CHAPTER 5

COVID-19 WEARABLE DEVICE USING RSSI BLE MODULE MONITORING SYSTEM

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ABSTRACT

Self-quarantine is essential for persons returning from overseas or red zone locations. It is critical that the self-quarantine be completed without incident, since this might result in the self-quarantine individual becoming a carrier of COVID-19 in the community. The majority of nations worldwide have developed a variety of COVID-19 monitoring and tracing systems in order to navigate and address this issue. However, some constraints and limitations may result in deliberate non-adherence. Individuals who have been quarantined may continue to roam within the community by detaching their wristbands or by submitting a false contact status in the tracing application. This article proposes a novel configuration for an obligatory self-quarantine system. It will facilitate communication between wearable and contact tracing technologies, ensuring that authorities maintain complete control over the system. The suggested system's hardware in the wearable device is low-cost, lightweight, and safe for the next user after the quarantine period is complete. The software (both software and database) that connects the quarantine user to the normal user makes use of cutting-edge artificial intelligence (AI) reporting and flagging techniques.

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INTRODUCTION

The current Coronavirus 2 Severe Acute Respiratory Syndrome (SARSCoV2) pandemic, also referred as COVID-19, has had a significant influence on our society, owing to the dangers to our health. It has altered our way of life in numerous ways. COVID-19 was proclaimed as a Public Health Emergency of International Concern (PHEIC) by the World Health Organization (WHO) in January 2020, because of the virus's rapid proliferation and transmission around the world (O'Neil, 2020). Numerous nations are compelled to legislate and implement a limited number of security measures in order to withstand and conquer a virus or epidemic. Lockdown means limiting community movement, encouraging remote work and recommending self-quarantine for anyone returning from overseas or red zones. COVID-19 is significantly more infectious than other coronaviruses such as SARS and MERS, and has a greater fatality rate. Someone may be a COVID-19 carrier without exhibiting any signs or symptoms. Owing to the virus's extensive time of incubation, the carrier that is tested as positive may begin experiencing symptoms 2 to 14 days after tested positive. Thus, in that case, the infection could have been transmitted from person to person, allowing it to spread throughout the neighbourhood (Criddle, 2020).

On 10 June 2020, a new and mandatory law was imposed by the Malaysian Government that forces "A mandatory 14-day quarantine period for all Malaysians and non-citizens who have been cleared by the Ministry of Health from COVID-19 will be enforced upon arrival in Malaysia, and will be monitored using the "MySejahtera" application." People who are isolated for 14 days will indeed be issued a quarantine bracelet that will limit and prevent movement during quarantine. However, this solution has created a difficulty due to the isolated individual's non-adherence, since he or she continues to circulate throughout the community after removing the wristband (MOH, 2020, MOTAC, 2020).

In Malaysia, contact tracing has created and incorporated an application named "MySejahtera" for contact monitoring (MOH, 2020). At the entry point of public areas such as stores, restaurants and public transport, this application requires users to scan a QR code with this app to check in and register by themselves. Nevertheless, the application has its drawbacks and limitations, especially when interacting with people that do not obey the rules. The refusal to check in upon entering any location falls under this category of non-compliance.

An infected person may also leave confined facilities and come into touch with people they do not know and cannot recognize from the general public (Change, 2020). Infectious disease tracking may become easier with the development of mobile phones, data and other computer-enabled technologies. Defining smartphone contact tracing entails a variety of framework layers and capabilities, which vary according to the country that adopts the technology. Integration of the region-based contact tracing applications allows for the collection and interpretation of information using a wide variety of methods and technologies. For example, position monitoring and contact tracing may be achieved by GPS, whereas contacting and distance tracing can be accomplished via Bluetooth and self-reporting (Shahroz, 2021).

Following the WHO's declaration and proclamation of the COVID-19 epidemic as a PHEIC in January 2020, the majority of countries have employed a number of monitoring and tracking mechanisms. The community's health must be protected at all costs; hence, it is essential to monitor and stop the spread of diseases. As a result, a well-known concept that was recently coined, called "digital epidemiology", was presented (Salathé, 2018). This term refers to related methods and technologies that are employed for treating diseases. The Chinese government has proposed an application for the Health Code (China, 2020) to monitor community movement. The technology that underpins the application is known as QR codes. It will evaluate the user's travel history, as well as any chance of any level of communication with a COVID-19 patient, and it will also verify other significant individual information, including the telephone number, address, passport number and more identifying information.

According to the research, those who have been placed in a state of self-imposed or government-mandated quarantine for a period of 14 days are signified by the colour red. The colour code amber indicates individuals who are prepared to be isolated for a period of seven days; on the other hand, a user is no longer at risk of contracting the disease if the colour code is green. The Ministry of Health in Singapore has also released and recommended an application for contact tracing in the month of March 2020, called "TracedTogether" (Trace together, safer together, 2020). The program is built on top of BLE, which stands for Bluetooth technology. This technology is associated with the transmission and sharing of a pseudo-random ID, which maintains the broadcasting background. The technology that was utilised looks as remarkable as the notifications of the Google or Apple Exposure (Apple, 2020) that was developed and deployed by Google and Apple. Since 25 May 2020, this service has been implemented in a number of areas around the United States and the United Kingdom.

Singapore has also put forth an application along those same terms (Trace together, safer together, 2020). The 'TracedTogether' program will produce its unique networking token for each user that has registered with it. The Bluetooth will be in charge of the process of exchanging the application's each token with other user applications and storing it. The wearable device and the mobile phone work together as part of the system to retrieve the health parameter from the wearable sensor, and then send it to the mobile device. Asymptomatic COVID-19 close contact subject with temperature, blood pressure, respiration rate, blood oxygen saturation, pulse rate and everyday routines are some of the parameters (Khan, 2016).

In this work, a server-to-edge device has been employed to implement an obligatory self-quarantine platform that interacts with contact tracing, wearable and AI facial recognition to assure that the quarantine is well-executed under various front-end and back-end management systems. Using biodegradable materials and low-cost hardware, the wearable (hardware) system presented is environmentally friendly and cost effective. Additionally, the software system (database and software) works to centralise data that are handled by quarantined and non-quarantined users. Systematic reporting and flagging is recommended in order to implement rigorous quarantine measures to stop the pandemic. A post-vaccination symptom can be detected by the proposed wearable system for further action and healthcare monitoring, which can then collect the vaccinated person's health parameters, like blood oxygen saturation and heart rate.

SYSTEM ARCHITECTURE

The newly proposed framework will consist of three individual parts: the monitoring approach and its operating mechanism, front-end and back-end structures, and the design of the wearable hardware.

Design and working principle

The normal users or citizens, quarantine users, as well as the medical officials are involved to develop the entire system. A centralised method is proposed for the system, allowing for full data interaction between the three parties. As part of the system, data are obtained and transmitted via Live Signal (Wi-Fi/Telco Data) and Bluetooth. Figure 1 depicts the interaction between quarantined and normal users along with the working principal of the proposed system.

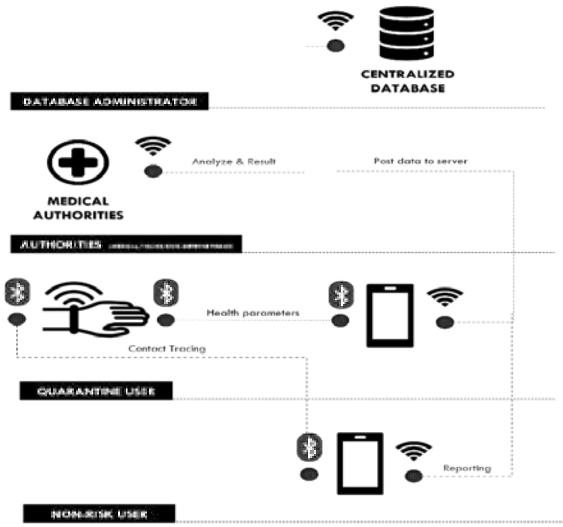


Figure 1: An architecture of the quarantine monitoring process.

The registration of the quarantine person is the first stage or prerequisite of the application. Figure 2 depicts a proposed normalised database entity-relationship diagram. Quarantined users will verify their user IDs with the administration. In addition to the user's ID card number, gender, address, email, gender, a wearable form of identification, and face data are also required (the database stores the photo uploaded by individuals). The application for the users of the quarantine is developed primarily for the purpose of monitoring health data, location data, as well as reporting and flagging processes. The application just requires the always discoverable and reporting system to be used by a user who does not pose a risk.

There will be two different tables for registration purposes. One database table will be designated specifically for users who are placed in quarantine, while the other database table will be reserved for those who are not considered to be at threat. The wearable device is constructed with two BLE Modules, one of which is designed to be primarily and always discoverable for the purpose of user tracing. The Received Signal Strength Indicator (RSSI) is a methodology that is used in the tracing method to be applied as a way to collect and monitor the quarantine user in a location that has a setting range (for example, more than 2 metres). Additional BLE module serves the primary purpose of acting as a data transmitter in order to send the health parameter that was received from the oximeter sensor located on the wearable. The purpose of the suggested 2 BLE Modules is to assure that the activity of tracing can proceed by mitigating limitations imposed on the data transmission. BLE modules are used due to the benefits that they offer in terms of power consumption, as well as cost, when compared to the most recent Ultra-Wide Band Module that Apple Inc. has offered (Bender, 2020).

It is the purpose of the wearable, in which the user's health parameter is retrieved in order to detect their vital signs (heart rate in beats per minute and blood oxygen saturation/SpO2) while they are in quarantine. The application that the quarantine user is using will perform routine checks on the user's health parameters, and the sensor will transmit the results of those checks to the application. The data will then be entered into the database by the application after this step. The heart rate, blood oxygen saturation and id will be recorded in the 'hid' database along with the health parameter. For the purpose of ensuring that all quarantined users have the correct user ids, the database was built with a primary key that links the 'users' table with all five tables ids. The initial key comes from the "users" table, whereas the "hinfo," "lid," "binfo," "finfo" and "uinfo" tables are used for the foreign key (Figure 2). Using only their own smartphones as a primary peripheral to identify non-adherence quarantine individuals, the working principle is applied for non-risk user's works. Following registration verification and when Bluetooth is turned on by all users, the process begins.

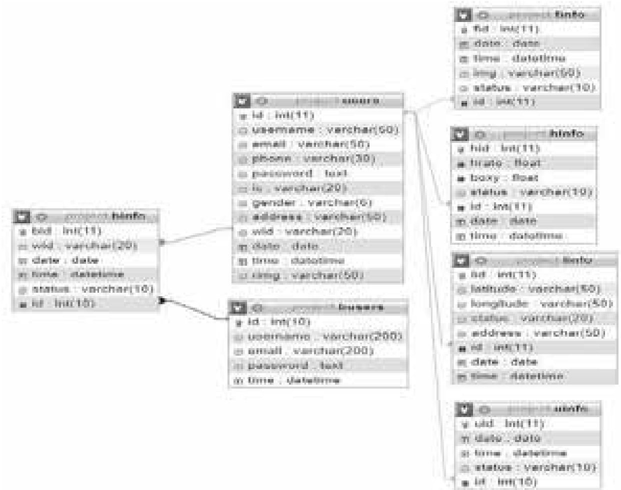


Figure 2: Entity-relationship diagram (ERD).

Application activation will begin with the search for registered quarantine users' Wearable Devices whenever Bluetooth is enabled. Whenever a quarantined user is found to have revoked the regulation, the application will begin displaying a caution interface and a report button. Wearable id scans will transmit information to a local database that is defined as "binfo" and alert authorities that someone in the neighbourhood, who is quarantined, is out and about in contact with the community (Figure 3). With the proposed approach, quarantine users can have their movements restricted. By utilising the support of the community, quarantined users' presence and location trackers can be accounted for.

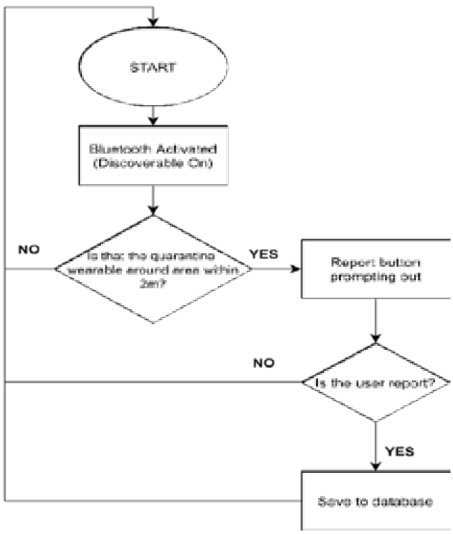


Figure 3: Working principle of the normal user application.

System development

Table 1 shows the logo design for both applications used in this proposed system.

Table 1: System development environment.

Users	Interfaces/Apps	Development Environment	Platform
Quarantine Users	HEISM Healthcare · Isolation · Monitoring	Front-end: Android Studio Back-end: php, MySQL	Android Smartphone
Non-risk Users	CTRACE Isolation Wearable Tracing App	Front-end: Android Studio Back-end: php, MySQL	Android Smartphone
Authorities or Database Administrator	HEISM Monitoring Dashboard	Front-end: HTML, CSS Back-end: php, MySQL Face Recognition Engine: OpenVINO	intel Intel-Based Computer

Quarantine users can utilise HEISM (Healthcare, Isolation and Monitoring) whereas non-risk users can use CTRACE (Isolation Wearable Tracing App). The Android Studio is the primary development platform for these apps. An improved recycler view section, notice prompted to specified conditions and data posting to a localhost server (phpMyAdmin) have all been implemented to develop PHP scripts for the design and interactivity of data retrieval. The users' application procedures, for instance front-end and back-end systems, are shown in Table 1, along with the development platform.

The OpenVINO face recognition technology has been integrated into the HEISM Monitoring Dashboard as a server-to-edge device face recognition solution. As contrast to existing quarantine monitoring applications, the Android Smartphone Biometrics API stores encrypted fingerprint or face information directly on the smartphone. Due to the shortcomings, some users will prefer to switch to a different device by altering the biometric information on their smartphone, such as their fingerprint or facial scan. Face recognition on the edge device OpenVINO forces quarantined users to upload selfies on a regular basis. An OpenVINO camera will snap a picture on the first day of quarantine registration, and compare it to the one in the quarantine database to see how similar the two photos are. The HEISM Monitoring Dashboard has a reporting and flagging feature that allows quarantined users to report and flag 5 non-adherence possibilities. Programming in PHP and MySQL interacts with data from quarantined and non-risk users, as well as with the dashboard's actions to the database. OpenVINO's HTML dashboard architecture is shown in Figure 4.

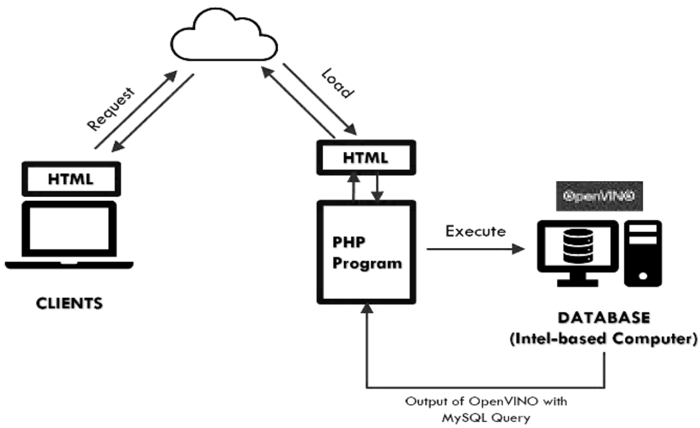


Figure 4: The architecture of OpenVINO carry out in the HTML dashboard.

Wearable device with BLE module

The core microcontroller (Arduino Lilypad) with the ATmega328P, a GY-MAX30100 pulse oximeter sensor and 2 JDY-08 BLE Bluetooth Modules are used to create and implement the wearable. The components that can be used are shown in Figure 5.

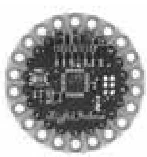
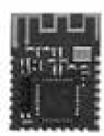
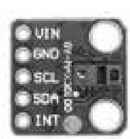
		
ATmega328P Compatible	JDY-08 BLE Module	GY-MAX30100 pulse oximeter sensor

Figure 5: Wearable hardware components.

Solidworks is used to create a 3D model of the wearable exterior, which includes two layouts: one for the top half and one for the bottom half.

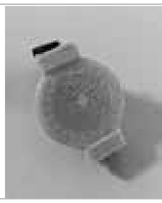
		
Front View	Bottom View	Side View

Figure 6: Wearable prototype.

Figure 6 depicts the wearable 3D diagram's design. By putting all of the components together, a working prototype of the wearable is created. Figure 6 depicts the prototype from various perspectives.

Wearable devices integrated BLE module for HEISM (Healthcare· Isolation· Monitoring) and CTRACE (Isolation Wearable Tracing App)

In this section, various aspects are discussed, including the HEISM and CTRACE application, the HEISM Monitoring Dashboard, the OpenVINO Face Recognition Engine Integration, and other features. An overview of the HEISM and the CTRACE application is shown in Table 2.

Table 2: HEISM & CTRACE application.
HEISM

Login Page	Main Page
	

CTRACE

Login Page	Sign Up Page	Main Page
		

HTML programming was used to create the HEISM Monitoring Dashboard depicted in the following figure.

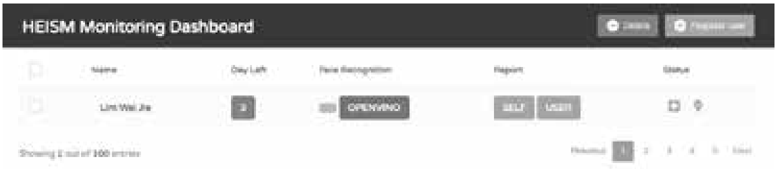
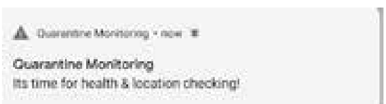


Figure 7: HEISM monitoring dashboard.

Quarantine user's health parameters and location monitoring are included in HEISM. An example of how to execute periodic reporting is shown in Table 3.

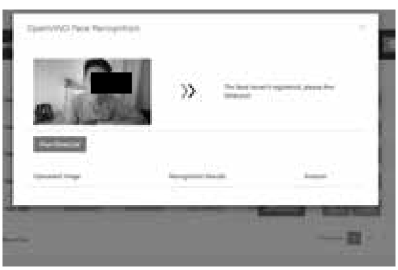
Table 3: Procedure of the HEISM app.

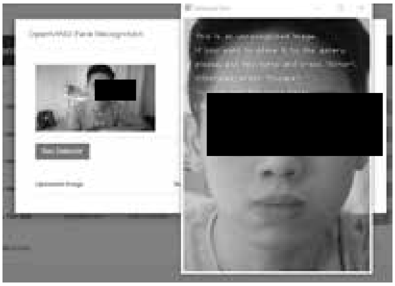
Steps	Description
	1. Notifications will be sent out every 20 minutes to quarantined individuals. Once they have gotten the notification, users must click on it to launch the HEISM app, where they must take a selfie photo.
	2. Once the app displays the 'Checking BPM & SPO2' message, the wearable has been properly paired to Bluetooth. Health parameters and location data will be sent to the server by the application.

Steps	Description
	3. The 'Health' and 'Location' tabs allow users to see all of their previous check results. All of this information will be uploaded to the server and analysed there. To complete the countdown and be released from quarantine, repeat steps 1 to 3.

The HEISM Monitoring Dashboard uses face recognition to confirm that the application is being used by the same person who registered. The Integrated OpenVINO Face Recognition Engine is depicted in Table 4.

Table 4: Integrated OpenVINO Face Recognition Engine.

Steps	Description
	1. The OPENVINO will be displayed in the face recognition column of the HEISM Monitoring. During the registration process, a picture of the quarantined user will appear on the page. The engine will begin evaluating the registration image as soon as the detector is activated.

Steps	Description
	2. Python OpenCV window prompts the user to enter his or her name during the registration stage once the detector has finished running.
	3. According to the method mentioned in Table 3 (step 1), images will be uploaded by quarantine users every 20 minutes. After uploading an image, the results will be displayed beside the image after completing the analysis. Moreover, the name and percentage of similarity will be displayed in the output image.

An entire reporting and flagging process has been established, and it has been incorporated with the capability of being carried out by the users of the quarantine. Since this technique is especially useful for quarantine or isolation purposes, it can be avoided by any non-adherence. The reporting and flagging structure is depicted in Figure 8.

Figure 8: Reporting and flagging system

The reporting and flagging system will be activated as soon as the users disregard the instructions to isolate themselves and leave the authorised region of quarantine. Reporting and flagging approaches are summarised in Table 5, whereas the Edge AI Face Recognition reporting technique is summarised in Table 6.

Table 5: Summarisation of the reporting and flagging system.

Report Status	**Conditions (Go out)**	**Reasons**
	Yes Wearable No Smartphone	1. Overtime reporting via a smartphone 2. Outside the quarantine zone and report, the wearable is tracked by a user who is not at risk. 3. Health status not reported 4. Location not reported
	No Wearable No Smartphone	1. Overtime reporting via a smartphone 2. Health status not reported 3. Location not reported
	No Wearable Yes Smartphone	1. Overtime reporting via a smartphone 2. Health status not reported

Report Status	Conditions (Go out)	Reasons
	Yes Wearable Yes Smartphone	1. Non-risk user track wearable at outside and report

Table 6: A summary of the reporting framework for edge AI facial recognition.

Report Status	Description
	Results match and no incoming uploaded photo
	Available incoming uploaded photo (tap and start recognition)
	Found not match result

Analysis and comparison between different devices and accuracy of RSSI

The reference value provided by the Android Beacon Library (https://altbeacon.github.io/android-beacon-library/distance-calculations.html) states that the RSSI value for the overall system is roughly 2m (Table 7). An experiment was carried out to examine the error of the RSSI influenced by various BLE modules from five different smartphone brands, as presented in Figure 9. The brands include Xiaomi 9, Huawei P40, Honor 20, Samsung Galaxy S3 and Redmi k20. Table 8 lists the corresponding distances for various types of smartphones.

Table 7: Android beacon library reference value.

Transmission power (dBm)	Estimated distance (m)
0	50
-50	1
-40	3
-20	12

Transmission power (dBm)	**Estimated distance (m)**
-16	18
-12	25
-8	35
-4	40

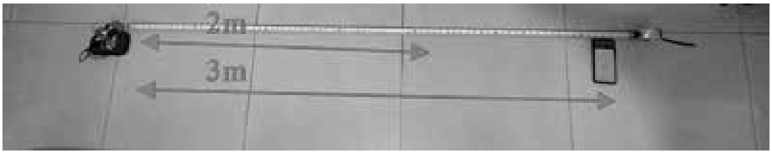


Figure 9: RSSI accuracy measuring.

Table 8: Actual distance vs RSSI distance.

Model	**1m (-50dBm)**	**2m (-45dBm)**	**3m (-40dBm)**
Huawei P40	1.12	2.13	3.11
Honor 20	1.22	2.21	3.25
Xiaomi 9	1.05	2.09	3.11
Redmi K20	1.04	2.05	3.09
Samsung Galaxy S3	1.27	2.24	3.24

At first, a smartphone will be assigned to users within a range of 2.5 metres. There are three versions of the software that can be compared to RSSI values of -40dbm(3m), -45dbm(2m) and -50dbm (1m), respectively. Various sorts of smartphones are shown to have a low error rate for determining RSSI, as shown in Figure 10. Thus, it is concluded that from a Bluetooth device to a wearable, the measured value is not directly influenced or fluctuated by the type of smartphone used.

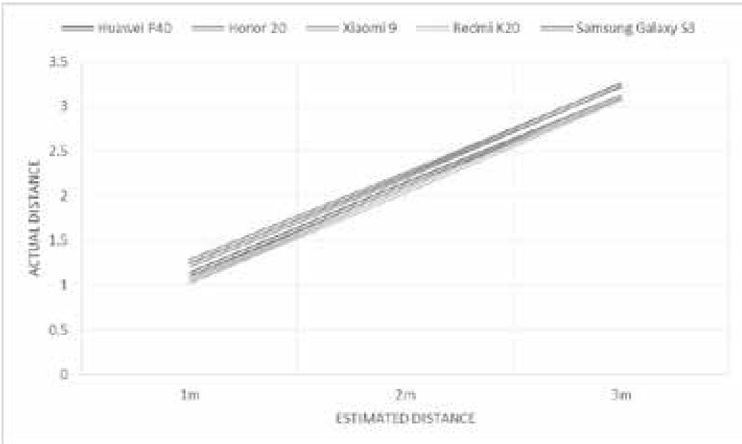


Figure 10: Graph of actual distance vs estimated distance (RSSI).

Key factor of the proposed system

The world's quarantine monitoring applications have been compared in market research. For COVID-19, Malaysia presently has a contact tracing program, however, it is not designed for quarantine monitoring specifically. Figure 11 illustrates a comparison of matrices for applications in order to the monitoring of quarantine and isolation. As shown in Figure 11, the wearable device that is currently being used in Hong Kong and Poland cannot provide regular health status monitoring. When compared to the existing systems, none of them provide wearable tracing and live reporting for flagging systems like the one proposed in this study.

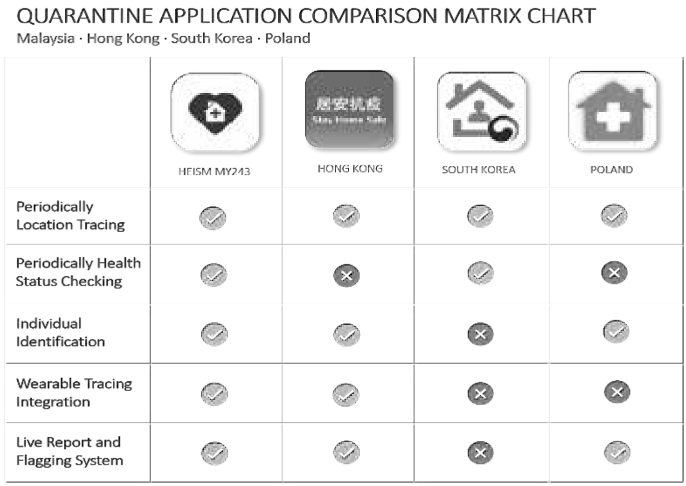


Figure 11: Advantages and benefits of the proposed system.

CONCLUSION

This research provides a comprehensive and integrated method for checking up on the quarantine process in the world at large. Artificial intelligence (AI) facial recognition, location tracking, health status reporting and risk-free user discovery are all part of the system's novel architecture. Due to its usage of Dual Bluetooth technology, it is possible for the wearable to track users and send data about them to a smartphone, as well as a central database. An Intel OpenVINO-powered facial recognition engine that utilises a convolutional neural network gives the functional flagging system a powerful and effective way of dealing with issues or instances of non-adherence as well. It is indeed effective when the COVID-19 outbreak is over. As a home healthcare monitoring device, it could be particularly useful for the elderly and mentally challenged. The proposed approach could be improved in the future by employing an established dataset or model to track post-vaccinated persons' vital signs or symptoms in order to detect adverse occurrences, including blood clots. The statistics are significant because they provide the community with accurate and reliable vaccination data.

REFERENCES

Apple (2020). Exposure Notification reference 2020. https://www.apple.com/covid19/ contacttracing

Bender, P. Ultra-Wideband vs. Bluetooth Low Energy. 2020. https://www.airfinder.com/blog/ultra-wideband-vs-bluetooth-low-energy

Cecelia Change. (2020). Here Are the Pros and Cons Between Checking In With MySejahtera And Manual Form-Filling. https://worldofbuzz.com/here-are-the-pros-and-cons-between-checking-in-with-mysejahtera-and-manual-form-filling/

China launches coronavirus' close contact detector' app. 2020. https://www.bbc.com/news/technology-51439401

Criddle, C., & Kelion, L. (2020). Coronavirus contact-tracing: World split between two types of app. https://www.bbc.com/news/technology-52355028 https://altbeacon.github.io/android-beacon-library/distance-calculations.html

Khan, Y., Ostfeld, A.E., Lochner, C.M., Pierre, A., & Arias, A.C. (2016). Monitoring of vital signs with flexible and wearable medical devices. Adv. Mater. 28, 4373–439.

Ministry of Health (MOH) Malaysia. (2020). MySejahtera Application. https://mysejahtera.malaysia.gov.my/intro/

Ministry of Health (MOH) Malaysia. (2020). GUIDELINES FOR ENTRY POINT SCREENING OF TRAVELLERS (SCREENING FOR COVID-19). http://covid-19.moh.gov.my/garis-panduan/garis-panduan-kkm/

Ministry of Tourism, Arts and Culture. (2020). Requirements to All Travelers Entering Malaysia From Overseas. http://www.motac.gov.my/pengumuman/requirements-to-all-travelers-entering-malaysia-from-overseas

O'Neill, P.H., Ryan-Mosley, T., & Johnson, B. (2020). A flood of coronavirus apps are tracking us. now it's time to keep track of them. https://www.technologyreview.com/2020/05/07/1000961/launching-mittr-covid-tracing-tracker/.

Salathé, M. (2018). Digital epidemiology: What is it, and where is it going? LifeSci., Soc. Policy, 14(1), 1.

Shahroz, M., Ahmad, F., Younis, M.S., Ahmad, N., Boulos, M.N.K., Vinuesa, R., & Qadir. J. (2021). COVID-19 Digital Contact Tracing Applications and Techniques: A Review Post Initial Deployments. Transportation Engineering. https://doi.org/10.1016/j.treng.2021.100072

Trace together, safer together. 2020. https://www.tracetogether.gov.sg/