

# Conceptualization Of Smart Personal Protective Equipment For The Prevention Of Community Transmission Of Respiratory Diseases

Gopika D<sup>1</sup>, Sujay E<sup>2</sup>, Dharmendra M<sup>3</sup>

<sup>1</sup> Clinical data analyst at Origin Health, <sup>2</sup> Co-founder of Biznustek Systems Pvt Ltd, <sup>3</sup> Founder of Biznustek Systems Pvt Ltd  
Email: [1gopikanov@gmail.com](mailto:gopikanov@gmail.com), [2sujay@biznustek.biz](mailto:sujay@biznustek.biz), [3dharmendra@biznustek.biz](mailto:dharmendra@biznustek.biz)

\*Corresponding Author: Gopika D  
Clinical data analyst at Origin Health.  
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## Abstract

We all know that the major cause of the proliferation of many communicable diseases is community transmission. Thus, our objective is to impede community transmission of respiratory-based communicable diseases. This can be achieved using surgical masks in a “smart way” with embedded systems and IoT. This smart mask will help to ease the burden of front-line workers, mildly affected and asymptomatic individuals. According to a recent study [1], the reports states that surgical masks like N-95 are not very effective in blocking the complete transmission of air-borne pathogens or viruses from infected individuals. The notion is, to optimize the existing purification process used in the masks available today. We know that surgical N-95 masks which are commonly used today are used to let the purified air in. But, this smart personal protective equipment helps to let the purified air out. By letting the virus-free air out through UV-C purification, it results in slim chances of an infected or asymptomatic individual spreading the disease.

**Index Terms**— Asymptomatic individual, community transmission, health-care, and personal protective equipment.

## INTRODUCTION

Community transmission is the spread of infectious diseases from infected individuals to a group of people. It usually becomes difficult to track the source of spread, in the case of this transmission. According to the Centers for Disease Control and Prevention [2], there are two modes of transmission – they are, direct and indirect transmission. The one which we are dealing with now (COVID-19) is indirect transmission caused by aerosol. This aerosol transmission occurs when the virus is carried by dust particles suspended in the air. This type of airborne transmission was the major cause of the proliferation of the recently experienced COVID-19 pandemic.

An asymptomatic individual means a person who is not showing any visible symptoms of the disease, but they are still known to be tested positive for the disease and transmit it. When an asymptomatic or mildly infected individuals cough or sneezes – there is a high possibility of other people getting infected by the disease.

This type of chain transmission is very difficult to control, as it involves contact tracing the source of the spread. Another study affirms that [3] airborne transmission was the dominant route for the transmission of COVID-19. The solution to this problem which was faced worldwide is only through rigorous testing methods and contact tracing.

However, there are other possible preventive measures that can be analyzed and implemented in order to find the root cause and solve it before it begins to proliferate.

## OBJECTIVE

Our aim is to prevent airborne community transmission with the use of smart protective equipment. This PPE (Personal Protective Equipment) concept arose during the peak pandemic[4]. Our team brainstormed on how to reduce the spread. By working towards many iterations of the workflow and methodology, we finally came up with this workflow and 2D and 3D design. The implementation is the need of the hour, the smart mask is connected to the UVC chamber through a surgically disposable tube thus helping in letting the purified air out. The proposed system also has embedded systems and IoT to increase its efficiency.

## MATERIALS

The design of smart PPE will require the following components - as mentioned in table 1

Major components	Quantity
N-95 surgical mask	1
Surgical disposable tube	1
Arduino Uno Rev3	1
Pressure sensor	1
Micro vacuum pump	1
Mini electronic solenoid valve	2
Light Emitting Diode (LED)	1
12 V - Batteries	4
UV- C chamber	1

**Table 1:** List of components

### 1. N-95 surgical mask

This mask which is shown in figure 1 is used by most of our front-line workers, clinicians, and, affected individuals. The mask is the fundamental component of the design in smart PPE. Even here it serves the same purpose of protecting individuals from direct exposure to the virus.



**Figure 1:** N-95 surgical mask

### 2. Surgical disposable tube (Preferred model - FR 26)

This tube illustrated in figure 2 serves as a connection between the surgical mask and the UV-C chamber. It also consists of the attachment of a few electronic components like a micro-vacuum pump and a microvalve for controlling the inlet.



**Figure 2:** Surgical disposable tube

### 3. Embedded system

**a. Arduino Uno Rev3**

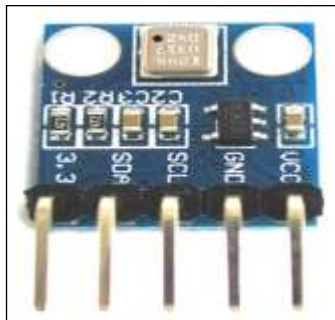
The Arduino board as shown in figure 3 is used for the reception and transmission of signals from the pressure sensor, micro vacuum pump, inlet–outlet valves, batteries, and UV-C chamber.



**Figure 3:** *Arduino Uno rev3*

**b. Pressure sensor (GY-63 MS5611-01BA03 high precision pressure sensor)**

The sensor in figure 4 is used to detect the pressures which exceed the maximum inspiratory and expiratory pressures [5] to sense a cough or sneeze of a particular individual.



**Figure 4:** *Pressure sensor*

**c. Micro vacuum pump (2V 0.25A 37ml-min silicone tube liquid pump)**

The pump in figure 5 is useful for sucking sneeze or cold droplets after receiving the signal from the microcontroller.



**Figure 5:** *Micro vacuum pump*

**d. Mini electronic solenoid valve (DC 5V 2-Position 2-way small mini electric solenoid valve for air/gas)**

This valve in figure 6 helps in controlling the inlet and outlet of the sneeze or cough droplets to the UV-C chamber.



**Figure 6:** *Mini electronic solenoid valve*

**e. 12-volt rechargeable battery with USB cable**

The battery in figure 7, is used to support the functioning of the vacuum pump and the microvalve. Four 12V batteries can be serially connected to produce a battery bank of 48V with a battery capacity of 26Ah. Thus, enabling to power the embedded circuit.



**Figure 7:** *12 volt rechargeable battery with USB cable*

**f. LED**

LED in figure 8, is used to indicate the pressure sensor activation after it exceeds the pressure threshold.



**Figure 8:** *LED*

**4. UV-C chamber**

This chamber in figure 9, is used for purifying the infected air by the use of UV-C LEDs in the UV-C chamber [6]. The UV-C LEDs emit radiation in the range of 200 to 280 nm, long time exposure to this causes skin rashes in humans. So this is designed to be placed in the backside of the individual. This chamber is powered and controlled by the microcontroller. This can be implemented in the future with the aid of recent research works on UV-C chamber design [7].



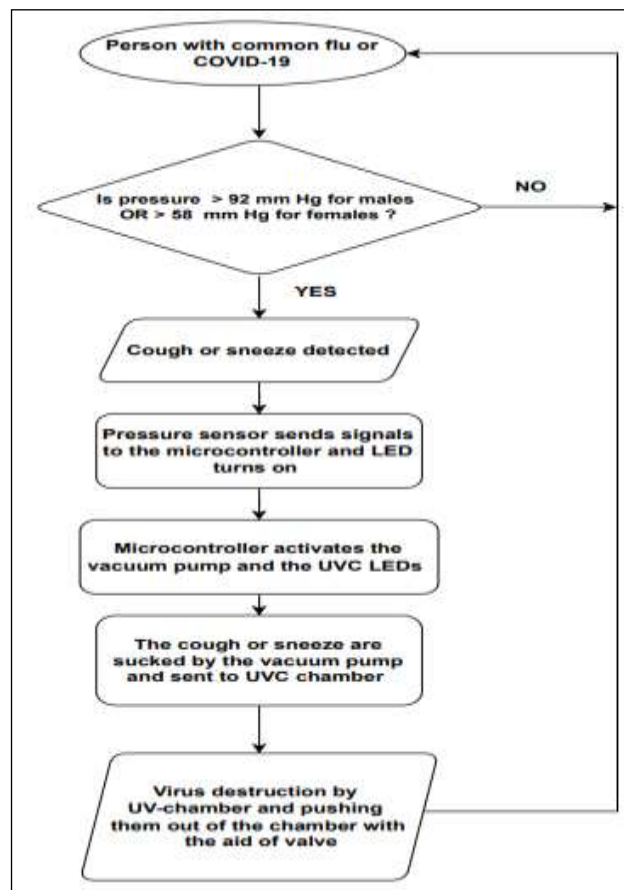
**Figure 9:** UV-C chamber

## METHODOLOGY

Functioning of this Smart PPE is as follows:

When the mildly symptomatic individual or asymptomatic individual experiences a cold/sneeze the pressure sensors in the surgical N-95 mask get activated. After checking the pressure threshold [5] based on maximal respiratory pressures - the maximal inspiratory and expiratory pressure varies from 69 to 92 mm Hg for males and 47 to 58 mm Hg for females respectively, if the pressure exceeds the threshold, then the sensors get activated, LED turns on and sends a signal to the microcontroller. The microcontroller activates the low-power vacuum pump and the UV-C LEDs. The droplets are sucked by the pump and into the UV-C sterilization chamber through surgical tubes. UV-C light sterilizes the air by destroying the RNA strand of Coronavirus. The sterilized air is then let out into the atmosphere through the controlled action of a microvalve.

Following in figure 10 is the clinical workflow of the Smart PPE



**Figure 10 :** Clinical workflow

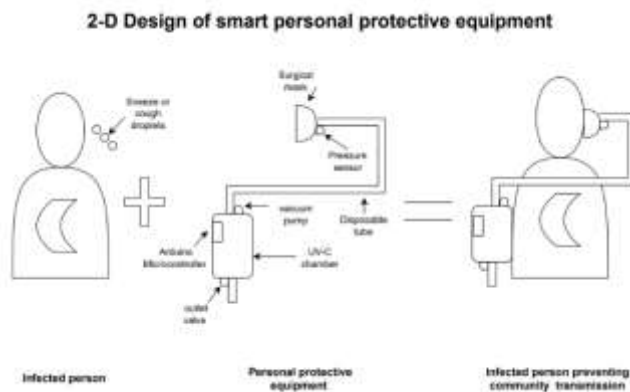
## DESIGN

### Two-dimensional design for the proposed system

We have been developing a design model using diagrams.net [8] to explain the equipment workflow.

When an asymptomatic individual coughs or sneezes beyond the maximum expiratory and inspiratory pressure, the pressure sensor gets activated, and the microcontroller signals which the vacuum pump for sucking the droplets. This, in turn, switches on the microvalve and sends the infected air to the UV-C chamber. The UV-C chamber is designed to be behind the back of the individual to minimize exposure of the individual to UV-C radiation. The working of the pressure sensor module with LED is explained further in the virtual simulation section.

The 2-D design of the model is shown below in figure 11



**Figure 11:** 2-D design of the proposed model

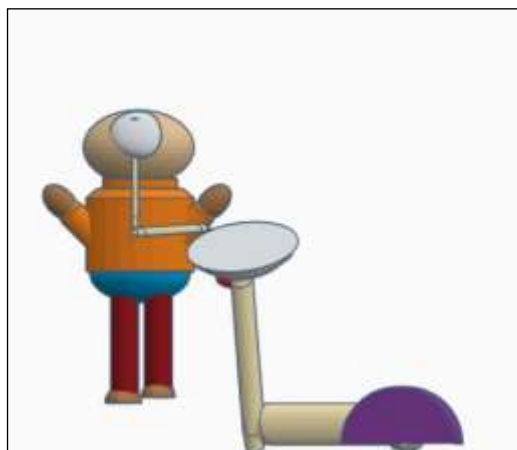
### 3-dimensional model for the proposed system

Our team has come up with a real-world 3D dimensional model of the proposed system with the aid of Tinker CAD, having used different tools like the workplane tool, and ruler tool to visualize how will an individual wearing the smart PPE will look like. We have modeled two designs, one is the magnified view of the smart PPE, other is the individual wearing the PPE.

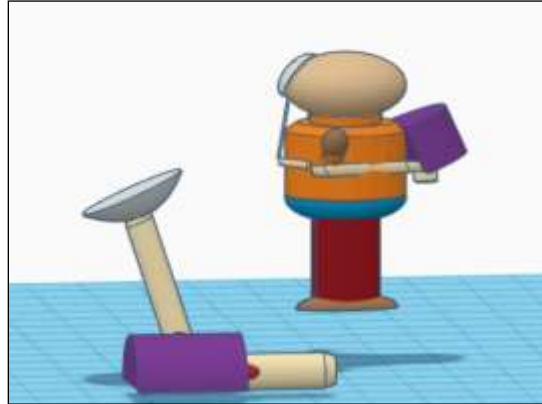
The front view as shown in figure 12 consists of the mask, surgical tube, and pressure sensor. The right view, which is figure 13 consists of the UV-C chamber and the outlet valve.

The back view in figure 14 explains how the UV- C chamber will fit the back of the individual.

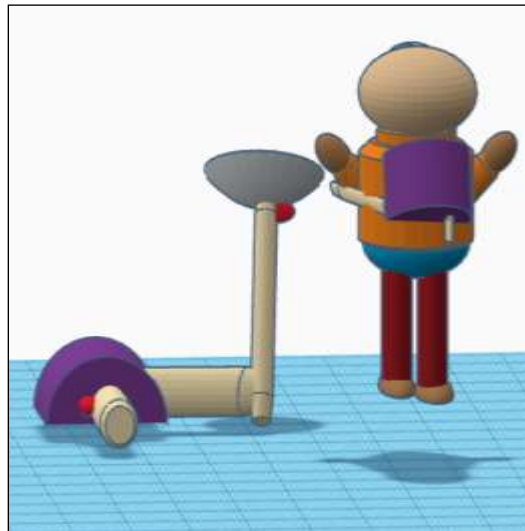
This is the 3D design of the proposed model.



**Figure 12:** Front view showing the mask, pressure sensor and the surgical disposable tube



**Figure 13:** Right view showing the UV- C chamber, surgical disposable tubes and the outlet valve

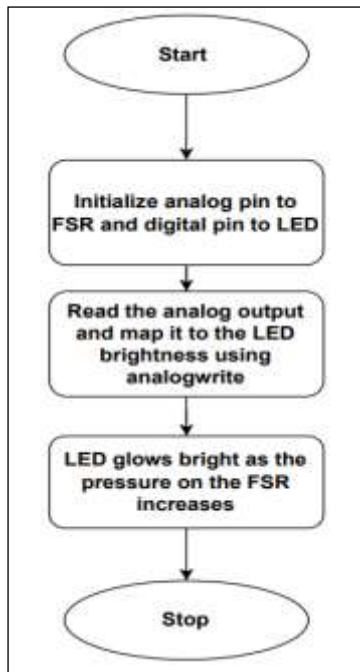


**Figure 14:** Back view showing the sensor and the valves, also illustrating how the UV-C chamber fits in the back of the individual

## VIRTUAL SIMULATION

### Workflow

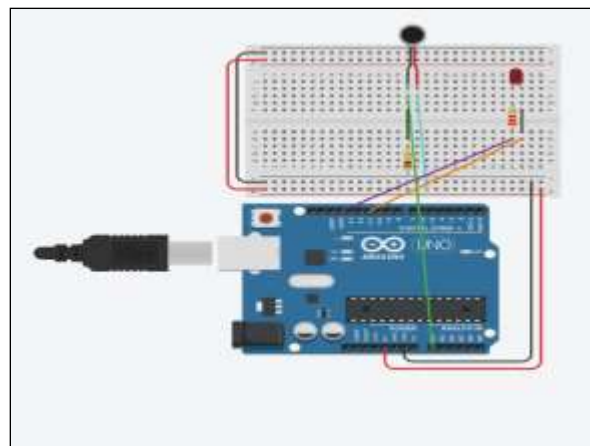
The flowchart, as shown in figure 15, starts with the initialization of the LED and Force Sensing Resistor (FSR) [9]. The FSR is connected to the analog pin and the digital pin is connected to the LED. The analog output is mapped to the LED's glow. As the pressure on the FSR increases the LED glows brighter.



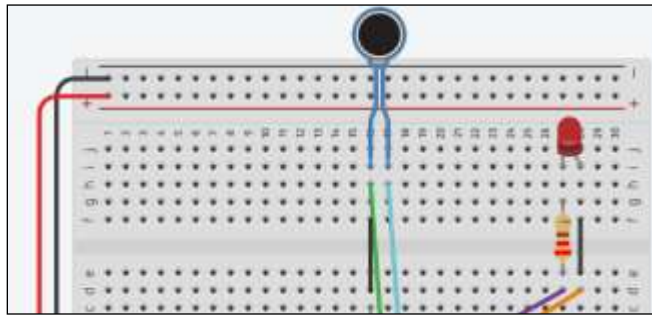
**Figure 15:** *Flowchart of the FSR*

#### Virtual simulation of the FSR module

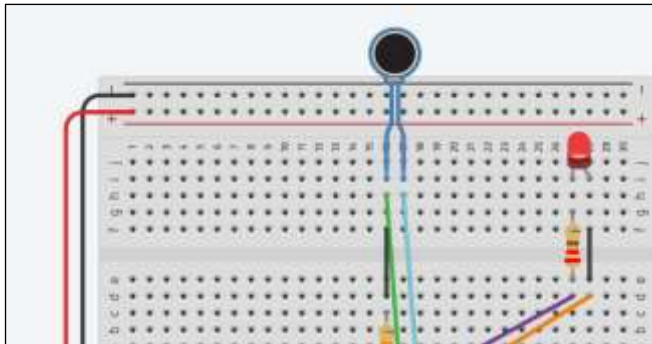
The FSR is approximately equivalent to the pressure sensor and the simulation has been carried out using an Arduino board and resistors [10]. When the pressure on the FSR is applied the LED starts glowing, this is an indication to the microcontroller to turn on the vacuum pump. Figure 16 shows the circuit when switched off. Figure 17 shows the turning in of LED due to pressure in the FSR. Figure 18 shows the LED glowing brightly due to the harder pressure on the FSR.



**Figure 16:** *Circuit with FSR before activation*



**Figure 17:** *Circuit when the FSR is pressed slightly – LED glows dimly*



**Figure 18:** *Circuit with FSR after activation – LED glows brightly*

## CONCLUSION

We have conceptualized the smart PPE system. Finalized the design specifications and designed the model in 2D and 3D. We have also researched FSR modules. Designed the workflow of the FSR with the flowchart, a virtual simulation of the FSR that is equivalent to a pressure sensor.

The future scope includes the simulation of the micro vacuum pump and the outlet module. It involves designing a UV-C chamber and optimizing the design of the mask for operation with increased efficiency.

Decreasing the size of the UV-C chamber without causing much exposure to radiation would prove very beneficial.

Additionally, complying with and oversight of medical device regulations of different countries is necessary for commercialization.

## ADVANTAGES

The advantages of this system are:

- 1) This concept, if implemented will be very useful in preventing the air-borne transmission of any respiratory-related infections or diseases.
- 2) It will aid as a smart personal protective equipment for healthcare line workers, and volunteers during the pandemic.
- 3) The use of smart personal equipment is beneficial for mild and asymptomatic individuals who are in home isolation.

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