Journal of Ambient Intelligence and Humanized Computing (2023) 14:11153–11164
https://doi.org/10.1007/s12652-022-04395-7

ORIGINAL RESEARCH

IoT-Based Smart Mask Protection against the Waves of COVID-19

Vishal Goar[1] · Aditi Sharma[2] · Nagendra Singh Yadav[1] · Subrata Chowdhury[3] · Yu-Chen Hu[4]

Received: 19 July 2021 / Accepted: 30 August 2022 / Published online: 12 September 2022

Abstract

In the year 2020, the word "pandemic" has become quite popular. A pandemic is a disease that spreads over a wide geographical region. The massive outbreak of coronavirus popularly known as COVID-19 has halted normal life worldwide. On 11th March 2020, the World Health Organization (WHO) quoted the COVID-19 outbreak as a "Pandemic". The outbreak pattern differs widely across the globe based on the findings discovered so far; however, fever is a common and easily detectable symptom of COVID-19 and the new COVID strain. After the virus outbreak, thermal scanning is done using infrared thermometers in most public places to detect infected persons. It is time-consuming to track the body temperature of each person. Besides, close contact with infected persons can spread the virus from the infected persons to the individual performing the screening or vice-versa. In this research, we propose a device architecture capable of automatically detecting the coronavirus or new COVID strain from thermal images; the proposed architecture comprises a smart mask equipped with a thermal imaging system, which reduces human interactions. The thermal camera technology is integrated with the smart mask powered by the Internet of Things (IoT) to proactively monitor the screening procedure and obtain data based on real-time findings. Besides, the proposed system is fitted with facial recognition technology; therefore, it can also display personal information. It will automatically measure the temperature of each person who came into close contact with the infected humans or humans in public spaces, such as markets or offices. The new design is very useful in healthcare and could offer a solution to preventing the growth of the coronavirus. The presented work hasa key focus on the integration of advanced algorithms for the predictive analytics of parameters required for in-depth evaluations. The proposed work and the results are pretty effectual and performance cognizant for predictive analytics. The manuscript and associated research work integrate the IoT and Internet of Everything (IoE) based analytics with sensor technologies with real-time data so that the overall predictions will be more accurate and integrated with the health sector.

Keywords COVID-19 · New COVID strain · IoT · Smart mask · Thermal imaging · Healthcare

1 Introduction

When the SARS-CoV-2 pandemic broke out last 2019, protective steps were put in place right away to stop the virus from spreading across the air as presented in Leung et al. (2020). Citizens around the world were urged to take

✉ Yu-Chen Hu
ychu@pu.edu.tw

Vishal Goar
dr.vishalgoar@gmail.com

Aditi Sharma
aditi11121986@gmail.com

Nagendra Singh Yadav
nksyadav100@gmail.com

Subrata Chowdhury
subrata895@gmail.com

1 Govt. Engineering College Bikaner, Bikaner, Rajasthan, India

2 Department of Computer Science and Engineering, Parul Institute of Technology, Parul University, Vadodara, Gujarat, India

3 Department of Computer Science & Applications, SVCET Engineering College, Chittoor, Andra Pradesh, India

4 Department of Computer Science and Information Management, Providence University, 200, Sec. 7, Taiwan Boulevard, Shalu Dist, 43301 Taichung City, Taiwan, R.O.C.

steps such as social distancing, facial coverings, and proper grooming, while policymakers implemented technologically innovative steps such as eye-tracking. Also with elevated levels of exposure in closed spaces, face coverings are beneficial in preventing the spread of the virus study as presented in Chu et al. (2020). On the other hand, established face masks do not respond to changing levels of exposure and instead have passive protection. Consequently, since these quantities are unstable and fluctuate over time, as they usually are, they are inefficient as proposed in Greenhalgh et al. (2020). Masks are expected to be used worldwide, resulting in massive demand as studied by Leung et al. (2020). To suit demand, the World Health Organization recommended that businesses and governments expand respiratory protective equipment by 40%. Apart from everyday consumer use, the air-purifying respirator market is expected to expand in industrial use, as they are commonly used in a variety of industries to shield staff from dust, smoke, fumes, vapors, mists, and silica particles. If the demand for respiratory protective equipment continues to expand, all participants have appealing prospects, as presented in Zhai (2020). There is a market for multipurpose respiratory protective devices. Masks that are digitalized carry personal protection into the wired IoT and AI age reported by World Health Organization (2020). ICT combines the security of physical gear with a comprehensive digital bundle of sensing, analytics, and internet services—creating a new business segment in the smart wearable industry studied by World Health Organization (2020).

The pandemic affected the world and overall social scenario to a huge extent. In addition to shielding users, the Smart Mask will detect COVID patients in markets, educational institutions, and other public spaces, and it will constantly monitor the temperature of anybody who comes into direct contact with infectious humans or humans in public spaces like markets or workplaces, and report it to the city's medical and administrative authorities. The presented work focuses on the development of sensor-based data fetching and predictive mining with the suggestive model for overall performance. The new design is extremely useful in healthcare and can provide a method for preventing the spread of the coronavirus.

The United Kingdom, Britain has reported the very first new SARS-COV-2 Variant popularly known as NEW COVID STRAIN. As per the initial findings, the new variant is more likely to spread faster than the initial one. A preliminary set of investigations is being carried out to determine the various aspects related to the new strain, i.e. spread rate, and how it impacts human health once infected reported in SARS-CoV-2 Variant (2020).

In the meantime, several systems on smart city networks have been built for COVID-19 investigated by Kai et al. (2020). Services for BlueDot and HealthMap were implemented (Halegoua et al. (2020). The BlueDot technique was initially used to classify the rare pneumonia cluster in Wuhan and eventually identified the epidemic as a pandemic (Javid et al. 2020). The virus was also expected to spread from Wuhan to Bangkok, Taipei, Singapore, Tokyo, and Hong Kong. The San Francisco-based HealthMap service detected infected humans due to cough as a symptom of COVID-19 with the use of Artificial Intelligence and big data technologies described in Mittal et al. (2020). In the study (Garcia et al., 2020), a review on the use of facemask to reduce the development of COVID-19 is discussed.

In the study (Allam et al., 2020), a smart city network infrastructure focused on how it was possible to share data during the outbreak of COVID-19 was designed. The suggested one talks about the opportunities for urban health data in terms of economic stability and national security issues. The study found that when coughing or sneezing, the masks that can fit perfectly were capable of stopping the spread of air droplets. Jiang et al. (2020) suggested a face mask detection model called Retina Face Mask combined with a cross-class object elimination algorithm. The developed model involves a single-stage detector composed of a pyramid network feature that produces marginally greater accuracy and recollects than the baseline outcome. They also applied to minimize the scarcity of datasets to a well-known deep learning method, transfer learning.

Gupta et al. (2020) suggested a model for implementing social distance using the smart city and Intelligent Transportation System (ITS). Their model defined the implementation of sensors to track the real-time movement of objects in various locations in the city and provided a forum for data sharing. Won Sonn et al. (2020) described the notable contribution of a smart city in managing coronavirus outbreaks in South Korea. The contact monitoring in the area, which comprises patient movement, transaction logs, and smartphone geolocation, was accelerated by a time-space cartographer. In the hallways of residential houses, real-time surveillance has been executed with the help of CCTV monitors. Singh et al. (2020) centered on how IoT should combat COVID-19.

The method developed emphasizes interconnected instruments or operations to track patients together with careful situations. A well-informed community is developed using interconnected devices to significantly classify the clusters. Sonn et al. (2020) have outlined an exceptional pandemic surveillance paradigm without lockout in a smart city. The patients were interviewed and their recent movements were tracked.

They believed that some patients were attempting to hide their past mobility, but the specific information was found in the real-time monitoring system. During COVID-19, Jaiswal et al. (2020) suggested a method to reduce the harm. Their recommended model used technology's role in tracking infected individuals. Drones and robot systems have offered appropriate care to infectious persons as emergency staff. Wang et al. (2020) reviewed the development of smart cities under COVID-19 and the management of the pandemic in China. The continuous delivery to the community of vital materials and the contactless logistics transfer of systems provided the way to minimize coronavirus dissemination. ITS and real-time map reflection methods have been used to restrict the passage of vehicles during the pandemic. Furthermore, driverless cars were used to track the situation in the region.

The rest of this paper is organized as follows. The processing steps of the proposed technique as conceptual paradigms are described in Sect.2. Section3 illustrated the methodology and implemented framework architecture. The proposed work strategy and the experimental setup are described in Sect.4. Simulated outcomes, key results, and performance comparisons are listed in Sect.5, and Sect.6 concludes the paper.

2 Smart mask conceptual paradigms

The integration of the smart module's goal is to offer users precise and trustworthy information, such as regarding the air quality under the mask or probable mask movement. As a result, in this project, we focused on the sorts of sensors that need to be put into the Smart Mask prototype to gather this necessary information and data.

Sensors of many sorts can be used to detect various kinds of events. As a result, any mask movement can be detected in a variety of ways. In theory, a mask that does not adhere effectively to the user's skin gives only limited protection. Ambient Light Sensors (ALS), for example, can be installed underneath the mask to assess light intensity. When the available light intensity reaches a threshold amount, it might be considered that the mask does not sit properly on the user's skin and hence does not adequately protect the user. Similarly, the data from an accelerometer may be used to calculate the smart mask's perspective movement. Sensors may also be inserted in the mask's holder, and by monitoring variations in resistance, it is possible to deduce that the mask has moved and that the user has to adjust their mask.

Similarly, an equivalent Carbon dioxide (eCO2) sensor, which can also detect the amount of total volatile compounds in the air, may be used to assess the air quality underneath the mask (see e.g. Gorbunov (2020); Cheng et al. (2020)). If the air quality underneath the mask deteriorates, users are more inclined to touch their mask to release heated air trapped under it. Users can spread the infection to their masks if they contact it. To maximize the user's level of protection, the user must avoid moving away from the mask, whether intentionally or unintentionally.

Sensors incorporated in the smart mask must generally supply users with precise and trustworthy data. As a result, we looked at sensor placement within the mask on sensor readings. For a few decades, researchers have been investigating facial recognition systems. With rapid advances in performance and memory processing, computer vision online and live video processing in portable devices became accessible, as presented in Seyhan et al. (2021). When monitoring the temperature underneath the mask, for example, we discovered that the location of the sensor (e.g., at the mask's button or on the side of the mask) had an impact on the temperature acquired.

As a result, a temperature sensor can yield greater temperature readings depending on where the sensor is placed in the mask. As previously stated, one of the important aspects evaluated throughout the design and development of the Smart Mask was the air quality under the mask. It was discovered that immediately after the user puts on their mask, the temperature swiftly rises. However, if the user maintains a constant temperature, the temperature will saturate after a while (e.g., when sitting on a bus). It was discovered in this study that the filter used had an effect on the saturation temperature. It's worth mentioning that each user will have a different level of comfort and, as a result, a distinct temperature threshold that is acceptable behind the mask. As a general rule, the bigger the filter (i.e., the better the particle protection), the hotter the air underneath the mask might be.

Once sensor data has been received, it is critical to communicate the sensor information to consumers as soon as possible. We focused on the real-time connection between the sensors and the user's smartphone. Wi-Fi connectivity was used to create the Smart Mask prototype. However, in the future iteration of the prototype, we are considering adopting the Bluetooth Low Energy (BLE) connection instead of the Wi-Fi connection owing to the needed data rate and to improve the Smart Mask's energy efficiency. The Smart Mask's energy management is a key feature. For user happiness, battery life is crucial. In other words, users may become irritated if they must frequently recharge their mask's battery. Furthermore, the mask's rechargeable battery is one of the most significant contributions to its weight. Suppose communication between the Smart Mask and the smartphone consumes a significant amount of energy, and/or getting data from sensors rapidly depletes the battery's State of Charge (SoC). In that case, a bigger battery capacity may be required, increasing the mask's total weight.

In conclusion, numerous factors must be addressed to provide users with a smart and lightweight Smart Mask design. For starters, sensor data must be precise and dependable.

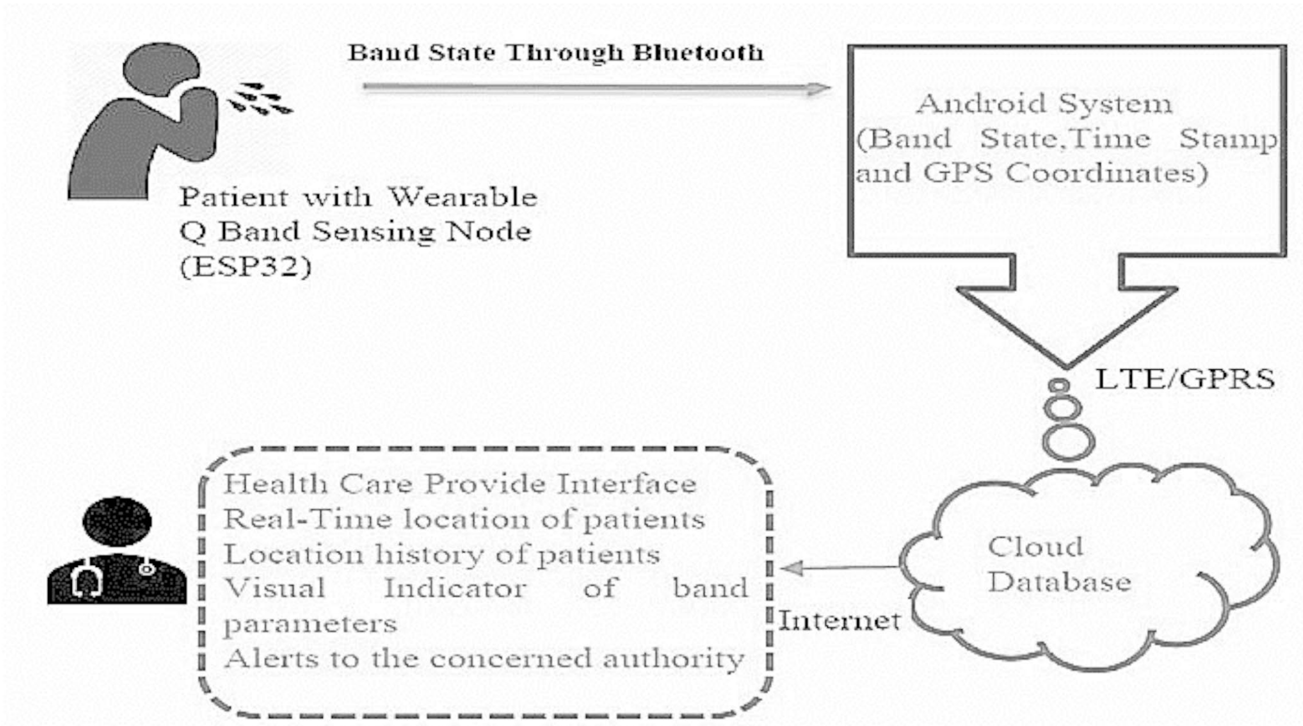


Fig. 1 IoT-based monitoring of people

The type of sensor used and where it is placed influence the measurement findings. Second, real-time communication guarantees that users are immediately notified if their mask has a problem that requires care. Finally, enhancing and optimizing the smart mask's battery life provides customers happiness and comfort while wearing it.

3 Methodology and implemented framework

The work proposes the use of IoT-based sensors and real-time data fetching for the health care sector and thereby, the overall analytics will be more accurate. We have proposed an automated smart mask for screening humans by thermal imaging System and IoT technology to detect and diagnose COVID-19. The smart mask cameras are used to obtain images from communal places, after which images are inserted into a system that recognizes a human who is affected with COVID-19 appears in the image. Post this information is broadcasted to the authorities to carry out further actions. The proposed algorithm implemented the testbench for hardware simulation and carried the experimental work performance over the predesigned smart mask methodology.

3.1 Framework implementation as workflow

The sections in the framework give a detailed view of the model-based approach and use assorted sensors for accurate predictions and data analytics. Each section explains the workflow for three subsystems to execute the entire application because of the interrelationship between the two. Besides, the image processing module, which is the portion of the required device excluding the decision-making module, is in charge of the data of the optical and thermal cameras. The camera and optical modules are pretty effective so that dynamic images can be taken with evaluation patterns using advanced programming libraries.

Also, the task of collecting appropriate data is allocated to the smart mask, if necessary. The interfacing is performed by a modular framework based on the IoT communication connection and the Global System for Mobile (GSM) communication. This device provides a warning if the temperature is higher than the normal body temperature. After tagging, the GPS module determines the location coordinates, and a notification is sent via a GSM to the assigned smart mobile. Then, the concerned officer obtains facial and temperature data to identify the person indicated as COVID-19 infected, as shown in Figs.1 and 2. Figure1 illustrates the Android module, cloud database, wearable Q band sensing node, modules related to the user interface.

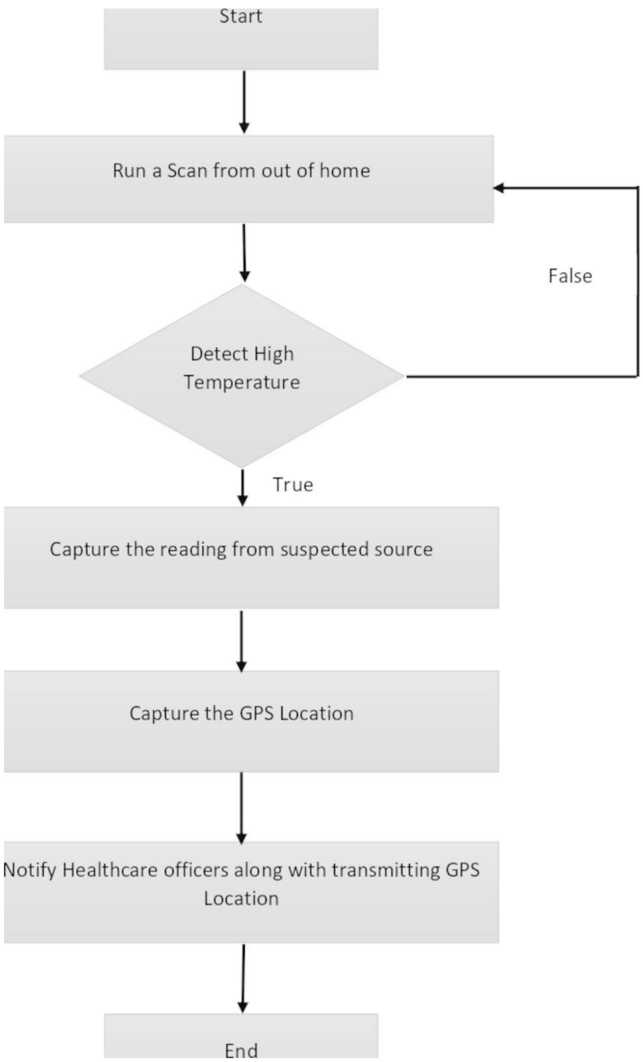


Fig. 2 Data-flow diagram for the proposed model

The proposed smart mask is divided into three parts. The system's first section includes the mechanism's input point, which consists of the thermal camera, optical camera, and mobile device. The development of a processor was the second phase of device development. The microcontroller processor was inserted into this section using the Arduino Integrated Development Environment (IDE) program to write the source code. The program allows the necessary commands and source codes to be compiled into the NODEMCU V2 processor. The system's third section focuses on the instrument's output origin. The smart mask was fitted with two separate types of cameras, which allowed the collection of accurate facial detection data and temperature measurement information. The optical camera and a thermal infrared camera provided details about the temperature at which different focal points of interest were located.

A thermo-graphic camera utilizes infrared radiation to create an image similar to a traditional camera that requires a good amount of light to generate images. This module considers the segmentation approach of an image by using the reported temperature and the color images captured by the optical and thermal cameras. For the identification of hot bodies, a thermal camera is used; the variations in the temperature amongst objects inside the scanned region are measured. When the temperature rise is encountered or visualized by the thermal camera, it produces elevated rates of infrared spectra.

3.2 Framework implementation as hardware

We used the following hardware: an Arduino board, an MLX90614 infrared temperature sensor, a laser diode, a push-button, a battery clip, an SSD1306 OLED display, a 9-V battery, and connecting wires (see Fig.3). The Arduino IDE was used in this project, a cross-platform application written in Java. This application includes code editor functionality, such as highlighting syntax, auto-indentation, and brace matching. Alternatively, the IDE uploaded an Arduino board using the critical one-click method that used compiled and uploaded programs. It also allows using C and C + + languages to order the code by using special rules.

The Arduino IDE also uses a wiring project that generates numerous input and output procedures to provide the program library known to Wire (see Fig.3). It is used to draw multiple schematics and simulate real-time circuits that provide access during the running process; therefore, it creates simulations in real-time, as studied in Howard et al. (2020); Desai et al. (2020). The illustration uses the EmguCV cross-platform for the face-detection operation. The Net wrapper was added to the image processing library of Intel OpenCV and C#.Net. The normal PIs were created by the OpenCV library during programming. The Arduino UNO board was used with an Intel processor-derived machine arm. Face detection was performed using the Cascade Classification algorithm based on the hair function. Besides, the machine learning algorithm was used to train both positive and negative images with a cascade function, as proposed in Kumar and Sukavanam (2020). The OpenCV library already detects Cascade objects that recognize the face of the captured image. Lots of common features are captured with the help of the human face to create a standardized rectangle that allows the equalization of the gray-scale image preprocessing algorithm and histogram as studied in Kai et al. (2020).

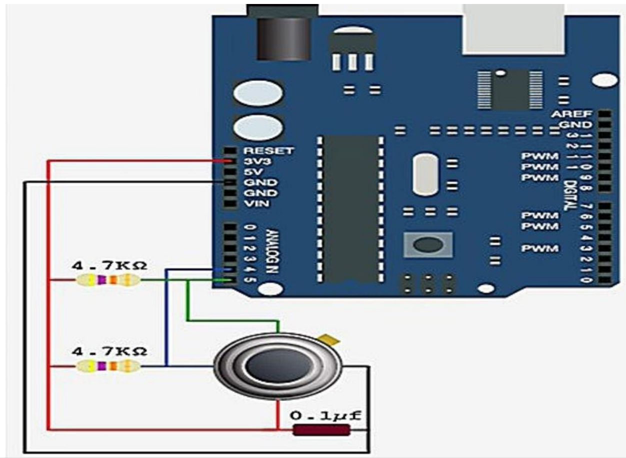


Fig. 3 Arduino temperature sensor board with an infection state

4 Experimental setup and working strategy of proposed smart mask

In the beginning, the presented design is tested by the simulation to analyze its achievability and confirm the unwavering consistency of the control technique. Figure4 shows a basic model of the created system. To tentatively authorize the program, the testing process focused on the software's conceptual interims; this ensured that all claims were checked and a practical interim was conducted to find the errors inside the tests. It also maintained that the given input would produce real results that were coordinated with the necessary outcomes. To develop and deploy real-time applications, there is a need to integrate the testing modules so that overall accuracy can be analyzed and elevated. Various levels of testing for the programs and models were

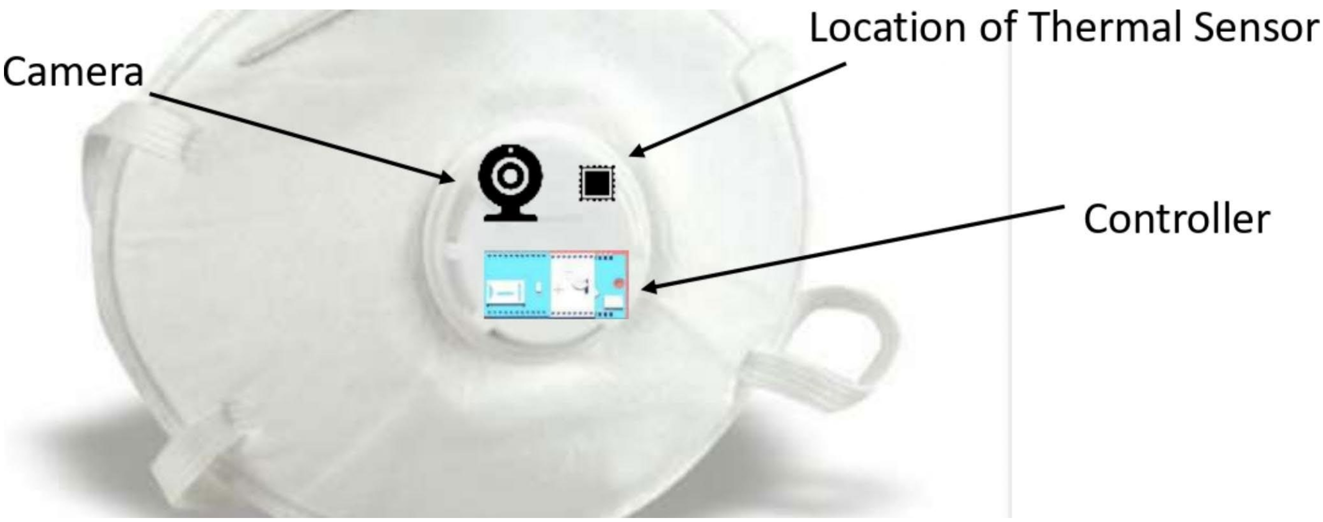
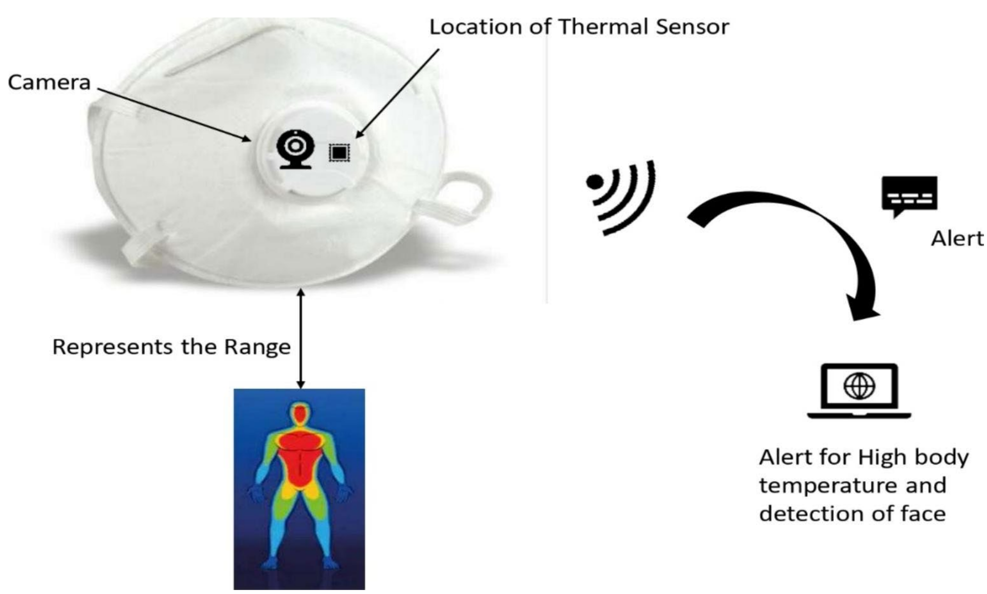


Fig. 4 Proposed smart mask

Fig. 5 Working strategy of a smart mask



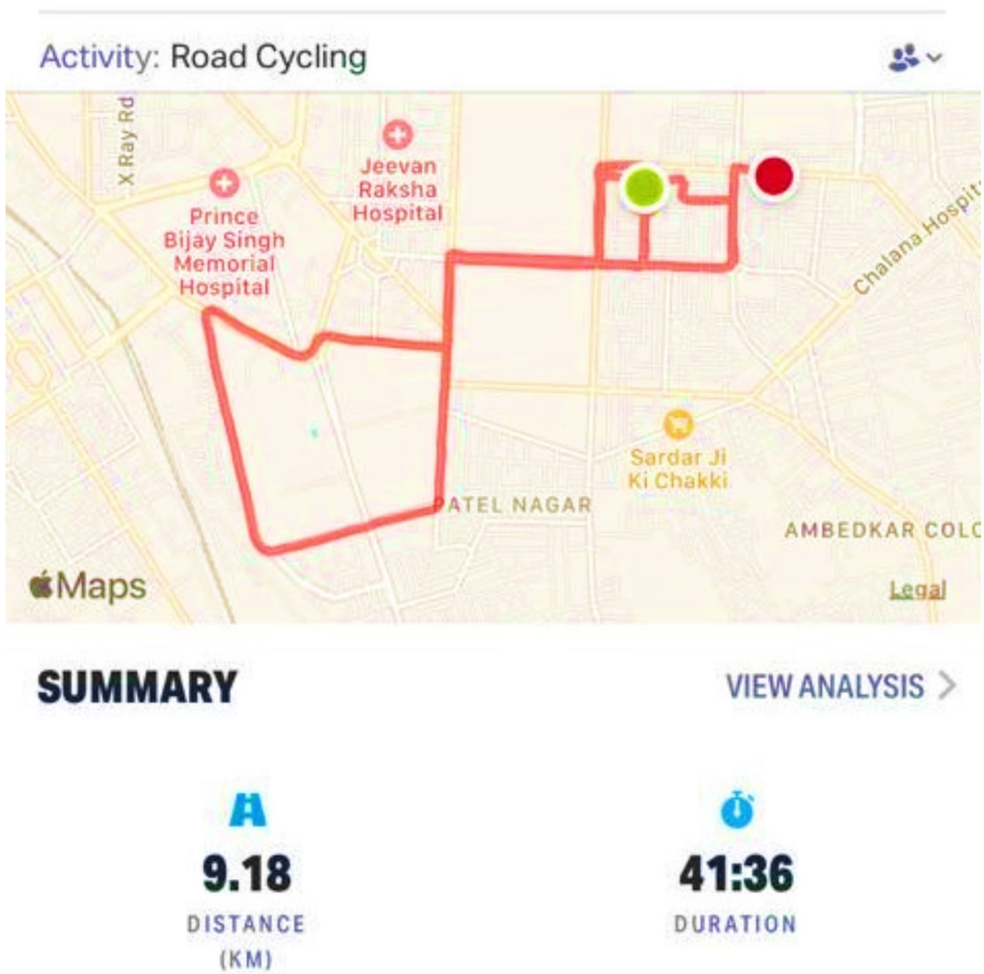


Fig. 6 An example of google location history

incorporated and performed. The simulation of the circuit imitated the output of the real electronic system and the circuit on the machine aided by mobile phones. Selenium, Postman and assorted units with stress testing modules are integrated for robustness and cumulative performance.

Figure5 shows the device setup. The proposed innovation concerns the applicable thermal imaging frameworks for detecting and monitoring body temperature increases. In particular, an enhanced mask-fixable camera system could be published instantly, used to display high-resolution thermal images for the infected site, and coordinated with the eye of the user while maintaining the focus. Fever, that is, elevated body temperature, is a significant indication of infection.

Thermograph-based implementation is the ideal procedure for scanning individuals and people with large flows. The temperature is captured, and an alarm is activated for high temperatures. This enables fast and accurate detection of individuals having elevated body temperatures so that they can be isolated for more detailed investigations. In addition to checking the body temperature, COVID-19 can be diagnosed using artificial intelligence. Infer Vision, a program that detects symptoms automatically from screening images, can make the identification faster and reduce the risk of human error. Figure5 shows the general workings of the smart mask.

Conventional computer vision algorithms, such as the Viola-Jones object detection framework, deformable component methods, and associated extensions, have genuinely advertised high performance in the sense of restricted conditions. Besides, the Google Location History (GLH) can give the system details of the places visited by the infected persons. GLH itself is a Google service that tracks where every mobile device user has gone. Figure6 depicts an example of the google location history.

To improve user experience, any Google App or service can use GLH, as shown in Fig.7. Similar to most Google services and features, the entire history and management are fully connected to the Google user account similar to most features and services offered by Google. GLH has been used to evaluate the habits of the users, as explained in Kumar and Sharma (2019), and the mobility of the user, as presented in Cheng et al. (2020). Besides, GLH helps in visualization, as studied by Zhou et al. (2020), including

Fig. 7 Dynamic temperature measurement

infrastructure planning, infectious disease control, and appropriate response to disastrous occasions.

After integrating Arduino's facial information, body temperature, and GPS locations of contacts, these values were transferred to the microcontroller (type NodeMcu) over the Web to provide worldwide independent access to this information. For this purpose, an external server called Blynk was used. The system notified the authorities of the threat when the thermal camera detected a person with a high body temperature, as shown in Fig.7. Then, the system took pictures and send them to the health officer. These images will be referenced for further Covid examination of the patient. In this method the hardware interacts with the user through the GPS module and information is carried forward for WWW with the virtual hypervisor over the cloud to store and process the data. Here AWS storage is used for maintaining cloud activities.

5 Results and discussions

The mask prediction on a dynamic level is quite challenging and is a crucial task in this research manuscript. The Smart Mask is a necessary safety face mask with a wireless upgradeable sensing service that consists of a sensing module with an integrated IoT device core, rechargeable batteries, Bluetooth radio, and essential sensors. The sensing and communication module aims to offer precise and reliable information, as studied in Dash et al. (2021) regarding the air quality under the mask or probable mask movement. As a result, this project focused on the sorts of sensors that need to be put into the Smart Mask prototype to gather this necessary information and data.

Table1 presents the evaluation of the stability points with the proposed approach in which accuracy is the primary factor and parameter of effectiveness. The stability points are analyzed in parallel to execution time, meaning that the

Table 1 Performance analytics on stability points

Iterations	Execution Time (In Microseconds)	Stability Point (Accuracy Evaluation)
10	1.21	98
30	1.23	93
60	1.26	94
70	1.46	95
100	1.33	97
120	1.31	95

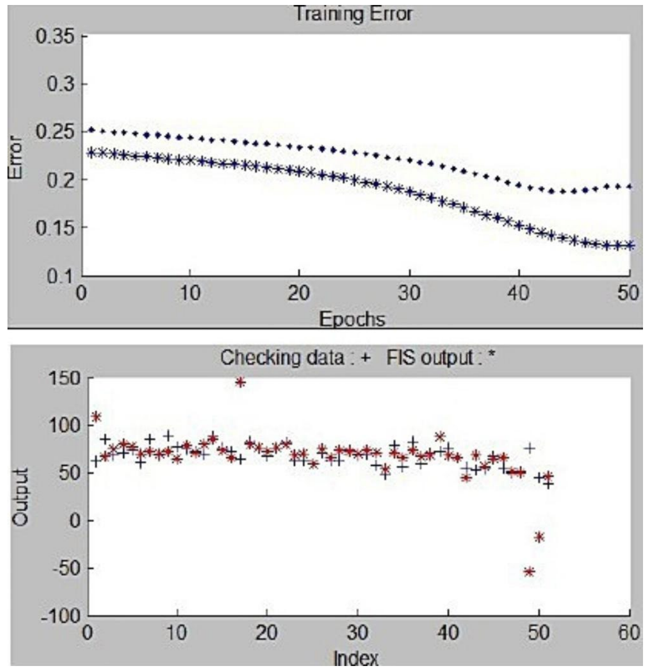


Fig. 8 Output on diverse points with fuzzy integrations

execution of the proposed approach is less with a higher degree of accuracy.

The implementation scenarios are simulated with the programming environment, and execution time is logged. The stability points are pretty effective with the dynamic execution time towards the projected approach (Fig.8).

The evaluation of training and testing with the validation is required to analyze the accuracy and reduce error factors. The training error is evaluated to analyze the overall patterns of the datasets under evaluation.

With the increasing attempts with the epochs on the simulation scenario, the errors are decreasing, which denotes the cumulative effect of the approach. The integration of a fuzzy system is required to handle the varying inputs effectively. The implementation of a fuzzy system is done so that the variations in environmental conditions can be handled effectively by the approach. The fuzzy-based model ensures the integrity and performance of fluctuating and varying data.

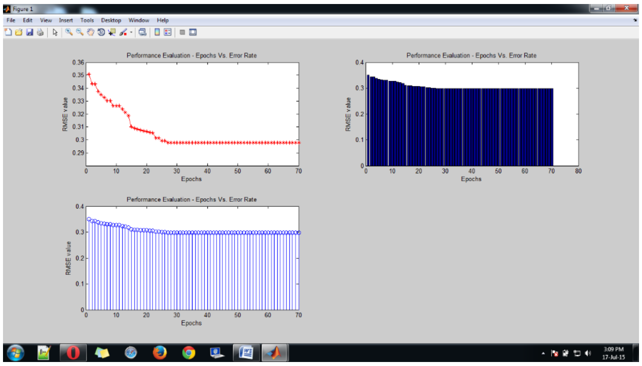


Fig. 9 Epochs and performance evaluation

The implementation patterns of the ensemble-based approach are quite performance-based and used in the outcomes and the accuracy and elevated with the outcomes with the integration of the dataset and its evaluation patterns. The execution scenarios are implemented with multiple epochs with the real-time scenario in Fig.9. With the increasing number of epochs, the error factor associated with Root Mean Square Error (RMSE) is decreasing, which depicts the proposed system's overall performance and higher accuracy.

COVID-19 cannot spread through regular breathing or talking because of the smart mask solution. Some sensor measurements, such as fever, can be customized with the smart sensing module. However, this will be extremely handy when work masks add more picture and audio acquisition capabilities.

Currently, "unintelligent" fabric masks, respirators, and surgical masks dominate the mainstream market. There are just a few devices on the market that attempt to add intelligence to the mask. The most advanced masks on the market are "stand-alone" items with a few extra features (e.g., fans that help with breathing through masks or sensors that monitor air intake), rather than integrated and intelligent systems like Smart Mask (i.e., device + cloud + application).

Smart Mask is compared to other options in Table2. Filtration is the mask's most basic function, its capacity to filter out undesired chemicals, as shown in Table2. If the mask has a medicalgrade, it is considered for medical use. Style/fashion demonstrates whether the mask can have varied styles or patterns, elements that make the mask more appealing. The term "comfort" refers to how pleasant to wear. Added electrical features, such as sensing, assess if the mask can monitor a variety of elements.

*Multiple vendors including Razer & DIY. **Multiple vendors including 3M, Honeywell, Kimberly-Clark, and Owens & Minor.

The term "ventilation" refers to the presence of a fan within the mask. As a result, voice correction improves/amplifies speech. Intelligence capabilities such as AI-based guidance studies are available if the mask provides guidance, alerts, and notifications for the user. The ability to offer counsel to the general public is referred to as population-level guidance. Such techniques are also referred to as the swarm-based intelligence techniques widely used for assorted applications. Such integrations are quite effective for fetching and analyzing the data in real-time with higher accuracy and minimum error rate.

Other options include LG PuriCareTM, Razer, and AirPop, all of which are already available or will be available in 2021. Forcit, like Smart Mask, is a research project that is still in the works, with prototypes available for testing. Non-smart masks include cloth masks, respirators, and surgical masks, which are included here for comparison.

The comparison was performed using information from the vendor's websites. Our smart mask system offers digitalized wearable protection. The Smart Mask will provide a completely new product to the market, aimed at clients who are prepared to spend money on personalized safety. Smart Mask delivers "intelligence as a service" and highly personalized health and wellness advantages, as discussed in Kumar (2017). It's a reusable N95 respirator mask with interchangeable sensors, real-time links to backend analytics, and a mobile app for the user.

6 Conclusion

An innovative monitoring system for the real-time early detection of coronavirus was developed with the help of a smart mask that was integrated with a thermal imaging system. The smart mask could detect persons with high body temperatures in a crowd and send the calculated data to be viewed on a phone screen. Early identification of the signs of coronavirus would be one of the best ways to prevent the coronavirus from spreading. Given that high body temperature is the most common symptom, a real-time screening process monitoring system is required that automatically shows the thermal image of a person's body temperature.

This system would make the screening phase less time-consuming with fewer human encounters to further spread the coronavirus. The proposed remote sensing procedures, which include different ways to recognize, feel, and track COVID-19, have tremendous potential to meet the demands made on the healthcare system. Integration of the FPGA hardware module (see e.g. Bhadada et al. (2014); Sharma et al. (2017)) will enable security standards as presented in Sonowal et al. (2021) for the detection and monitoring

Table 2 IOT enabled Smart mask in comparison to other masks

LG PuriCare TM	Razer	Forcit	AirPop	Cloth mask*	Respirator**	Surgical mask**	Smart Mask (see e.g. Masna et al. (2020))	IOT enabled Smart Mask (Proposed Work)	Properties
Excels Air Puri-fication, and enhanced Breathing, Adding UV light option for more features	Provides UV light interior which kills bac-teria and viruses as the mask charges.	expelled by a person, Wearer gets protection against large droplet	To provide clean air for breathing and light weight	Reduces the amount of expiratory droplets	expelled by a person, Wearer gets prote–ction against large droplets and splashes of oth-ers bodily fluids	Protects wearer by reducing exposure to air-borne particles (only non-oil aerosols)	Protects wearer by reducing exposure toairborne particles	Protects wearer by reducing exposure to airborne par-ticles and detect the infected person in crowd, warning as distance maintaining, Track-ing and monitoring	**Purpose**
Close-Fitting	Close-Fitting	Close-Fitting	Close-Fitting	Loose-fitting	Loose-fitting	Tight-fitting	Close-fitting	Flexible- Close Fitting	**Face seal Fit**
High Level	High Level	High Level	Moderate Level	Low level	Moderate level	High level (95%)	Removes all large (dia. > 5 _m), and tiny (dia. < 5 _m) airborne particles/droplets	High Level, Also provides warning at the time of high temperature infected person	**Filtration**
Breathable	Breathable	Breathable	Breathable	Breathable	Breathable	Difficult	Breathable	Breathable	**Breathability**
Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	**User seal check requirement**
Minimal leakage	Minimal leakage	Minimal leakage	Minimal leakage	Through cloth	Around mask edges	Minimal leakage	Minimal leakage	Minimal leakage	**Leakage**
Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	**Sensor to detect droplets**
Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	**Spraying mechanism**
No	No	No	No	No	No	No	No	Yes	**Sensors to detect infected person in crowd**
No	No	No	Yes	No	No	No	No	Yes	**IOT enabled device**
NA	NA	NA	Yes	NA	NA	NA	Yes	Yes	**Medical use**
NA	NA	NA	NA	Yes	Yes	NA	NA	NA	**Style/fashion**
Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	**Comfort**
Yes	NA	NA	NA	Yes	NA	NA	No	Yes	**Sensing**
NA	Yes	Yes	NA	NA	NA	NA	NA	Yes	**Ventilation**
NA	NA	Yes	Yes	NA	NA	NA	NA	Yes	**Voice correction**
Yes	No	No	Yes	Yes	No	No	No	Yes	**Real-time AI based guidance**
Yes	No	No	No	No	No	No	No	Yes	**Population level advice**

of the person in the crowd. The system motivates the work integrated into the cyber-physical system as a future scope.

The social distancing integration in this study will help evaluate the distance to be maintained among persons to safeguard coronavirus transmission. The future scope of the presented work is quite challenging and several advanced algorithms can be associated, including meta-heuristic approaches and nature-inspired techniques in integrating machine learning and deep learning libraries. These integrations will provide a higher degree of accuracy and performance levels.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12652-022-04395-7.

Declarations Not applicable.

References

Leung CC, Cheng KK, Lam TH, Migliori GB (2020) Mask wearing to complement social distancing and save lives during COVID-19. Int J Tuberculosis Lung Disease 24(6):556–558

Chu DK, Akl EA, Duda S, Solo K, Yaacoub S, Schünemann HJ, Hajizadeh A (2020) Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a system. Lancet 395(10242):1973–1987

Greenhalgh T, Schmid MB, Czypionka T, Bassler D, Gruer L (2020) "Face masks for the public during the covid-19 crisis,"British Medical Journal, vol. 369,

Leung CC, Lam TH, Cheng KK (2020) Mass masking in the COVID-19 epidemic: people need guidance. Lancet 395(10228):945

Zhai J (2020) Facial mask: A necessity to beat COVID-19. Build Environ 175:106827

World Health Organization (2020) "Advice on the use of masks in the context of COVID-19," interim guidance, 5 June 2020 (No. WHO/2019-nCov/IPC_Masks/2020.4). World Health Organization

World Health Organization (2020) "Rational use of personal protective equipment for corona virus disease (COVID-19)," interim guidance, 27 February 2020 (No. WHO/2019-nCov/IPCPPE_use/2020.1). World Health Organization

https://www.who.int/csr/don/21-december-2020-sars-cov2-variant-united-kingdom/en/

Kai D, Goldstein GP, Morgunov A, Nangalia V, Rotkirch A "Universal masking is urgent in the covid-19 pandemic: Seir and agent based models, empirical validation, policy recommendations," arXiv preprint arXiv:2004.13553, 2020.

Halegoua G (2020) Smart City Technologies. Smart Cities. doi: https://doi.org/10.7551/mitpress/11426.003.0005

Javid B, Weekes MP, Matheson NJ (2020) "Covid-19: should the public wear face masks?"

Mittal R, Ni R, Seo JH (2020) "The flow physics of COVID-19,"Journal of Fluid Mechanics, vol. 894,

Garcia LP (2020) Uso de máscara facial para limitar a transmissão da COVID-19. Epidemiol e Serv saude Rev do Sist Unico Saude do Bras 29(2):e2020023

Allam Z, Jones DS (2020) On the corona virus (COVID-19) Outbreak and the Smart City Network: Universal Data Sharing Standards Coupled with Artificial Intelligence (AI) to Benefit Urban Health Monitoring and Management. Healthcare 8(1):46

Jiang M, Fan X, Yan H "RetinaMask: A Face Mask detector," 2020. [Online]. Available: http://arxiv.org/abs/2005.03950

Gupta M, Abdelsalam M, Mittal S (2020) "Enabling and Enforcing Social Distancing Measures using Smart City and ITS Infrastructures: A COVID-19 Use Case," [Online]. Available: https://arxiv.org/abs/2004.09246

Won Sonn J, Lee JK (2020) The smart city as time-space cartographer in COVID-19 control: the South Korean strategy and democratic control of surveillance technology. Eurasian Geogr Econ 61:4–5

Singh RP, Javaid M, Haleem A, Suman R (2020) Internet of things (IoT) applications to fight against COVID-19 pandemic. Diabetes & Metabolic Syndrrome: Clinical Research & Reviews 14(4):521–524

Sonn JW, Kang M, Choi Y (2020) Smart city technologies for pandemic control without lockdown. Int J Urban Sci 24(2):149–151

Jaiswal R, Agarwal A, Negi R (2020) Smart Solution for Reducing the COVID-19 Risk using Smart City Technology. IET Smart Cities 2:82–88

Wang X, Le X, Lu Q (2020) "Analysis of China's Smart City Upgrade and Smart Logistics Development under the COVID-19 Epidemic," Journal of Physics: Conference Series, vol.1570, 012066,

Gorbunov B (2020) Aerosol particles laden with COVID-19 travel over 30 m distance. Preprints 2020040546. https://doi.org/10.20944/preprints202004.546.v1

Cheng KK, Lam TH, Leung CC (2020) Wearing face masks in the community during the COVID-19 pandemic: altruism and solidarity. The Lancet. https://doi.org/10.1016/S0140-6736(20)30918-1

Seyhan K, Nguyen TN, Akleylek S, Cengiz K, Islam SKH (2021) Bi-GISIS KE: Modified key exchange protocol with reusable keys for IoT security. J Inform Secur Appl 58:102788

Howard J, Huang A, Li Z, Tufekci Z, Zdimal V, van der Westhuizen HM, Tang V (2020) "Face masks against COVID-19:An evidence review,"PNAS2021,vol.118,no. 4, e2014564118, https://doi.org/10.1073/pnas.2014564118

Desai AN, Aronoff DM (2020) Masks and corona virus disease 2019 (covid-19). JAMA 323(20):2103

Kumar N, Sukavanam N (2020) "Detecting helmet of bike riders in outdoor video sequences for road traffic accidental avoidance,". In: Abraham A, Cherukuri A, Melin P (eds) Intelligent Systems Design and Applications. ISDA 2018 2018. Advances in Intelligent Systems and Computing, vol 941. Springer, Cham. https://doi.org/10.1007/978-3-030-16660-1_3

Kumar N, Sharma A (2019) "A spoofing security approach for facial biometric data authentication in unconstraint environment,". In: Pati B, Panigrahi C, Misra S, Pujari A, Bakshi S (eds) Progress in Advanced Computing and Intelligent Engineering. Advances in Intelligent Systems and Computing, vol 713. Springer, Singapore. https://doi.org/10.1007/978-981-13-1708-8_40

Cheng VC, Wong SC, Chuang VW, So SY, Chen JH, Sridhar S, Yuen KY (2020) The role of community-wide wearing of face mask for control of corona virus disease 2019 (COVID-19) epidemic due to SARS-CoV-2. J Infect 81(1):107–114

Zhou ZG, Yue DS, Mu CL, Zhang L (2020) Mask is the possible key for self-isolation in COVID-19 pandemic. J Med Virol 92(10):1745–1746

Dash R, Nguyen TN, Cengiz K, Sharma A (2021) FTSVR: Fine-tuned support vector regression model for stock predictions. Neural Comput Appl. https://doi.org/10.1007/s00521-021-05842-w

Masna NVR, Kalavakonda RR, Dizon R, Bhuniaroy A, Mandal S, Bhunia S (2020) "The Smart Mask: Active Closed-Loop Protection against Airborne Pathogens,"arXiv preprintarXiv:2008.10420.

Kumar N (2017) "Machine intelligence prospective for large scale video based visual activities analysis," 2017 Ninth International

Conference on Advanced Computing (ICoAC), pp.29–34, doi: https://doi.org/10.1109/ICoA
Bhadada R, Sharma A (2014) "Montgomery implantation of ECC over RSA on FPGA for public key cryptography application," 2nd International Conference on Emerging Technology Trends in Electronics, Communication and Networking, pp.1–5, 2014, doi: https://doi.org/10.1109/ET2ECN.2014.7044973
Sharma A, Bhadada R (2017) KOM multiplier for ECC implementation in FPGA. Int J Control Theory Appl 10:677–683 doi:ICoAC.2017.8441320
Sonowal G, Sharma A, Kharb L (2021) Spear-phishing emails verification method based on verifiable secret sharing scheme. J Inform Assur Secur 16(3):117–124