# Swab Testing Robotic Arm

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**Abstract:** ***This review paper describes the development of robotic arm swab testing system for COVID-19 disease and the evaluation of its safety and efficacy for the oropharyngeal-swab testing method in coronavirus detection. In this system, machine learning algorithms are used to detect the cotton swab and the region of swabbing, i.e., the back of the human throat. It employs a serially connected microcontroller-based robotic arm to pick up the cotton swab stick and perform the swab test by swabbing the cotton swab stick into the patient's throat and dropping the cotton swab stick back into the transportation test tube using a gripper. The main objective behind introducing this system is to reduce the risk to the lives of healthcare workers who perform swab testing due to aerosol from patients during the process of testing. Also the quality of manual swab testing is inconsistent among different collectors, which may lead to misdiagnosis. The replacement of manual testing by a robot has the potential to avoid close contact between healthcare workers and patients, and thus reduce the risk of Corona virus infection during testing.***

**Keywords:** COVID-19 disease, oropharyngeal-swab testing, robotic arm, machine learning algorithm, healthcare workers

## 1. Introduction

COVID-19 disease is an illness caused by a novel coronavirus that was discovered during an outbreak of respiratory illness cases in the Chinese city of Wuhan. The WHO declared the COVID-19 outbreak a global health emergency, which was then upgraded to a global pandemic.

The disease burden on the infrastructure has unexpectedly increased due to ongoing community transmission from individual to individual. As a result, there is an ongoing demand for front-line health-care workers in patient facing roles. Because this work requires close personal contact with COVID-19 patients, front-line healthcare workers are at a high risk of infection, contributing to the disease's spread. As a result, there is growing interest in robotic technologies for COVID-19 disease testing, as they can help reduce the risk of virus transmission to health care workers and patients.

Testing is crucial to identify and curb the spread of the COVID-19 disease. As a result, future testing capacity must be increased. Robotic testing technologies may help to increase testing capacity while also reducing the risk of viral transmission.

## 2. The SWAB testing robotic arm

The swab testing robotic arm performs mechanised swab testing, ensuring the safety of the health care personnel performing the swab tests. The swab testing robotic arm uses a pre-trained dataset model to determine the region of interest of the throat swabbing area and perform the swab testing activity.

First the arm sets itself to its default position 1 which is the swab stick pickup position. Once the cotton swab comes into the camera frame and is detected by the algorithm it picks it up from the test tube and drives itself to the position 2 near the mouth, aligns and detects the region of interest of the throat through the patient’s open mouth (i.e. the backside of the throat) positions the robotic arm forward of the detected position in the camera frame, and performs the swab test. The robotic arm for swab testing requires precise swab positioning in the target region of the throat, accurate swab positioning to the target region of the throat is essential for the robotic arm for swab testing. During the swab testing procedure, the patient's throat may become irritated, resulting in a gag reflex.

Then it drives to the position 3 and drops the swab stick back to the transportation test tube. Finally, it gets sanitized by the sanitizer spray and resets itself back to the reset position and carries out the whole process again. As shown in the fig. 1

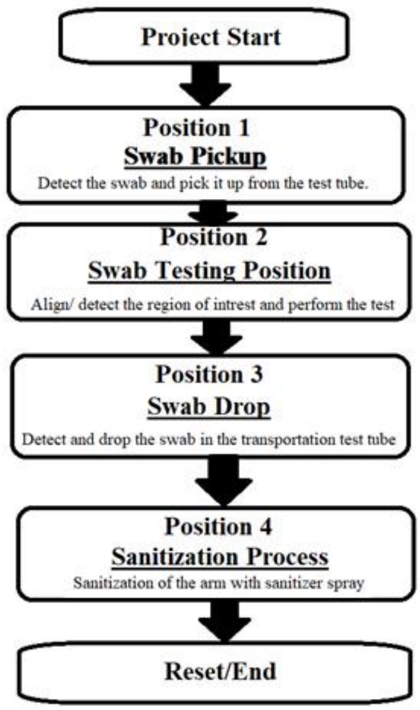


**Figure 1:** Working of the Swab Testing Robotic Arm

**Mechanical Design**

The swab testing robotic arm is comprised of five attachments: the base, shoulder, elbow, wrist, and gripper. The base provides horizontal X axis motion, the shoulder provides vertical Y axis motion, the elbow provides Z axis motion, and the wrist provides pitch and roll motion. The schematic diagram of the robotic arm is shown in figure 2.

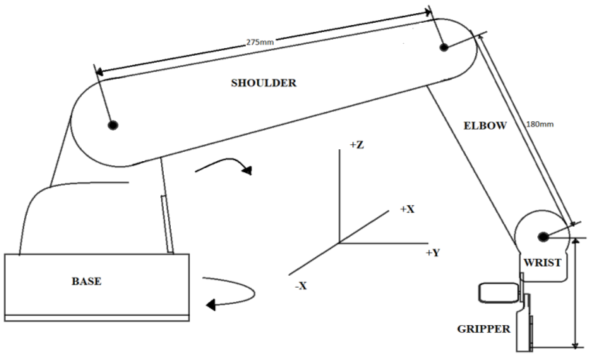


**Figure 2:** Swab Testing Robotic Arm

The base of the swab testing robotic arm consists of a nema17 DC stepper motor, the shaft of this motor is connected to the base of the robotic arm via a gear and belt system. The robotic arm rotates 360-degree with the assistance of this mechanism. The motor is controlled by the Arduino microcontroller board. This motor requires a 12V DC power supply to function, which is provided by the TB6600 stepper motor driver connected to the Arduino, and the power supply provided by the buck boost converter. Arduino controls the system and moves the base to the required position based on serial commands received from the microprocessor system for the robotic arm to perform the required function.

The swab testing robotic arm is designed to replicate the working of a human arm. This robotic arm is designed to ensure the safety of our frontline health workers and ensure an efficient swab test. The robotic swab testing arm is a five DOF (Degree of Freedom) robotic arm, as shown in fig.2. Each joint provides $180^0$ movements across the structure. Five degrees of freedom provide movement across X, Y, and Z axes (horizontal, vertical, and depth), pitch, and roll. It is made up of 3D printed and laser cut parts. Working on two stepper motors, Nema17 and Nema24, and four MG995 servo motors. All the motors are programmed and controlled through the Arduino board. The robotic arm is built mainly of 3 parts, i.e., the links, joints, and the end effector. The links like the shoulder, elbow, and wrist are connected through the joints as shown in fig.2, which are used to give motion to the links. The end effector in this robotic arm is the gripper, which has the function of grabbing the swab and releasing it into the transportation tube after the swab testing process.

The Arduino board controls two stepper motors and four servo motors on the entire arm. At various joints, these motors act as actuators. The NEMA17 stepper motor is used to rotate the base, while the NEMA24 stepper motor is used at the shoulder joint to lift the weight of the entire arm and the object. The four servo motors used are mg955 metal gear servo motors. All of these servos are capable of rotating $180^0$ degrees clockwise and anticlockwise. Servos are used to provide high stall torque at the elbow and wrist joints in order to lift the weight of the link, which can handle 10 kg.cm at 4.8V and 12 kg.cm at 6.6V stall torque.

The microprocessor detects the position of the cotton swab stick, region of interest of the throat, and the transportation tube via the camera frame and sends it serially to the Arduino board. An endoscopic camera is used in the robotic arm due to its small size. This camera has a good picture quality and night vision that helps to identify the region of interest inside the mouth very easily. The Arduino moves each motor of the arm to achieve the desired positions in the x, y, and z coordinates. Inverse kinematics is used to guide the movement of a servo to a specific position. In the case of a stepper motor, it is accomplished through stepping.

**Software Design**

The swab testing robotic arm detects the cotton swab stick and region of interest of throat from real-time images using machine learning algorithms. In case 1, the robotic arm is in its default position, i.e. position 1. Through the camera mounted on the gripper, the robotic arm detects the cotton swab stick in the test tube kept on the table. After the cotton swab stick is detected into the camera frame, it draws a bounding box around the cotton swab stick using its position in the form of coordinates. Following swab stickdetection, these coordinates are serially shared with the Arduino microcontroller that controls the robotic arm. Which moves the motors in accordance with the shared coordinates, aligns the robotic arm, and removes the cotton swab stick from the test tube using the gripper.

The microprocessor begins the swab testing procedure with the second case by aligning the robotic arm to its second position in the frame, where the patient is already present in the testing area and has been instructed to open the mouth. With the help of the camera, it detects the region of interest of the swabbing area, i.e., the backside of the throat, and the bounding box is drawn around the region of interest in the form of coordinates and is serially shared with the Arduino microcontroller. The Arduino controls the motors, moves the gripper with the cotton swab stick inside the patient's mouth to the backside of the throat, and aligns the robotic arm in front of the patient's mouth. When the cotton swab comes in contact with the the backside of the throat of the patient it stops and rotates the cotton swab around itself with the gripper and collects the swab sample. As shown in Fig.3.

The third case in the program begins when the robotic arm reaches position 3, detects the swab transportation tube, aligns itself properly on the top of the swab transportation test tube, and drops the collected swab sample into the transportation test tube, which is then sanitized by the sanitizer spray. As a result, this system can be used to replace humans in the swab testing process, reducing the risk of coronavirus contamination in health care workers.

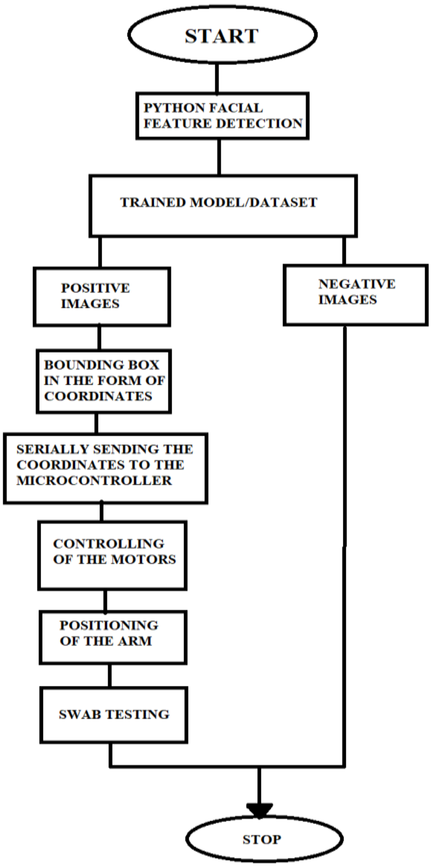


**Figure 3:** Algorithm for the swab testing robotic arm

The swab testing robotic arm processes data using machine learning algorithms. This method is extremely accurate, approaching and, in some cases, surpassing human accuracy. Because it does not require much image rendering. The robotic arm performs the task of facial feature detection using computer vision and machine learning algorithms. The detection of facial features (such as the mouth, throat, nose, or eyes) in real-time images and videos in digital format is referred to as facial feature detection.

This project employs facial feature detection to classify the mouth and throat, particularly in real-time image and video processing. The facial feature detection algorithm allows the robotic arm to identify the region of interest in images or videos containing the mouth and the throat. The region of interest in this project is the patient's backside of the throat. To detect the region of interest, pre-trained datasets with positive and negative images are created using the cascade classifier. The positive images in this case are of the backside of the throat, while the negative images are of the lips, teeth, tongue, hard palate, and soft palate, which should not be touched. This dataset is trained by using 300 positive and 900 negative images. This dataset is used in the main algorithm for the robotic arm to detect the region of interest through the camera mounted on the robotic arm.

The algorithm outputs four coordinates of the bounding box around the throat (x, y, (x+h), (y+w)) from the pre-trained dataset. The coordinates are then serially sent to the Arduino microcontroller board, which controls the robotic arm's motors. The pre trained model operates in such a way that it sends a test image or a frame from a real-time image/video as input to the algorithm and receives the output in the form of pixel coordinates in the image. These coordinates can be used to draw the bounding box for the detected throat/swab and visualize the detected region of interest. Pre-trained datasets are also created in this project for detecting cotton swab sticks for pickup and transportation tubes for drop positions in the swab testing process using the object detection method.

The robotic arm's motors are controlled by an Arduino microcontroller. It must perform serial communication between the microprocessor and the Arduino microcontroller. The system detects the position of the swab and throat using distance algorithms, and corresponding commands are passed to the Arduino microcontroller in the form of coordinates. The microprocessor commands are serially transmitted via USB cable. All commands are received on the serial monitor of the Arduino microcontroller, and the motors rotate in accordance with the commands. A USB cable is used for serial communication because it provides high-speed data transmission.

## 3. Results and Analysis

When the program is run, the cotton swab is detected by the camera and fed into the microprocessor. The output is given in the form of a bounding box around the cotton swab stick, as shown in fig.4 and is sent to the microcontroller in the form of coordinates. After receiving serial signals from the microprocessor, the microcontroller initiates motor movement based on the position of the cotton swab stick in the test tube on the table. The cotton swab is picked after it is aligned in the centre of the frame of the bounding box in the camera, and the perpendicular distance is measured through the camera on the robotic arm by aligning the centre of the camera frame and the centre of the bounding box, which gives the input to the microprocessor using distance algorithms and sends the output to the microcontroller as the distance of the cotton swab from the base of the robotic arm, giving the necessary movements to the motors. The motor movements are given in the form of angles to the servo motors and in the form of steps per rotation to the stepper motors of the coordinates received.

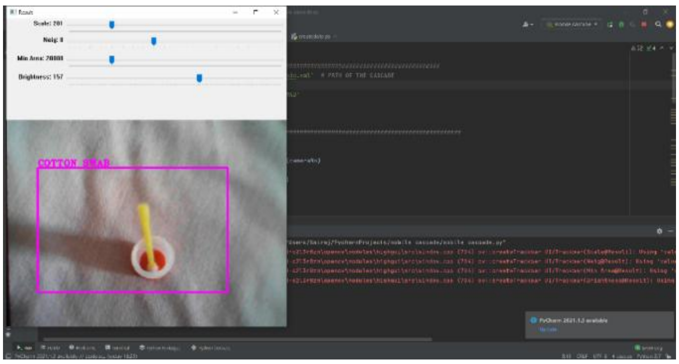


**Figure 4:** Bounding Box around the Cotton swab

After picking up the swab, the program proceeds to the next task, which is swab testing. The patient is instructed to open the mouth and keep it in the frame where the robot aligns with the camera frame, bringing the throat to the centre of the frame in the bounding box. As shown in Fig.5 The centre of the camera frame and the bounding box are aligned, and the distance of the region of interest from the base of the robotic arm is calculated using distance algorithms, and the cotton swab is entered into the throat until it touches the back of the throat. The gripper rotates and the sample is taken after the swab touches the back of the throat.

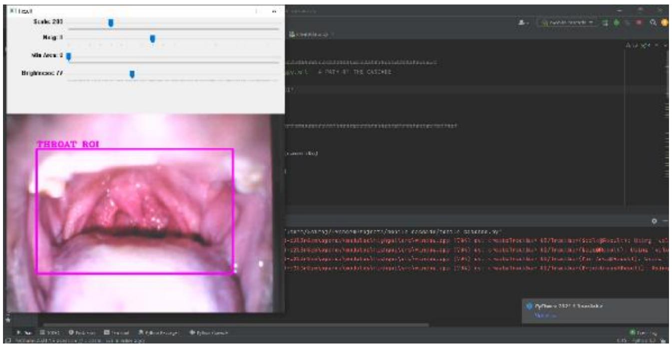


**Figure 5:** Bounding Box around the region of interest

Finally, the robotic arm comes to position 3, detects the transportation test tube, drops the tested swab into it, and sanitizes itself. The entire process then stops and is repeated for the next individual. Fig.6 depicts the prototype model of the swab testing robotic arm, which shows the gripper holding a cotton swab in the swab testing position.

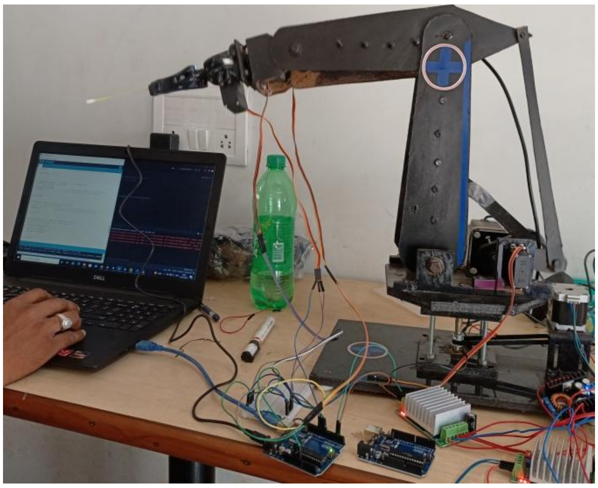

**Figure 6:** Prototype model of the swab testing robotic arm

## 4. Conclusion

This paper presented a prototype robotic swab testing system that detects and collects swab samples from patients. The acrylic laser cutting and 3D printed plastic parts make up the robotic arm structure. This robotic arm detects the region of interest for swab testing procedures on the patient using machine learning algorithms and computer vision in Python. It is also programmed to detect, pick up, and drop the cotton swab using the gripper back into the transportation tube. The program makes use of datasets from the throat's region of interest. These datasets, which are used in the analysis, are trained using various images of the region of interest of the throats and cotton swabs kept in the tube. and are used in the program. After the detection the signals are shared directly with the microcontroller controlling the movement of the motors attached to the robotic arm.

This robot can be improved further by using advanced computer vision technologies in Python to detect and accurately detect the required region of interest. The project's accuracy can be improved by using distance sensors to accurately measure the distance from the gripper to the required region of interest for the operation to be performed, as well as force sensors to precisely measure the swabbing force for the robotic arm, which can make the robot more accurate. To improve detection of the region of interest in the throat, the robotic arm can be equipped with an additional tongue depressor. It will be possible to create a machine capable of conducting a greater number of tests per day without any human interference using current prototype technology.

As testing is one of the most powerful weapons in the fight against this pandemic, the invention of the swab testing robotic arm will allow for more tests to be performed per day, reducing the workload on frontline healthcare workers and the risks to their lives. Science and technology advancements, such as the swab testing robotic arm, will aid the world in combating the COVID pandemic and restoring normalcy.

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