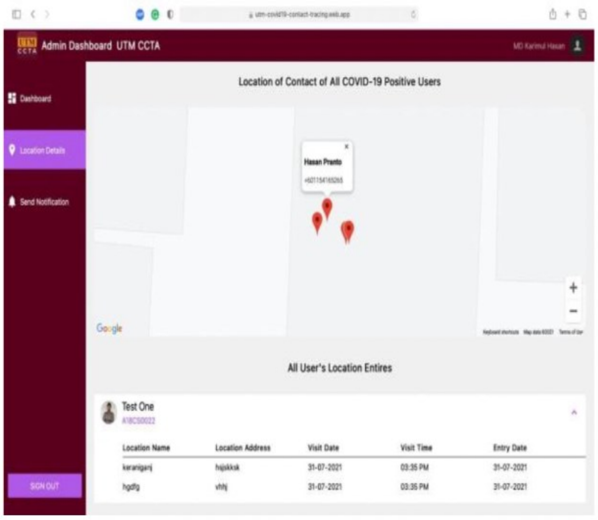

Fig. 8. Location Details Web Interface for Admin

E. Black Box Testing

Black box testing is a testing method that applies to software to test its functionality without testing or having specific knowledge of the code. This testing method mainly focuses on the input and output of a particular system. This method is entirely based on the requirements and specifications gathered during the requirements analysis phase. For Black Box testing several test cases have been created based on uses case modules. Table II shows sample test cases carried out in the testing phase.

TABLE II. TEST CASE

Test ID	Test Case Details			
	Input	***Actual Output***	***Expected Output***	***Status***
TC20	• The user enters Exhibiting two or more symptoms with "Yes" • The user enters COVID symptoms with "No" • The user enters the Immunocompromised field with "No" • The user enters the travelled outside of Malaysia field with " " • The user enters the Close contact with COVID-19 patient field with " " • The user enters the COVID status field with "Negative"	Prompt error The message "Please fill in all the fields"	Prompt error The message " please fill in all the required (*) fields"	PASS

VI. RESULT AND DISCUSSION

The UTM COVID-19 Contact Tracing System (UTMCCTA) boasts a comprehensive set of innovative features designed to enhance strategic pandemic preparedness. Firstly, the Trace Nearby Contacts is a cornerstone of this system, allowing users to automatically identify and record individuals they come into proximity with during their daily routines. This data forms the foundation of the application's strategic preparedness, as it enables health authorities to map potential transmission networks swiftly and efficiently. Secondly, the Access General Location of Contact feature provides crucial insights into the geographical spread of interactions, aiding in the identification of localized hotspots and trends. Moreover, the Send Contact Exposure Alert function empowers individuals to proactively notify their contacts if they test positive for COVID-19, contributing to rapid containment efforts. Conversely, the Receive Contact Exposure Alert feature keeps users informed of potential exposure, fostering responsible behavior and further limiting the virus's spread. These multifaceted features collectively showcase the UTMCCTA's innovativeness by not only monitoring but also actively participating in the strategic pandemic preparedness, offering a powerful tool to navigate and mitigate the challenges posed by COVID-19.

VII. CONCLUSION

In conclusion, UTMCCTA, meticulously developed through iteration and phases in Rational Unified Process Model represents a pioneering leap in strategic pandemic preparedness. The inception phase, crucial for anticipating and mitigating potential challenges, ensures the system's long-term viability. In the elaboration phase, stakeholders' and users' needs are methodically elicited, encompassing both functional and non-functional requirements, providing a robust foundation for the system's functionality. The design process further solidifies UTMCCTA's innovative approach by establishing its architecture, product breakdown, database design, and user experience, all meticulously organized. With both mobile and web application versions seamlessly integrated, rigorous blackbox testing guarantees the absence of bugs. UTMCCTA not only resolves the inefficiencies of traditional manual contact tracing but also serves as a forward-looking automated solution, empowering UTM health authorities to respond proactively to the evolving COVID-19 landscape. Additionally, it offers users the opportunity to self-quarantine should any of their contacts test positive, contributing to a safer and more prepared campus environment.

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CONFLICTS OF INTEREST

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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