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Smart Mask for Health Monitoring

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Abstract

Face masks provide effective, easy to-use, and low-cost protection against airborne pathogens or infectious agents, including SARS-CoV2. Existing masks are all passive in nature, i.e., simply act as air filters for the nasal passage and/or mouth. This paper presents a new "active mask" paradigm, in which the wearable device is equipped with smart sensors and actuators to both detect the presence of airborne pathogens in real time and take appropriate action to mitigate the threat. The proposed approach is based on a closed-loop control system that senses airborne particles of different sizes near the mask and then makes intelligent decisions to reduce their concentrations. The system communicates with the user via a smart phone application that provides various alerts, including the need to recharge and/or decontaminate the mask prior to reuse. The application also enables a user to override the on-board control system and manually control the mist generator if necessary. As an implementation step, working of a "smart mask" is demonstrated on wooden circuital-board.

1. Introduction

The world has been witnessing the increasing spread of COVID-19 since the beginning of 2020. This novel virus has brought everyone's lives to a standstill and the economy to its knees. Although most people are actively following social distancing norms, proper hygiene, and other technologically advanced preventive measures, it is likely that normal day-to-day life will continue to be affected until an effective vaccine is developed. To mitigate this situation and return to some semblance of normalcy, we believe there is a need for preventive methods that actively combat the virus instead of providing passive protection (e.g., physical barriers). Implementing such improved methods requires smart devices that can detect, quantify, and actively eradicate viruses and other pathogens. Typical Personal Protective Equipment (PPE), such as face masks (cloth, surgical, or N95), face shields, eye protection, disposable gloves, and coveralls all provide passive protection: these devices only prevent pathogens from entering the body by filtering them out. By contrast, active protection devices can actively attack and destroy pathogens near vulnerable parts of the body (e.g., the nose and mouth). Here consider closed-loop active or "smart" masks for use in places where potentially virus-laden respiratory droplets (typically 0.1- 10 μm in diameter) are most likely to be transmitted; examples include bathrooms, doctor's offices, daycare centers, and public transportation.

Such active closed-loop protection can remove viruses (and other pathogens) from the air before they infect others, thereby reducing the need for periodic disinfection of the area, while providing increased protection to the wearer. Hygiene mask for regular use.

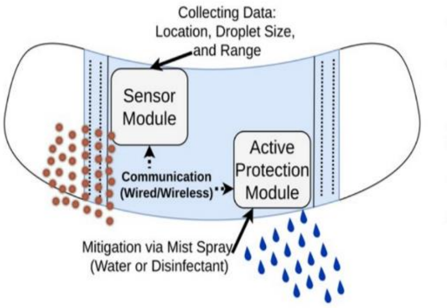

Figure 1 Overall architecture of the proposed smart mask

2. System Architecture

The smart mask has two main components: a particulate matter (PM) sensor and an IoT connected device. These methods have the advantage that the sampled pathogens can be analyzed, identified, and quantified using sensitive lab-based techniques, such as real-time polymerase chain reaction (RT-PCR) or surface-enhanced Raman spectroscopy (SERS)

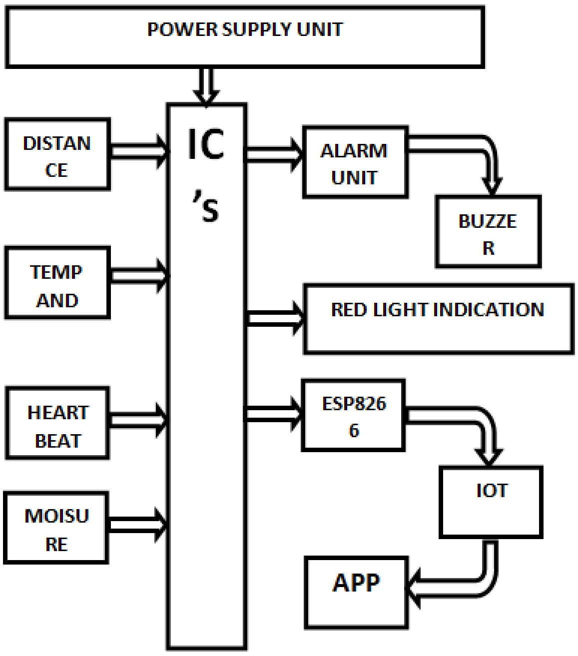

Figure 2 Block diagram of smart mask

However, incorporating such sensitive detectors into a wearable form factor is extremely difficult. Due to this limitation, we focus on a remote detection approach. Remote (also known as standoff) detection of pathogens has been demonstrated using a variety of optical methods, using asymmetric microsphere resonant cavities, laser induced fluorescence and random Raman lasing, as well as non-optical methods, such as imaging and spectroscopy. Here, we use a PM sensor that makes use of laser scattering to precisely count airborne particles in multiple size “bins”. In addition, the control algorithm also uses data from auxiliary sensors (such as relative humidity and temperature) while determining the optimal parameters for the mitigation device (i.e. mist generator), since aerosol travel distances depend on such environmental factors. The mitigation device generates aerosolized mist on-demand using a piezoelectric transducer. The best disinfectant for a given pathogen can be found using guidelines provided by the U.S. Centers for Disease Control and Prevention (CDC) and Environmental Protection Agency (EPA). Common disinfectants include diluted bleach, soap, and > 70% alcohol solution.

3. Operational Principles

The smart mask integrates a sensing module that senses the presence of airborne aerosol droplets (typical diameter 0.1- 10 μm) in the vicinity of the user’s respiratory tract. It incorporates an optical detector system and auxiliary humidity and temperature sensors (as described previously) to quantify the total number and size distribution of these droplets as they approach the protected region (i.e., the nose and mouth). The outputs of both sensors are processed by an air quality analyzer module. The latter uses algorithms to analyze sensor data and thereby classify the quality of the incoming air stream based on health risk (e.g., “very high”, “high”, “moderate”, and “low”). These risk categories are then encrypted for security and sent to the protection module either wirelessly (e.g., over Bluetooth) or by using a wired connection. A “high risk” output triggers the active protection mechanism. The hardware and software required for both sensing and protection modules are implemented using low-cost commercial off-the-shelf components (a low-power microcontroller and a wireless system-on-module) built within a mask, thus enabling widespread deployment in the vulnerable population. The smart mask can also connect to authorize mobile devices through its wireless module. Users can use a mobile application to monitor current air quality, check system status (e.g., battery and liquid levels), and also manually override the on-board mitigation algorithm.

4. Proposed Framework

The development of the COVID-SAFE platform relies on three parts, including a wearable IoT device, smartphone app, and fog (or cloud) server. The software parts include an application program interface (API) for interacting with users on a smartphone, and a fuzzy decision-making system on the fog server.

Nodes collect specific vital data from participations and upgrade their decision-making regulations to aid users in various scenarios, such as the need to refer to a doctor, maintaining physical distance from others, and alerts regarding high-risk areas.The IoT node enters this mode when a 4G/5G/Wi-Fi connection is not available. A possible situation is in rural areas with limited Global System for Mobile Communications (GSM) coverage.

5. Wearable IoT Device

This IoT node works in association with the user's smartphone to collect proximity data using Bluetooth and to communicate with the server through the cellular data network. It consists of a RPIZ as the central processor, temperature, and a LoRa module for data communication in the absence of a cellular data network and WiFi. The system then is synchronized with the software to monitor the user's behavior during daily activities. In Scenario-1, the IoT node sends the sensor data to the smartphone app via Bluetooth connection. The smartphone then sends the data stream to the server via 4G/5G or WiFi. The server feeds the app with the latest updates. The app can notify users of new restrictions and provide useful tips given by the health service and governments. Meanwhile, the app sends the participations' body parameters for further processing. The cloud server receives all the information and applies a fuzzy inference system on the data, and finally sends back the risk score to the phone for the user. The second mode of operation (Scenario-2) is a LoRa-based network. The IoT node enters this mode when a 4G/5G/Wi-Fi connection is not available. A possible situation is in rural areas with limited Global System for Mobile Communications (GSM) coverage. The RPIZ has a 1 GHz single Central Processing Unit (CPU) core with 512 MB of Random Access Memory (RAM), several Global Purpose Input/Outputs (GPIOs), wireless LAN, and Bluetooth connectivity, all in one platform. These features make the RPIZ a suitable choice for implementing many IoT-based systems. he RPIZ is equipped with an internal Bluetooth and Wi-Fi module, which makes it easy to interface with a smartphone app. The IoT node is battery operated and is designed with a 3D printer as a finger clip to encapsulate the necessary hardware and to be friendly for the user during daily activities. In order to measure the power consumption of the system, the wearable IoT device is connected to a digital wattmeter. The data is logged in a computer that produces the wattage measurements.

6. Smartphone APP

Figure. 3 shows the COVID-SAFE smartphone app, which is built to interact easily with users. First, the user has to create an account and answer general background questions such as gender, age, weight, height, and history of diseases. Fig. 3(b) shows the general information page. By accumulating this information, the system can provide an individual risk factor for the user. Fig. 3(c) shows the radar dashboard; in this menu, all adjacent nodes in the range of 3 m are shown on the screen.

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TheThe red dots illustrate nodes in the range of 2 m or less, the yellow dots indicate nodes between 2 to 3 m, and green dots are nodes placed at 3 m or further. The app notifies the user as soon as the second node comes closer than the specified range. The positions of nodes on the radar screen are separated for better visualization purposes. The app can display the heart rate, body temperature, blood oxygen saturation, and individual risk factor in real-time mode as Fig. 3(d) shows. The output of the decision-making system is depicted in Fig. 3(e). In this fragment, the app asks for symptoms following the body parameters, and it provides the risk evaluation, and sends some useful tips

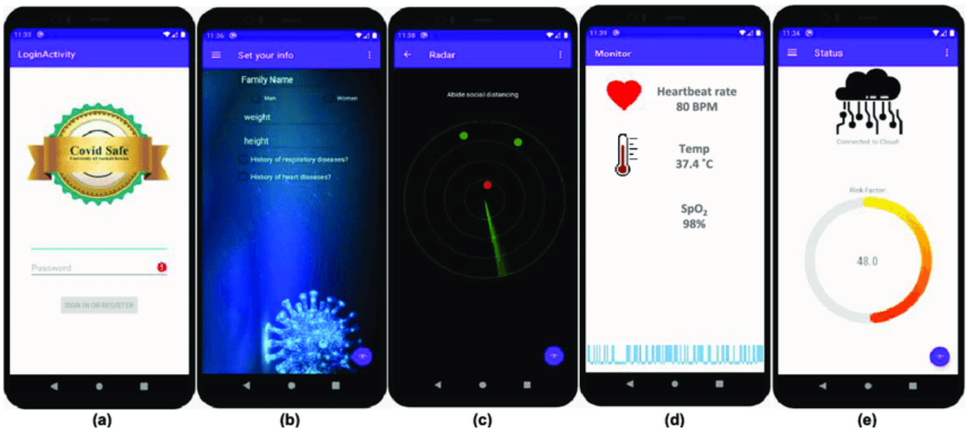

Figure 3 COVID-SAFE application which is connected to fog server based on predefined API, a) login menu b) general information page c) radar dashboard d) health monitoring menu and e) individual risk factor.

7. Conclusion and Future Work

We have proposed and demonstrated a new 'smart mask' paradigm of active closed-loop defense against airborne pathogens including SARSCoV-2. Various levels of smartness can be incorporated into the system to control the time, duration, and intensity of mitigation based on awareness of the location (e.g., hospitals, quarantined zones, or care facilities), ambient conditions (e.g., humidity and air temperature, human occupancy), and overall health of the user (e.g., age, pre-existing conditions, etc.). The proposed mask can also be extended to i) protect against pollutants, dust particles, and pollen, e.g., for vulnerable populations with pollen and/or dust allergies, and ii) other usage scenarios, e.g., military personnel exposed to harmful airborne particles, dentists performing dental procedures, and day-care or elementary schools where social distancing is hard to maintain. While more testing and evaluation is needed to fully establish the merits of the smart mask and identify remaining design challenges and trade-offs, the initial results are highly promising. The approach can be applied to existing masks as an addon, as well as to new mask designs as demonstrated here; it may eventually replace traditional masks for specific applications.

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