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A Novel Control System for a Laptop with Gestures Recognition

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Abstract

An important lesson learned during the pandemic is that the devices utilized by many people (vending machines, elevators, etc.) can spread the virus and take advantage of contactless programs that can be enabled through gesture recognition. It's a major enabler of smart living and human-computer interaction. It is widely used in controlling equipments. This research presents a novel vision-based real-time gesture recognition system for controlling a laptop. It's a comprehensive system that can do all the required functions needed to remotely control a laptop through hand gesture recognition rather than employing a mouse or keyboard. This system allows changing the position of the mouse point, performing left-click, right-click, double-click, and scrolling up and down. It also provides all the keyboard shortcuts, Print Screen (PrtScr), and Backspace. Furthermore, it allows shutting down as well as creating files and folders. Additionally, it allows playing, muting, pausing media playback, reducing/increasing the brightness, and turning the volume down/up. Moreover, it allows advancing to the next and previous page of the slideshow, as well as zooming in/out. Finally, the system allows gestures to open the most frequently used applications based on the user's choice. In comparison to the previous work, this system is considered unique in that it performs all the functions needed to remotely control the laptop. Previous systems only offer a subset of the tools provided by this proposed system Additionally, it is unique because the user operates all functions solely through gestures, without the need for additional methods.

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1. Introduction

Hands are the most helpful communication tools among other parts of the body. The term "gesture" refers to a wide range of human movements involving the face, arms, and hands, many of which convey information effectively [1].

Hand gestures are a significant aspect of human interaction. People use them to communicate through nonverbal visual cues [2]. Generally, humans use them in their everyday communication to make their intentions clearer [1]. They are a type of body language where the shape and position of the fingers and palms deliver specific information. It consists of both dynamic and static movements. The former involves a series of hand movements and rely on the hand's movement to convey information, whereas static gestures rely solely on the form of gesture's to deliver information [3]. Owing to the cultural uniqueness and diversity of gestures, they are described differently by various people.

A pandemic has taught us that common device (vending devices, elevators, etc.) can transmit viruses prompting the adoption of contactless procedures. Hand gesture recognition can facilitate these procedures effectively [2]. It means tracking the representation of a gesture and then translating it to a particular command [1]. It plays a vital role in conveying information in a very convenient manner in the digital domain [1], [3]. Furthermore, it's a major enabler of smart living and human-machine interfaces [2]. It is considered a crucial research field in computer vision and aims at identifying the limbs' structural parameters, such as the orientation and position of the head and the outline of the body. Its approaches rely on nearly all technologies and theories of computer vision, such as statistics, pattern recognition, graphics, artificial intelligence, and machine learning. A variety of them have been introduced [4]. Therefore, research in this area has become very exciting and popular [5]. This is because there are many applications that require input to complete their tasks, such as pausing and playing a movie, scrolling down and up, and so on [6].

In the past, gesture detection was performed with glove-based sensor systems. Where wearable sensors (identifying responses based on finger bending or hand motions) are mounted

on gloved hands. Then, the collected data is processed by computers attached to these gloves [7]. The shortcomings of these systems (uncomfortable and contactless) have led to the advancement of a more cost-effective and promising technology that does not require wearing bulky gloves, namely camera vision-based sensor techniques (computer vision-based approaches). It can employ various kinds of cameras, such as time-of-flight, RGB, night vision, or thermal cameras [2], [7]. It provides the needed contactless identification and is precise in planned environments [2].

Subsequently, it has become simple than ever to recognize hand gestures [7], which can be utilized in various applications like virtual environments, translating sign language, gaming, human-to-machine interfaces, robot control, augmented and virtual reality, smart TVs, music creation, banking sectors, PlayStation consoles, clinical operations, virtual controllers, and home automation [1]-[2], [7]-[8].

Recently, authors have concentrated on vision-based hand gesture recognition. However, accomplishing an effective one in real-time remains a challenge. The ability to recognize hand movements immediately and without delay is called real-time gesture detection. It must be performed without overburdening the computation. Additionally, image processing offers a vital role in gesture feature extraction and segmentation phases. Recognition and image processing techniques, processing speed, and appropriate delay in delivering the results vary between real-time and non-real-time gesture detection [3].

Computer vision algorithms have been advanced. They try to partition and identify hand characteristics like appearance, bone, movement, skin color, etc. [7]. They rely on tracking hand movements and translating them into specific commands. The main goal is to identify certain gestures and then utilize them for control and command purposes or to convey information [7] (Figure 1).

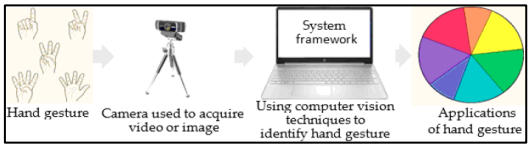

Figure 1. Gesture Recognition using Computer Vision Methods [7]

This work is based on static hand gestures that are based only on the hand's shape, in which we propose a novel comprehensive system for remotely controlling laptops (as

imagining our lives without them became impossible) through gesture recognition. It is the first time that a system can do all the required functions needed to remotely control a laptop with simple hand gestures.

1.1 The Functions Performed by the System are

The system initiates the camera upon app startup. It enables mouse cursor control through hand gestures for positioning, left-clicking, right-clicking, and double-clicking. Gestures also facilitate scrolling up and down. Keyboard shortcuts such as Ctrl + A (select all), Ctrl + C (copy), Ctrl + X (cut), Ctrl + V (paste), and Ctrl + Z (undo) are accessible through hand gestures. Additionally, PrtScr (print screen) and Backspace (delete) functions can be activated. The system supports hand gestures for shutdown and creation of files and folders. Media playback is managed with gestures for volume adjustment, play/pause, and mute. Brightness control and navigation in slide presentations for advancing, returning, zooming in/out, and opening browsers or other applications set by the user are also enabled through gestures.

The second section introduces the previous works. The Model View Controller used is given in Section 3. Section 4 explains the proposed system. The discussion section is in Section 5. The last part finishes up this article and highlights potential future work.

2. Literature Review

Vimali et al. [6] utilized 2 ultrasonic sensors, an Arduino UNO, and Python to execute a few tasks in 3 applications (a slide show, a media player, and a browser). Similarly, Mukherjee et al. [9] employed Python, Arduino, and sensors to perform a few operations. These are controlling the volume and the media player on a laptop. Using the same technologies, Sarita et al. [10] performed a few but different tasks, such as rotating images, zooming in and out, etc. Runwal et al. [11] employed ultrasonic sensors and an Arduino UNO board to control Google Chrome, Subway Surfers, and the media player. It's not easy to utilize and learn, probably because of the utilization of a synchronized mix of software and hardware to transform the employed gestures into commands. For example, the user has to place his hands in front of the ultrasonic sensor at a certain distance to Pause/Play the media player. However, he has to move his hand away from the right sensor to decrease the volume. Also, Vuyyuru and

Shirke [8] used Ultrasonic sensors, an Arduino board, and Python. Their proposed system performs a certain function based on the distance (between it and the hand) recorded by the sensor. The proposed operations are navigating, controlling a media player, reading files, and scrolling.

According to Steven Raj et al. [12], a computer vision system can be used to simulate mouse motions. However, it is not suitable for use in real time. This is because processing frames requires saving them beforehand, which costs time to the process. Another computer vision system is the work of Kavitha et al. [13]. While the authors did all the mouse's movements, the user must be very accurate when doing his hand gesture in front of the camera, which makes its use difficult. This is because the same gestures are used for different mouse functions (brightness and volume control), but they have to be in different places in front of the camera. Besides, the authors used a voice assistant to perform the copy, cut, and exit functions, but the proposed system has used hand gestures. Moreover, they only controlled the volume of the media player and did not include the other functions we propose in this work. Matlani et al. [5] proposed a computer vision system that only performs some mouse operations, such as dragging files and clicking. Kedari et al. [1] proposed a computer vision system to perform only ten functions through 10 hand gestures. However, many of them just open applications such as Google Chrome, VLC, Microsoft Edge, WhatsApp, and PowerPoint. The work of Jalab and Omer [14] was for operating only VLC as well as PowerPoint.

3. Model View Controller

A design pattern often employed to build user interfaces that divides program logic into 3 interconnected components (the controller, the view, and the model). Such a separation helps separate the internal information representation from how it's viewed and delivered by the user. Conventionally, it's employed for desktop graphical user interfaces. It became popular for designing web applications. Popular programming languages have (Model View Controller) MVC frameworks that simplify the implementation of this pattern [15].

- Model: For a structural organization of the data.
- View: Controls how data appears to the user.
- Controller: Controls the interaction between the Model and the View.

We utilize the MVC architectural pattern, as follows:

- The ‘Model’ is represented by the hand detector component, as it deals with data related to the points tracked by the system to interpret the gesture.
- The ‘View’ is represented by the main application class, which displays the initial user interface that prompts the user to start the application.
- The ‘Controller’ in the system is represented by the hand control part, which includes the procedures for compiling the user's gestures into functions executed by the computer.

4. Proposed System

4.1 The Used Software Tools

- Python [16] and its various libraries, such as OpenCV [17], autopy, os, numpy, and Tkinter.
- MediaPipe [19]: Provides libraries to implement machine learning solutions into applications. It is developed by Google for creating real-time, cross-platform, gesture recognition, hand tracking, and sophisticated computer vision systems. It provides finger and hand tracking by precisely recognizing the gestures. Furthermore, it’s an open-source framework with a hybrid platform, which generates pipelines for dealing with perceptual data (e.g., audio, videos) [20].

4.2 The Used Hardware

As for the hardware, we don't employ any additional hardware other than the laptop. We employed the laptop's camera to take the hand photos that are processed to identify the gestures being made. By utilizing it, we overcome the problems related to camera orientations [3]. This system was created on an Intel Core i5-5200U @ 2.20 GHz with 8 GB of RAM.

4.3 Methodology

- We employed a laptop webcam to capture videos by taking 90 frames per second. We employ OpenCV to capture these videos.

- The images are converted from BRG to RGB.

- We employed a multistage pipeline (MediaPipe Holistic) for feature extraction and data preprocessing. We utilized it to get the landmarks of the hand to know which finger is up. The hands' features are extracted as landmarks. It deduces about 21 3D hand landmarks comprising x, z, and y coordinates in one frame. We employed 5 out of them (4, 8, 12, 16, and 20) to determine which finger was pointing up. Integrating the hand keypoint localization model and the palm detection model produces the desired outcome [20]-[21]. We employed it to overcome the many difficulties faced when separating the foreground (the hand to be recognized) from the background and the other difficulties associated with obtaining effective and realistic real-time hand gesture recognition, like altering the image luminosity (the color of the background and the hand's skin) [3].

- We employed MediaPipe Hands to detect the hand [21].

4.4 The System Parts

This work includes various functions, which are described below.

a. The Mouse Control Tool:

Traditionally, the interaction between the computer and the user is performed through the input devices, such as the mouse (for scrolling, pointing, etc.) and the keyboard [9]. This tool provides an alternative for those who have difficulty utilizing a conventional mouse. Another benefit is that we can damage the mouse when we carry it around. Additionally, using a touchpad in a laptop and a mouse in a computer to accomplish difficult tasks takes time and is sometimes not practical or available. It provides an intuitive and natural manner to deal with the laptop. Hence, it enhances the accessibility of human-computer interaction, making it comfortable, fast, and having a variety of applications, such as games.

The tool allows the user to control the mouse's tasks through the hand's gestures without employing it. It classifies the hand gestures and converts them into mouse movements. As soon as a gesture is identified, it's converted to a corresponding mouse function performed on the screen. These are: move the cursor, left click, right click, double click, scrolling up, and scrolling down.

b. The Media Player Control Tool

Nowadays, one of the most widespread and basic uses of laptops is to watch movies [11]. For this reason, we propose this tool for performing the most frequently utilized functions of dealing with the media player. These are: Reduce the brightness, increase the brightness, volume Up, volume down, mute, and pause / play.

c. Presentation Control Tool

This tool allows you to perform the most frequently utilized functions when dealing with the slideshow. These are: previous page, next page, zooming in, zooming out.

d. Shortcut Control Tool

This tool provides an alternative for those who have difficulty utilizing a conventional keyboard. The tool allows all the keyboard shortcuts: taking a screenshot, backspace, creating a new text file, creating a new folder, and shutting down with hand gestures. These are: select all, copy, cut, paste, undo, backspace, print screen, create a new Word file, create a new folder, shut down.

e. The Favorite Applications Tool

This tool allows hand gestures to open the most frequently used applications based on the user's choice. For example, it allows opening the browser, Microsoft Word, and snipping tool.

4.5 The Proposed System Parts

a. The User Interface

After clicking the start button on the user interface (Figure 2), the program starts turning on the camera and opening a window to show the user his hand movements.

Figure 2. The User Interface

b. The Mouse Control Tool

After starting the program, the user can start the mouse control tool by lifting the index finger for 3 seconds. Then, the user will see a confirmation message to confirm the use of this tool. The user can perform several options and actions to control the mouse. One of the options is to right-click by lifting your index and middle fingers, as shown on the right in Figure 3. We show the result (the list for the right mouse button) on the left side of the same figure.

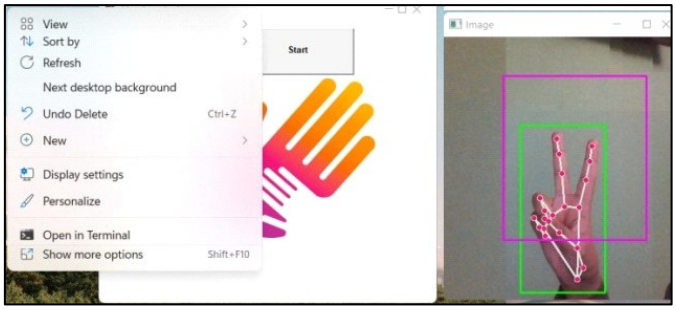

Figure 3. Right Click

When the right-click list appears, we can use the gesture on the right in Figure 5 to perform a left-click with your index finger and thumb pointing up. Click "Sort By" and a small list will appear (Figure 4).

To make the action double click, lift your little finger (Figure 5). The picture is opened after the double click on it (right side of Figure 5).

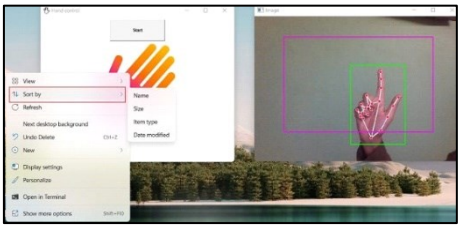

Figure 4. On the Right is the Left Click Gesture, and on the Left is the Result

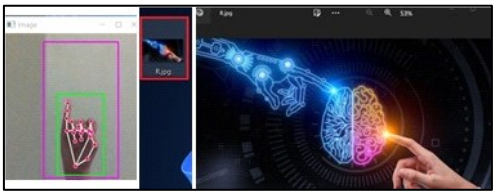

Figure 5. Double Click Option on the Left, Result on the Right

Figure 6 shows the scroll-down option. The left side of the figure demonstrates the movement of the hand (little finger and index finger raised) to scroll down, while the right side shows the results of scrolling on MediaPipe's website and how far the thumb in the scroll bar is from the bottom of the page.

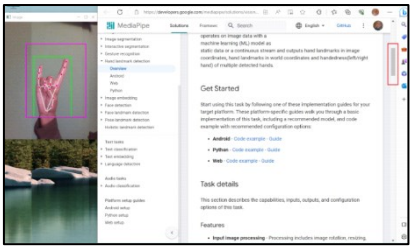

Figure 6. Scrolling Down the Mouse

After the scroll-down gesture, we can see the difference in position by how far the thumb is from the bottom of the page, and see other content below the currently visible area (Figure 7).

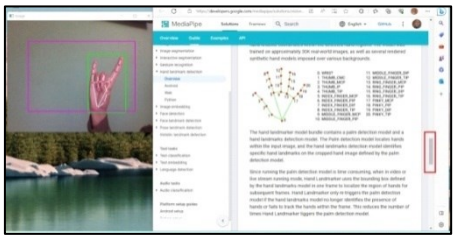

Figure 7. The Result of Scrolling Down the Mouse

We tested the scroll up on the website of MediaPipe. The results observed in the right side of the Figure 8 shows how far the thumb is from the top of the page. The left side of the figure shows the hand movement (little finger, index finger, and thumb raised).

After scrolling up, we can see the difference in position by how far the thumb is from the top of the page, and see other content above the currently visible area (Figure 9).

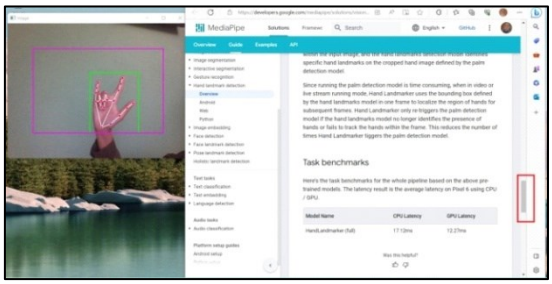

Figure 8. Scrolling up the Mouse

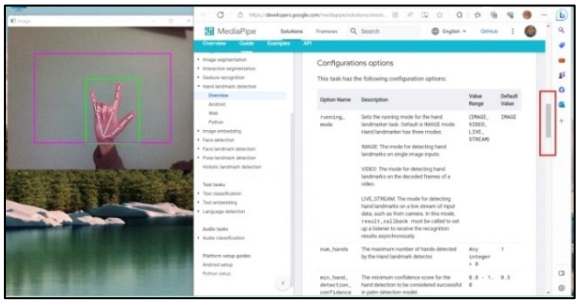

Figure 9. The Result After Scrolling up the Mouse

The user can stop the tool by using this motion and holding it for 5 seconds (all fingers up).

c. The Shortcut Control Tool

The user can activate the shortcut control tool through lifting the index finger and middle finger for 3 seconds. The user will see a confirmation message to confirm the use of the tool.

We test "select all" on the content of the website of MediaPipe by raising the index finger as shown on the left in Figure 10.

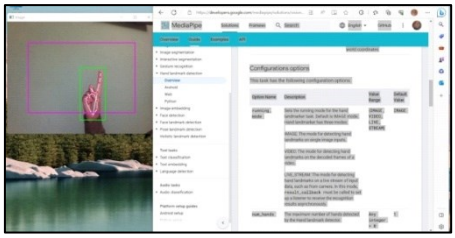

Figure 10. Selecting All

We tested the copy on the website of MediaPipe by holding up the index and middle fingers (shown on the left side of Figure 11).

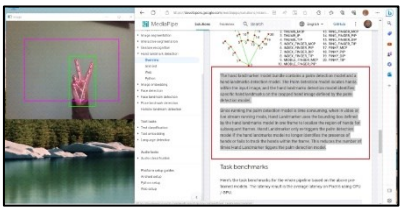

Figure 11. Copying Content

After copying the content, open WordPad to paste (lift the index finger and little finger) (Figure 12).

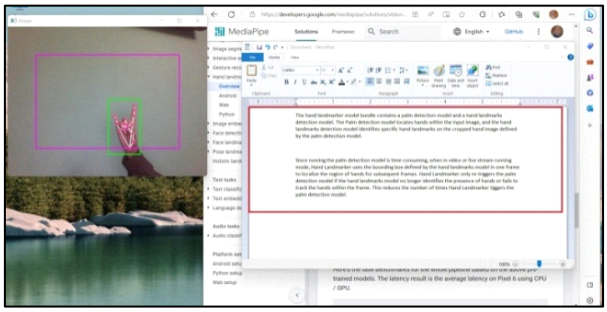

Figure 12. Pasting Content

In Figure 13, on the right is a folder containing video and HTML files, cut by holding up the index, middle, and ring fingers.

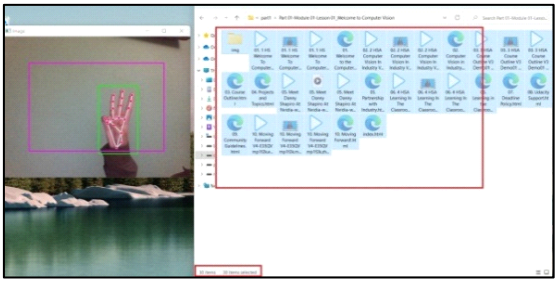

Figure 13. Cutting Content "Ctrl+x"

Capturing a screenshot of the entire desktop (PrtScr) is a useful tool for capturing images or error messages on your screen. Raise your index finger, middle finger, ring finger, and little finger to take a screenshot.

The user can create a new folder in the current direction by lifting the little finger and holding it for 3 seconds (Figure 14). The new folder was created on the desktop (on the right of Figure 14) because this was my current direction when we decided to create a new folder.

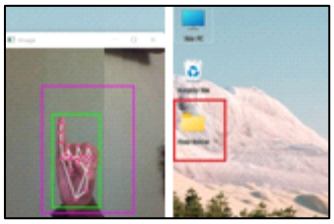

Figure 14. Gesture for Creating a New Folder on the Desktop and its Results

The user can create a new folder in the current direction by lifting the little and ring fingers and holding for 3 seconds (Figure 15). The new text file is created on the desktop because that's the current orientation when we decided to create a new text file (on the right of Figure 15).

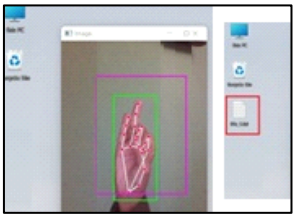

Figure 15. Gesture to Creating a New Text File and its Result

The user can turn off the computer by moving the hand as shown in Figure 16 and holding it for 5 seconds. Afterward, the operating system will display this message (Figure 16) informing that the computer will shut down in 1 minute.

Figure 16. Shutting Down

The user can stop the tool at any time by lifting and holding the finger for 5 seconds.

d. The Media Player Control Tool

The user can start "the media player control tool" by raising the index finger, middle finger, and ring finger (for 3 seconds). Then, he will see a confirmation message to confirm the start of the tool.

To turn up the volume, lift your index finger as shown on the right in Figure 17. We can see the action above the media player on the left side of Figure 17.

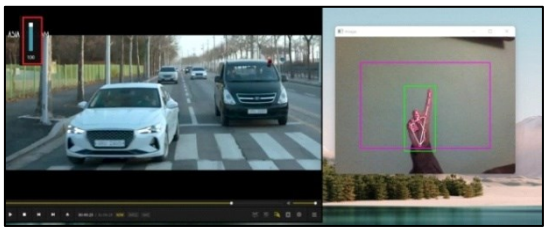

Figure 17. Volume Up

To lower the volume, lift your index and middle fingers, as shown on the right in Figure 18. We can see the action above the media player on the left side of Figure 18.

Figure 18. Volume Down

To mute the sound, lift your index and little finger, as shown on the right in Figure 19. The result is on the left side of Figure 19 and in the lower left corner of the taskbar.

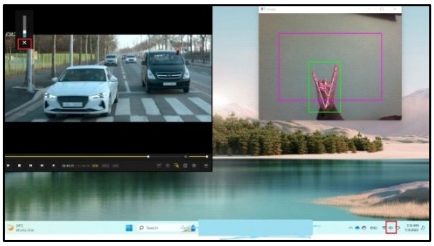

Figure 19. Mute the Volume

To play or pause the media player, lift your index, middle, and ring fingers (for 3 seconds), as shown on the right in Figure 20. The result is shown on the left side of Figure 20.

Figure 20. Pause or Play the Media Player

To reduce the brightness, lift your little finger as shown on the left in Figure 21. The result observed after and before reducing the brightness is on the right of this figure.

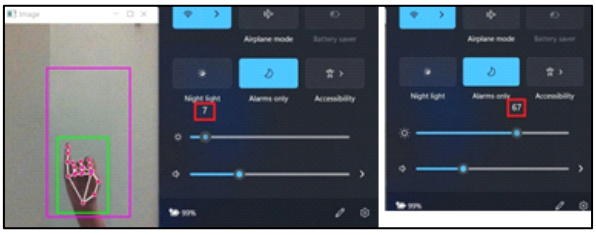

Figure 21. Gesture for Reducing the Brightness and the Results

To increase brightness, lift the little, ring, and middle fingers as shown on the left in Figure 22. The result of before and after increasing the brightness is on the right of this figure.

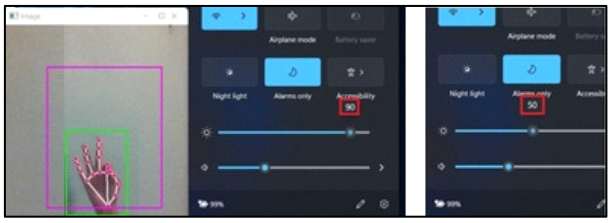

Figure 22. Gesture for Reducing Brightness and the Results

The user can stop the tool at any time by lifting all fingers and holding for 5 seconds.

e. The Presentation Control Tool (Controlling a Slide Show)

After the user launches the application, the presentation control tool can be launched by lifting the index finger, middle finger, ring finger, and little finger (for 3 seconds). The user will see a confirmation message to confirm the use of the tool.

The user moves to the next page by lifting the index and middle fingers (Figure 23). The current page of the presentation changes from 1 to 2 as a result of this hand gesture.

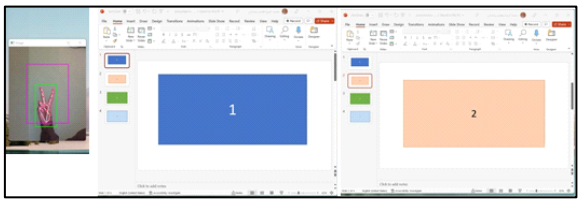

Figure 23. Gesture for Navigating Forward and the Result

The user returns to the previous page by lifting his index finger (Figure 24). The result of navigating back is on the right of this figure. The current page of the presentation changes from 4 to 3.

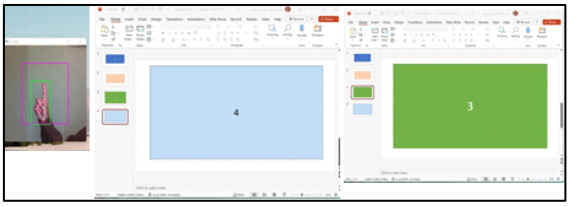

Figure 24. Gesture for Navigating Back and the Result

Users can zoom in on a page by lifting their index and little fingers (Figure 25). The result of zooming in was that the zoom percentage changed from 60% to 85% (on the right of Figure 25).

Figure 25. Gesture for Zooming in and the Result

Users can zoom out on a page by lifting their index finger, pinky finger, and thumb finger (Figure 26). The result of zooming was that the percentage of zoom changed from 79% to 50% (the right of Figure 26).

Figure 26. Gesture for Zooming Out and the Result

To go to the first slide in PowerPoint, lift your little finger (Figure 27). The result of moving to the first slide was that the current slide changed from 5 to 1 (on the right of Figure 27).

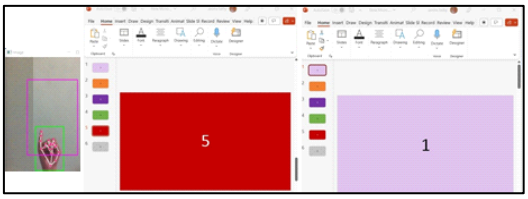

Figure 27. Gesture Going to Slide 1 and the Result

To go to the last slide in PowerPoint, lift your little and ring fingers (Figure 28). The result of the move to the last slide was that the slide changed from 3 to 6 (on the right of Figure 28).

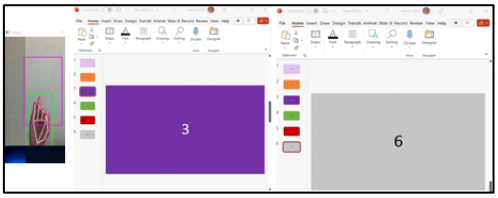

Figure 28. Gesture for Going to the Last Slide and the Result

To exit the current view (the reading view) in the PowerPoint, lift your index, middle, and ring fingers (Figure 29). The user can stop the tool at any time by lifting all fingers and holding for 5 seconds.

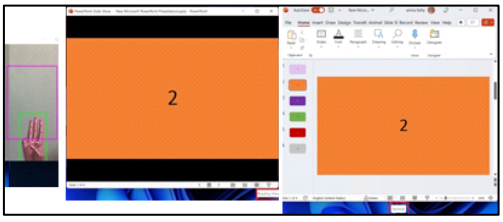

Figure 29. Gesture for Exiting the Reading View and the Result

f. The "Favorite Applications Tool"

The user begins this tool through raising his little finger and holding for 3 seconds. The user will see a confirmation message to confirm the use of the tool. The user can open the browser by lifting the index finger for 3 seconds. The user can open the word by lifting the index and middle fingers for 3 seconds. The user can open the snipping tool by raising the index finger, middle finger, and ring finger (for 3 seconds). The user can stop the tool at any time by lifting all fingers and holding for 5 seconds.

5. Discussion

Unfortunately, currently, most of the interaction between a computer and a user relies on the mouse or keyboard. In the future, employing gesture recognition will allow the advancement of a wide range of applications without the need for physical input devices [1].

While a lot of research has been done to control the mouse with gestures, none has been studied to perform all the functions needed to operate a laptop using hand gestures. We addressed this in this research to serve the community needing this, such as those who have difficulty utilizing the conventional keyboard and mouse and those who need to reduce utilizing these devices to avoid increasing the worsening of their fingers, wrists, and elbow injuries. This has become common in various professions, such as certain sports athletes, computer scientists, musicians, and surgeons. Recent medical studies and recommendations have demonstrated this fact and provided many guidelines for dealing with these injuries [22]-[23]. We have kept this in mind when developing this system. This is because all input functions can be performed through dynamic gestures; that is, they are utilized to tell the computer to perform tasks without touching it.

Controlling a laptop with your hands is easier, more natural, cheaper, safer, and more flexible than employing an input device. What’s more, we don’t need to deal with the technical problems that arise from these devices or sensors [7].

This system does not only involve controlling the mouse or performing only a few functions, like many previous works (e.g., Mukherjee et al. [9], and Sarita et al. [10], Steven Raj et al. [12], Kavitha et al. [13], Matlani et al. [5], and Kedari et al. [1]). The system is so comprehensive that various gestures can be used to control the laptop to perform all desired

functions from a distance. It consists of several parts (tools). All these tools work in the same systematic way, i.e., the steps for employing any of them are:

- Use the desired gesture to launch the desired proposed tool.
- Make the required hand gesture in front of the camera for the desired number of seconds.
- The corresponding function will be executed immediately on the screen.
- End the tool with the required hand gesture.
- Finally, turn off the machine with the required gesture.
- Using this system is very straightforward. All proposed tools (comprising the proposed system and its sub-tools) work only through hand gestures without employing additional tools, such as in Kavitha et al. [13]. This simplifies its use, especially if the general use of the computer is difficult. Moreover, there is no restriction on the position of the hand in front of the camera (as in Runwal et al. [11] and Kavitha et al. [13]), and it doesn't have to be in a limited range.
- The system is a computer vision system, i.e., it does not use any sensors or gloves (e.g., Mukherjee et al. [9], Sarita et al. [10]). This makes it an inexpensive and convenient system. No additional hardware is required other than a laptop with a webcam.

6. Conclusion and Future work

The article introduced a new comprehensive system for controlling a laptop through hand gesture recognition. For the first time, the system can do everything needed to remotely control a laptop (the easiest way to interact between a laptop and a human) with simple gestures. These functions include changing the position of the mouse point, performing left and right mouse clicks, double click, scrolling up and down, providing all the keyboard shortcuts and PrtScr and Backspace, shutting down, creating new files and folders, playing, muting, pausing media playback, reducing and increasing the brightness, turning the volume down and up, advancing to the next and previous page of a slideshow, zooming in and out, and opening the most frequently used applications based on the user's choice.

In the future, we can use two hands instead of just one. This is to simplify the use of more than one proposed tool at the same time. Additionally, we plan to completely enable hand-free control of the laptops in various environments (e.g., hazardous ones), which is new to our world. In this way, the need for input devices, such as a mouse and keyboard can be greatly reduced.

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