Touch-free operated Face shield-cum-mask for multifaceted applications– Vaktram Kavacham

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Abstract. There are various situations where face shields and mask play an important role such as for doctors in operation theatres, healthcare workers diagnosing/treating patients with infectious disease, traffic police and construction workers working in environments with high levels of dust and air pollution, welders working at high temperatures, bike, bicycle riders and many others. A face shield-cum-mask can be useful to protect from infectious bacteria, virus, parasites, debris, hazardous chemicals, sparks etc. Knowing the potential need and importance of face shield and mask, its usability can be further enhanced by operating them based on sensors. We have built a prototype of 3D printed visor attached with face shield-cum-mask integrated with proximity sensors, battery and circuitry which is used to move the visor above or in front of the face as and when required by movement of hand close to the sensor.

Keywords: Fused Deposition Modeling, Injection molding, 3D printing, sensors.

1. Introduction
Face shield and mask have nowadays become one of the basic requirements after the outbreak of Coronavirus disease. However, they are used in several other applications. Face shields are used in medical applications to guard the face and eyes from the splash of harmful chemicals. They are even used by police officers in riot situations, and as a protection from sparks, intense heat generated from welding equipment in case of welding applications [1]. It is also very useful for housekeeping staff, road sweepers and garbage collectors. Face masks are of different types namely homemade, surgical and N95. Homemade face masks are usually preferred to be used with face shield and they are not recommended for children below two years, people with breathing issues and those can’t be removing mask by themselves. They also need to washed after every use. Surgical masks are not reusable, they protect the wearer from spray, splashes or spill of large droplets and also prevents transmission of respiratory related infectious diseases infectious. N95 masks filters out 95% of virus, bacteria and small particles [2]. Masks should fit the nose and mouth region properly for it to be effective. We have developed 3D printed visor attached with face shield and mask. Fused filament fabrication (FFF) also known as fused deposition modeling (FDM) technique is used for 3D printing (MakerBot) the visor. The material used in the process for the visor and face mask is Polylactic Acid (PLA) and flexible PLA respectively. Face mask material is made flexible but also it is made sure that it perfectly fits the nose and mouth region of the face. It is provided with filters to protect the user from small particles and virus. Acrylic sheet is used for the face shield. The reason behind using 3D printing is that it is an
additive type manufacturing with advantages such as developing flexible designs, rapid prototyping, print on demand, strong and lightweight parts, cost-effective and fast design and production with minimal wastage. Additionally, it is easy to access, environment friendly and useful in healthcare [3]. In future, we have planned to use injection molding which is a technique in which plastic is melted, poured in a mold and cooled. This technique is best suited for mass production.

The 3D printed part is integrated with IR proximity sensors which in turn controls the movement of visor. Stepper motors are used to move the visor. The time for which the stepper motor will be operating depends on the amount of time the hand is in close proximity to the sensors. The prototype uses two sensors, one is used to rotate the motor in clockwise direction and other to move it anticlockwise so that the visor to cover or uncover the face. They are placed on either sides of the head i.e one to the left and other right. Logic circuitry is design to operate based on the output of the two sensors. They are used to control appropriate input pins of the motor driver used for driving the stepper motor. This paper elaborates the complete process, specifications used for 3D printing the visor and also the interfacing of sensors with the electronic circuitry and stepper motor. We also detail the working of the prototype.

The rest of the paper is organized as follows. Section II describes the FDM technique which is used for developing the visor and also discusses about the properties and advantages of using PLA. Section III describes the process of injection molding. Section IV explains the working of the electronic circuit connected to sensors and stepper motor. Section V outlines the design and specifications of 3D printed visor customized to hold the motor, sensor and circuitry and also presents the integration of the 3D printed part with electro-mechanical parts and the overall working. Finally, we conclude with summary of the work and future scope in Section VI.

2. FDM Technique used for 3D Printing

Fused Deposition Modeling (FDM) is by far the most widely used method for 3D printing as it is cost-effective. FDM can create production parts and functional prototypes with outstanding thermal, chemical resistance and excellent strength-to-weight ratios. Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid (PLA) are the common materials used in FDM. PLA is biodegradable thermoplastic polymer which is suitable for 3D printing. It is easy to print with detailing. ABS has better mechanical properties, known for its strength, flexibility and thermal stability. In FDM process, string of plastic is melted and the 3D printed structure is formed by applying the material layer by layer. It uses two materials, one as a build material and other to support hanging structure during the process [4].

A Computer Aided Design (CAD) file is fed as a Standard Triangulation Language (.STL) format to the printer. Once the printer has read the file it starts the execution. The process starts with nozzle moving up-down, vertical-horizontal to form a cross section. Plastic is melted and pushed out to the base with the help of the nozzle. The horizontal and vertical cross section get ready by following the coordinates which model maintains. This hot plastic cools down and sticks to the layer beneath it. This process is followed till the whole model is ready. As this is done layer by layer it's called additive manufacturing. Once a layer is ready it is pushed down to make space for the next layer. The correct dimensions are met by the movement of the base and the nozzle which is given as input to the computer itself. The time taken to make models depends on the size, dimensions and accuracy. The more geometrically complex the model the longer it takes to achieve the model.

FDM process is subdivided into pre-processing, production and post-processing. Pre-processing includes building software, feed STL file and calculating the path for extruding thermoplastic material, need for support structure. Production includes heating thermoplastic material to semi-liquid and while extruding from the nozzle it cools and solidifies. During the post processing support structure is broken away or dissolved using water [5]. The entire process followed in FDM is indicated in the Figure 1.
The main purpose behind using PLA as a 3D printing material is that they do not emit harmful gases, it can be printed without a base and also it is biodegradable. PLA is a stiff. But they are not heat or chemical resistant, it is fragile and can be strengthened or its chemical resistance can be enhanced by using additives. Additionally, it is easy to print, cost-effective and non-toxic.

3. Injection Moulding
Injection molding is a most obvious preference for manufacturing the described model in bulk. The other advantages are less unit price and cycle time. The process of injection molding is divided into six steps namely clamping, injection of melted plastic, apply pressure to make mold cavity filled, cooling, opening mold, taking out the product.

The initial stages of injection moulding machine include hopper, feeding area, barrel, screw and heaters which forms injection unit. Next to the nozzle, there is moulding unit, clamping unit and ejector. Injection unit melts the plastic by heat and injects the molten plastic into moulding cavity. Screw is used to rotate melted plastic which arrives from hopper. Molten plastic is accumulated at the front of screw, when sufficient amount is accumulated, molten plastic is injected. Injection speed is controlled and is made to flow into a mould cavity. Dwell pressure is controlled once plastic fills the cavity [6]. The complete work flow of injection moulding machine is as shown in Figure 2.

**Figure 1.** FDM process.
Mold is a fixed shape metal block which is hollow. Temperature is controlled by using hot water or oil and drilling holes into the block. Mold is removed after cooling; ejector is used to remove the product. Mold usually has multiple cavities to produce multiple products in one go. Small amount of reprocessed material may be used. Controlling parameters of molding include temperature of old, injection speed, dwell pressure and many others. Depending on these parameters, the properties, dimensions and appearance of product change.

4. Logic Circuit for movement of Visor

The logic circuit is designed using sensors, bipolar stepper motor 28byj-48, motor driver A4988 and logic gates. Figure 1 shows the circuit diagram of logic circuit which intends to move the visor over the head open sensing hand movement from one sensor placed at the left of visor as well to a position where face shield and mask covers the facial area properly upon sensing hand movement from another sensor placed right side of the visor.

From Figure 3 it can understood that Sensor outputs are given as inputs to the XNOR logic (XOR gate followed by NOT gate), output of which is given to pin number 1 of A4988 IC which represents active low enable. One of the sensor’s output is given to the NOT get to get the complement of it. The completed output of one of the sensors and output of another sensor in true form is given as input to AND gate. Output of the AND gate is fed to the direction control pin of the driver IC. This logic gates used for controlling the enable and direction pin of the motor driver is intentionally used so that visor moves only when it senses from one of the sensors. The stepper motor does not rotate when both the sensors are not sensing or even if both are sensing the hand movement.
555 timer is used in astable mode to generate continuous pulses which is fed to step input of motor driver IC. The type of sensor employed gives logic 0 output upon sensing movement. The range of detection can be changed by using potentiometer on the sensor. Two batteries of 12V and 3V are used. Two Stepper motors are connected in parallel such that one rotates clockwise, other runs anticlockwise as they are placed on either side of head on the visor. MS1, MS2 and MS3 are Microstep Selection Pins. They are used to operate the driver module in different step functions. But in our prototype, we haven’t used these pins as we are operating in full step mode. Stepper Motor wires is connected with output pins (1A, 1B, 2A & 2B) of driver module. Buckle buttons are provided over the visor so that battery connections are made and circuit is complete only when user wears it.

5. Integration of Visor, Circuit and Working of the Prototype
Integration of the circuit shown in Fig.3 printed on PCB, sensors, motors and 3D printed visor are integrated together as a working model. The Figure 4 shows the Computer Aided Design (CAD) model of the head band, visor frame designed for holding the PCB, sensors, motor, face shield and mask. The dimensions of CAD model are as shown in Figure 5 and 6. The frame is made of PLA and mask is made using flexible PLA. The file is fed to MakerBot fused filament fabrication (FFF) printer.
Figure 4. Isometric view.

Figure 5. Top view with dimensions indicated.
The specifications given to the 3D printer MakerBot to print visor and support for the mask is as listed in Table 1.

**Table 1. Parameters used for 3D printing**

| Parameters                  | Details |
|-----------------------------|---------|
| Thickness of the filament   | 1.75mm  |
| Type of material            | PLA     |
An illustration of the final prototype with the visor frame and mask made of PLA is shown in Figure 7. There are five segments indicated in Figure 6. PCB with circuit shown in Figure 3 but excluding sensors, stepper motors and battery is placed in Segment 1. Stepper motor is placed on either side of head at segment 2. Segment 3 is where batteries of 3V and 12V are placed. Segment 4 is where a kind of buckle is placed which completes the circuit when user wears it. This also ensures the design is energy efficient. Sensors are placed in Segment 5.

The working of the prototype is that the Face shield cum mask automatically moves on top of the head and moves back to fit the face as and when desired by placing the hand in front of the sensors. The novelty behind this work is that Face shield cum mask can be operated without touching which would be required in many situations such as for a doctor in operation theatre and in some other applications where this feature would be convenient for the user. Since this prototype is built using hardware components, its working can be shown as a demonstration but we have presented the pictures of 3D printed model and circuit employed for the working prototype.

6. Conclusion and Future Scope
In this paper, we have developed a cost-effective, energy efficient and a touch-free solution to face shield cum mask which is useful for varied applications. The main advantage of the developed prototype is that mask is attached with cantilever beams clinging to the visor. This avoids the use of elastic bands around ears which can be inconvenient for long durations. As a future work we want to build the prototype using injection molding which is suitable for mass production of visors. It can be further enhanced to support face shield of varied thickness and material of visor which is thermal resistant and sturdy. It is also envisioned to be implemented in helmets.

7. References
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