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Virtual AI Mouse Using Hand Tracking

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Abstract: ***The mouse is one of the best invention of Human-Computer Interaction technology. Nowadays, wireless or bluetooth mouse still uses device and it not free of devices since it uses batteries for power source and Dongles to connect to the personal computer. At emergency situation like wire damaged while in the meeting then the AI virtual mouse system will help. Like this problems can be overcome by using their webcam or a built-in camera for capturing of hand detection using computer vision. based on the hand gestures movement, the computer can be controlled virtually and can perform left click, right click, scrolling functions and computer cursor function without the use of the physical mouse. In the current situation where we are adjusting our living while being in the pandemic, a touchless mouse controller will be useful to eliminate the risk of spreading infection through touch on public service devices. In this project, we have created an AI- based Mouse Controller. It will first detect the hand landmarks, then track and then perform functions. We have also applied smoothing techniques to make it more usable. The virtual mouse will be operated without touching any device or screen. The domain of the project is AI/ML. The programming language used is mainly Python. This system is based on the concept of computer vision.***

I. INTRODUCTION

There has been tremendous development in budding areas of AR (augmented reality) and other peripheral devices that we use on the daily and many of these devices are getting smaller and portable with the likes of Bluetooth and other wireless technologies. In this paper, the proposition is that we use an Artificial Intelligence based mouse system that can recognize gestures made by hands and detect finger tips for executing mouse functions on a computer using computer vision. The main objective of the proposed system is achieving conventional mouse functions such as clicking and scrolling using a built-in camera or a peripheral web camera in the place of a conventional mouse device. Hand gestures and detection of the finger tips helps communicate with the computer. With this system one can trail the fingertip to indicate cursor movement by making use of the computer's web camera and perform cursor functions and scrolling operations. This paper focuses on the use of computer vision in place of Bluetooth or other wireless technologies like USB receiver technologies for achieving mouse operations using hand gestures and movements to move the mouse pointer on the computer screen. The hand movements are tracked and the frames are processed by the built-in camera of the computer to detect functions of mouse identical scrolling clicking, minimizing, maximizing, etc. by processing those gestures. In this system, Python programming language which is very popular for Artificial Intelligence projects, OpenCV which is an open-source library for working with image processing and performing computer vision tasks like face-detection and object tracking and other python packages such as AutoPy, Mediapipe and PyAutoGUI are used to move the cursor around in the application and perform functions of pointing, clicking and scrolling.

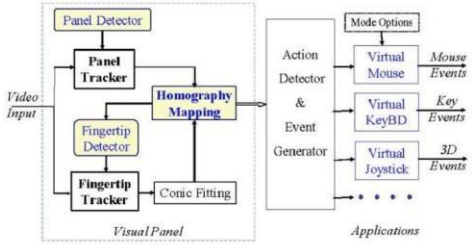

Figure 2.1: The system overview of Visual Panel (Zhengyou, Ying and Shafer, 2001)

This proposed model can work extremely well in real production environment and does not need the rendering power of a GPU (Graphics Processing Unit). The accuracy of the model is quite high and functional.

II. MOTIVATION OF VIRTUAL MOUSE :

It is fair to say that the virtual mouse will soon to be substituting the traditional physical mouse in the near future, as people are aiming towards the lifestyle where that every technological devices can be controlled and interacted remotely without using any peripheral devices such as the remote, keyboards, etc. It doesn't just provides convenience, but it's cost effective as well .

Artificial Intelligence (AI) is abroad field encompassing machine learning, natural language processing, and computer vision. These components collectively enable machines to simulate human intelligence, opening up vast possibilities for addressing complex challenges. In the context of climate change mitigation, AI's potential lies in its ability toprocess vast datasets, identify patterns, andmake predictions. Machine learning algorithms, a subset of AI, can analyses

historical climate data, facilitating thecreation of sophisticated climate models. Natural language processing aids in synthesizing diverse scientific literature, while computer vision contributes to environmental monitoring. This section delves into the foundational elements of AIand illuminates its transformative potential in mitigating climate change.

III. PROJECT OBJECTIVE :

The purpose of this project is to develop a Virtual Mouse application that targets a few aspects of significant development. For starters, this project aims to eliminate the needs of having a physical mouse while able to interact with the computer system through webcam by using various image processing techniques. Other than that, this project aims to develop a Virtual Mouse application that can be operational on all kind of surfaces and environment.

The following describes the overall objectives of this project:

- To design to operate with the help of a webcam. The Virtual Mouse application will be operational with the help of a webcam, as the webcam are responsible to capture the images in real time. The application would not work if there are no webcam detected.

- To design a virtual input that can operate on all surface. The Virtual Mouse application will be operational on all surface and indoor environment, as long the users are facing the webcam while doing the motion gesture.

- To program the camera to continuously capturing the images, which the images will be analysed, by using various image processing

techniques. As stated above, the Virtual Mouse application will be continuously capturing the images in real time, where the images will be undergo a series of process, this includes HSV conversion, Binary Image conversion, salt and pepper noise filtering, and more.

- To convert hand gesture/motion into mouse input that will be set to a particular screen position. The Virtual Mouse application will be programmed to detect the position of the defined colours where it will be set as the position of the mouse pointers. Furthermore, a combination of different colours may result in triggering different types of mouse events, such as the right/left clicks, scroll up/down, and more.

IV. PREVIOUS AI MOUSE FEATURES :

During the process of colour recognition, it contains 2 major phases which are the calibration phase and recognition phase. The purpose of the calibration phase is to allow the system to recognize the Hue Saturation Values of the colours chosen by the users, where it will store the values and settings into text documents, which will be used later on during the recognition phase. While on the recognition phase, the system will start to capture frames and search for colour input with based on the values that are recorded during the calibration phase. The proposed mouse system is beyond this limitation. This paper proposes a virtual mouse system based on HCI using computer vision and hand gestures.

Gestures captured with a built-in camera or webcam and processed with color segmentation & detection technique. The user will be allowed

to control some of the computer cursor functions with their hands which bear colored caps on fingertips. We have developed an AI virtual mouse system using python which can control the mouse functions by using hand gestures instead of using a physical mouse. Our system uses a webcam or a built-in camera which detects the hand gestures and fingertips and processes these frames to perform the particular mouse functions.

V. STANDARD DEVIATION CALCULATION

To obtain the maximum and the minimum of the HSV values, it requires to gone through the Standard Deviation calculation, a measurement used to quantify the amount of variation / dispersion among other HSV values. Furthermore, to obtain an accurate range of values, three-sigma rule are required in the calculation, so that chances of the captured values have a very high possibility to fall within the three.

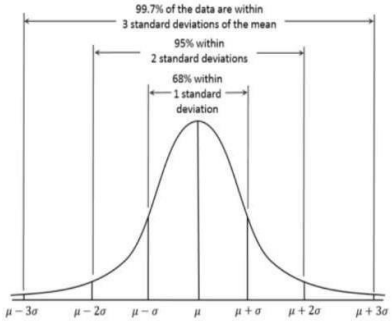

Figure 3.4: The distribution of three-sigma rule

Implementation Issues and Challenges Throughout the development of the application, there are several implementation issues occurred.

The following describes the issues and challenges that will likely to be encountered throughout the development phase:

- The interruptions of salt and pepper noises within the captured frames. Salt and pepper noises occurred when the captured frame contains required HSV values that are too small, but still underwent a series of process even though it's not large enough to be considered an input. To overcome this issue, the unwanted HSV pixels within the frame must first be filtered off, this includes the area of the pixels that are too large and small. With this method, the likelihood of interruptions of similar pixels will reduce greatly.

- Performance degradation due to high process load for low-tier system. Since the application is required to undergo several of process to filter, process and execute the mouse functions in real time, the application can be CPU intensive for most of the low-tier system. If the size of the captured frames is too large, the time-taken for the application to process the entire frame are increase drastically. Therefore, to overcome this issue, the application is required to process only the essential part of the frames, and reduces the redundant filtering process that could potentially slow the application down.

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The difficulties of calibrating the brightness and the contrast of the frames to get the required HSV

values. The intensity of brightness and contrast matters greatly when it comes to acquiring the required colour pixels. In order for the application to execute the entire mouse functions provided, all of the required HSV values to execute the specific mouse functions must be satisfied, meaning that the overall HSV values must be satisfied with the brightness and contrast as well. However, the calibration can be somewhat tedious as certain intensity could only satisfy part of the required HSV values, unless the original HSV values were modified to prove otherwise. To overcome this issue, the application must first start up with a calibration phase, which allows the users to choose their desired colour pixels before directing them to the main phase.

System Implementation

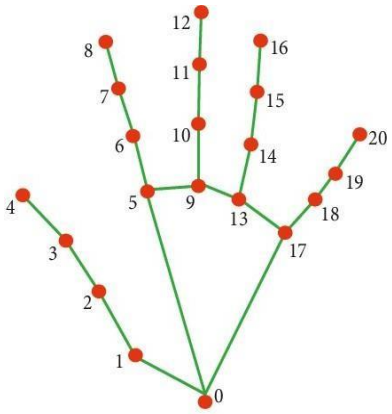
Capturing video

The use of the OpenCV module is to capture the realtime video using a webcam which acts as an input for further processing.
Find hand landmarks
Using Python libraries like CV2 and MediaPipe we coded the program to locate the hand landmarks. After recognizing hand it will locate 21 points as shown in the figure.

Get the tip of the index and middle finger
We also included different functions in a library named “Hand Tracking Module” for simplicity. This module includes the functions for detecting hands, locating fingers, counting which fingers are up, finding the distance between fingers, etc.

Frame rate
Frame rate helps us to check if the movements of the cursor are smooth or not Smoothen the values so the mouse is not jittery by observing the change in frame rate and movement of cursor we applied some

smoothing technique to mouse so that it is easy to use for user.



0. WRIST
1. THUMB_CMC
2. THUMB_MCP
3. THUMB_IP
4. THUMB_TIP
5. INDEX_FINGER_MCP
6. INDEX_FINGER_PIP
7. INDEX_FINGER_DIP
8. INDEX_FINGER_TIP
9. MIDDLE_FINGER_MCP
10. MIDDLE_FINGER_PIP
11. MIDDLE_FINGER_DIP
12. MIDDLE_FINGER_TIP
13. RING_FINGER_MCP
14. RING_FINGER_PIP
15. RING_FINGER_DIP
16. RING_FINGER_TIP
17. PINKY_MCP
18. PINKY_PIP
19. PINKY_DIP
20. PINKY_TIP

VI. IMPLEMENT THE FUNCTIONS

By locating the coordinates and tracking the fingers we perform the mouse functions virtually i.e. without any physical contact with the device.

Display

We also displayed the tracking by webcam to show implementation properly. The reason for choosing this methodology is due to the fact that the Virtual Mouse are still considered to be at the introduction stage, which means it still requires a great deal of extensive research and development before it could actually make it into the market. Therefore, this project requires a thorough yet iterative planning and requirements gathering where the lifecycle will be continually revisited to re-evaluates the direction of the project and to eliminate the ambiguities in the process of the development, and at the same time welcome changes of requirements, which promotes adaptability and flexibility. Furthermore, due to the Virtual Mouse application are more towards serving the users, this project requires continuous customer collaboration, as they're essential for gathering the proper requirements in all aspects. This is why that the agile methodology is the ideal approach for developing the project.

VII. IMAGE PRE-PROCESSING

The following describes the phases within the agile methodology approach:

- Planning

A thorough planning will be conducted in this phase where the existing systems/product, for this case, physical computer mouse will be reviewed and studied to identify the problems existed, a comparison of problems will be made to compare which problems are more crucial and requires improvement. An outline objective and the scope will be identified in order to provide an alternative solution to the problem.

- Requirement Analysis

The phase that gathers and interpreting the facts, diagnosing problems and recommending improvements to the system. In this phase, the collected problem statements will be extensively studied in order to find a proper solution or at least an improvement to the proposed system. All proposed solutions will be converted into requirements where it will be documented in a requirement specification.

- Designing

The requirement specification from the previous phase will be studied and prioritize to determine which requirement are more

important where the requirement with the highest priority will be delivered first. After the study, the system design will be prepared as it helps in defining the overall system architecture and specifying the hardware and the software requirements.

- Building

The phase where the actual coding implementation takes place. By referring to the inputs from the system design, the system will be developed based on the prioritize requirements. However, due to we're using the agile methodology approach, the developed system will be considered as a prototype system where it will be integrated and tested by the users.

- Testing

The phase where the prototype system going through a series of test. The prototype system will first undergo integration where the features from the previous iteration cycle are added to the latest cycle. After the integration, the prototype system will be thoroughly tested by the users to determine whether they are satisfied with the latest deliverables, the completion of the project depends on whether they've accepted it or otherwise. If the user requires additional features or modification, feedback gathering will be conducted, which resulted in further modification of the requirements and features where it will record and documented for the requirement analysis phase on the next iteration.

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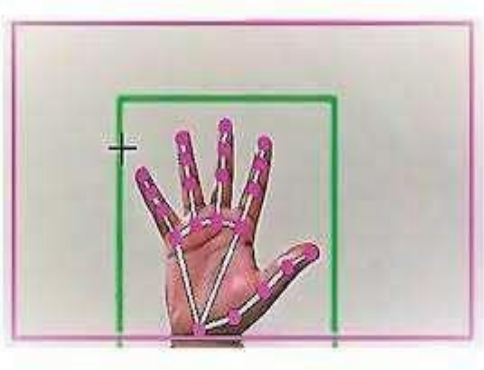
VIII. PROCESSING THE COLLECTED FRAMES

The web camera keeps on collecting the frames until the underlying program is closed.

The captured frames of video are collected in the BGR color format from the web camera. In order for OpenCV to process the frames, the BGR color format has to be converted to the RGB color format. Subsequently, OpenCV processes the frames to detect hands.

```
image = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
image = cv2.cvtColor(image, cv2.COLOR_RGB2BGR)
```

RECOGNIZING THE GESTURE :
At this point, the hand is being tracked and if any finger is held pointed, MediaPipe recognizes the finger and the tip with the help of the 21 co-ordinates on the fingers and after processing the gesture, the appropriate mouse operation is handled.

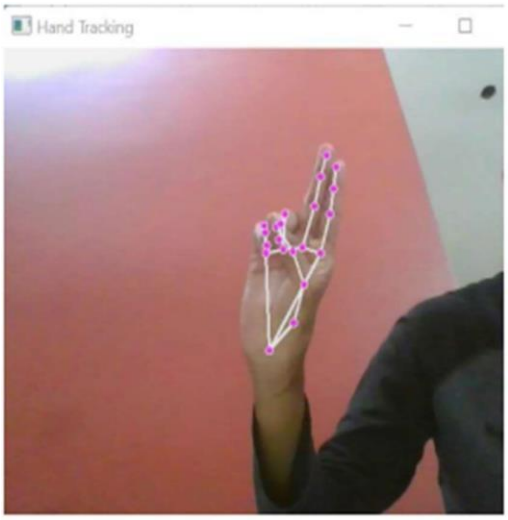


MOVING AROUND USING THE VIRTUAL MOUSE

OpenCV detects the hand and draws an rectangular window around the hand and uses a transformation algorithm that calculates the co- ordinates of the fingertips from the screen capture window to be able in the computer system and controls the pointer of the virtual mouse. When the finger tips detected that is connected to a particular gesture the box is drawn around and allows it to act as a pointer to perform basic moving functionality.

LEFT CLICK OPERATION :
If the tip of the index finger and the tip of the middle finger are held up such that the distance calculated between them amounts to approximately 40px and then both the fingers' tips are made to come closer a left click is performed.

RIGHT CLICK OPERATION :
If the tip of the index finger and the tip of the middle finger are made to come together and the points of the hand marks align such that the distance between the tips is below 40px then a right click operation is performed.



SCROLLING OPERATION :

Scrolling up
For scrolling up the tips of the index and the middle finger have to be brought close such that the distance is 40px or below and when the fingers gesture as to move from the bending position to straightening position.

Scrolling Down
For scrolling up the tips of the index and the middle finger have to be brought close such that the distance is 41px or above and when the fingers gesture as to move from the bending position to straightening position.

IX. RESULTS AND INFERENCES :

The proposed model of AI virtual mouse demonstrates the idea of computer vision technology and machine learning capabilities. For verifying and testing of the proposed AI virtual mouse system only a certain quantity of datasets are attainable. The hand tracking, finger-tip detection and gestures recognition have been performed in various illuminated conditions and at diversified distances from the camera. The results of the testing are given below. The test was performed 25 times by 4 persons resulting in 600 gestures with manual labelling, and this test has been made in different light conditions and at different distances from the screen, and each person tested the AI virtual mouse system 10 times in normal light conditions, 5 times in faint light conditions, 5 times in close distance from the webcam, and 5 times in long distance from the webcam, and the experimental results are tabulated in Table 1.

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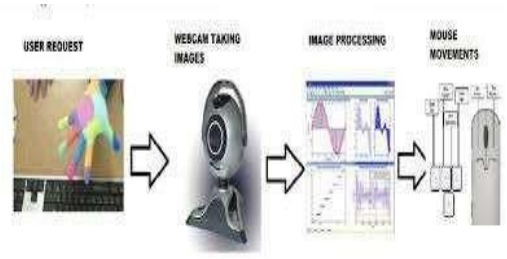
Mouse Function Performed	Correct Operation	Incorrect or failed operation	Accuracy
Pointer movement	100	0	100
Left click	98	2	98
Right click	94	6	94
Scrolling Up	98	2	98
Scrolling Down	99	1	99
Result	489	11	97.8

Table 1. Accuracy of mouse operations

The following bar graph shows the accuracy of operations that have been observed by testing the model under various illumination conditions and numerous operations. Table 1 shows the comparison between different functions and how they are accurate. Lets see the accuracy using bar graphs which is one of the most using statistical tool used to calculate the function parameters.

X. HOW VIRTUAL AI MOUSE WORKS:



A computer vision-based virtual mouse system that employs hand gestures and hand tip detection to replicate mouse motions was developed. The main objective of the proposed system is to replace the traditional mouse with a web camera or a built-in camera in the computer to perform computer mouse cursor and scroll task. The AI virtual mouse technology allows us to conduct mouse cursor
actions like scrolling and moving the pointer

while also monitoring the fingertip of a hand gesture using a built-in camera or web camera. In this study, the user uses a built-in camera or webcam together with hand gestures to operate a computer mouse, as opposed to using a wireless or Bluetooth mouse, which needs a particular peripheral such as a mouse, a dongle to connect to the PC, and a battery to operate. The suggested system uses a web camera to record, examine, and decipher the captured frames, identify various hand and hand-tip gestures, and then carry out the relevant mouse action. The Python programming language and the OpenCV package were used to construct the AI virtual mouse system. The suggested AI virtual mouse system leverages the Media Pipe package for hand tracking and hand tricks. Additionally, the desktop window may be moved around and operations like scrolling and left-and right-clicking are carried out using the Pynput, Autopy, and PyAutoGUI packages. The findings of the proposed model demonstrate a very high degree of accuracy, and it can operate in real-world applications using CPU utilization rather than GPU.

XI. CONCLUSION & FUTURE ENHANCEMENTS :

There are abundance of methods for computer interaction besides the traditional physical mouse interaction. With the evolutions of modern technology and programming, so does the Human Computer Interaction (HCI) methods, as it allows unlimited ways to access the computers. This approach allows the developers to design specific/unique system that suit the

needs of the users, from gesture movement tracking to coloured tracking, it's no surprise that in near future, physical mouse will no longer be needed and be replaced by video cameras that tracks gestures.

Gesture recognition gives the best interaction between human and machine. Gesture recognition is also important for developing alternative human computer interaction modalities. It enables human to interface with machine in a more natural way. Gesture recognition can be used for many applications like sign language recognition for deaf and dumb people, robot control etc. Gesture recognition gives the best interaction between human and machine. Gesture recognition is also important for developing alternative human computer interaction modalities. It enables human to interface with machine in a more natural way. Gesture recognition can be used for many applications like sign language recognition for deaf and dumb people, robot control etc.

This technology has wide applications in the fields of augmented reality, computer graphics, computer gaming, prosthetics, and biomedical instrumentation. Digital Canvas is an extension of our system which is gaining popularity among artists, by which the artist could create 2D or 3D images using the Virtual Mouse technology using the hand as brush and a Virtual Reality kit or a monitor as display set. This technology can be used to help patients who don't have control of their limbs. In case of computer graphics and gaming this technology has been applied in modern gaming consoles to create interactive games where a person's motions are tracked and interpreted as commands.

The major extension to this work can be done to make system able to work at much complex background and compatible with different light conditions. It can be made as an effective

user interface and which can include all mouse functionalities. And also, it would be ideal to research into advanced mathematical materials for image processing and investigate on different hardware solutions that would result in more accurate hand detections. Not only did this project show the different gesture operations that could be done by the users but it also demonstrated the potential in simplifying user interactions with personal computers and hardware systems.

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