AirCanva: Revolutionizing Digital Creativity Through Gesture-Based Interaction

Shalini S
Dayananda Sagar Academy of
Technology and Management

Nandini C
Dayananda Sagar Academy of
Technology and Management

K.Lakshmi Narayana
Dayananda Sagar Academy of
Technology and Management

K.Mahesh Babu
Dayananda Sagar Academy of
Technology and Management

M.Uday Kiran
Dayananda Sagar Academy of
Technology and Management

R.Siva Karthik Reddy
Dayananda Sagar Academy of
Technology and Management

Abstract - AirCanva introduces an innovative Gesture-Controlled virtual Canvas, an innovative system that allows users to engage with a virtual canvas using hand gestures. This system utilizes the HSV color space to achieve effective color detection and incorporates deep learning algorithms for accurate gesture recognition. As a result, hand movements are translated into various actions, including drawing, erasing, and selecting colors on the canvas. The use of the HSV color model ensures consistent performance under diverse lighting conditions, effectively mitigating issues such as background interference and gesture misclassification. This solution has significant implications for fields such as creative design, education, and accessibility. Experimental findings indicate a prominent level of accuracy and user satisfaction, highlighting the system's capability to transform gesture-based interactions between humans and computers.

INDEX TERMS **-** HSV COLOR SPACE, COMPUTER VISION, GESTURE RECOGNITION, HUMAN-COMPUTER INTERACTION (HCI)

INTRODUCTION

Gesture recognition is essential in the field of human-computer interaction, enabling users to interact intuitively and engage effortlessly with digital environments. This study centers on the creation of a gesture-controlled air canvas that converts hand movements into digital drawing instructions. The objective is to foster creativity, enhance educational experiences, and improve accessibility by allowing users to manipulate a digital canvas using their hand gestures. The system employs sophisticated color detection and deep learning methodologies to guarantee precise and dependable gesture recognition, even in diverse lighting scenarios. This innovative approach not only improves the user experience but also presents promising applications in the fields of art, education, and assistive technologies for individuals with physical disabilities[7].

The Gesture-Controlled Air Canvas initiative enables individuals to produce digital art by converting hand movements into actions on a virtual canvas. The key part of this interaction is using the HSV (Hue, Saturation, Value) color model. Unlike the traditional RGB model, HSV provides a clearer way to perceive colors as it separates the color tone (hue) from its brightness (value) and intensity (saturation). This distinction facilitates the identification and differentiation of colors in real-time, especially in dynamic settings where lighting and background conditions may fluctuate[5].

OpenCV (Open-Source Computer Vision Library) is a powerful open-source library designed for real-time computer vision and image processing. It provides a wide range of tools for tasks such as object detection, tracking, image filtering, and more, making it an essential framework for developing innovative computer vision applications. In our project, OpenCV plays a critical role in enabling the detection and tracking of hand gestures through the live webcam feed. By leveraging its robust image processing capabilities, we can accurately detect the user's fingertip and track its motion in real time, facilitating the creation of an interactive air-writing canvas[8].

Within our initiative, the HSV model is employed to identify specific colors such as red, blue, and green, which are subsequently associated with particular actions like drawing, selecting colors, or clearing the canvas. The model's proficiency in accurately segmenting colors

guarantees that the system effectively responds to various hand gestures, thereby delivering a smooth and engaging user experience[6]. By utilizing the simplicity and efficacy of the HSV model, we establish a more intuitive and responsive interface for users, thereby enhancing both the accuracy and fluidity of the drawing experience [4].
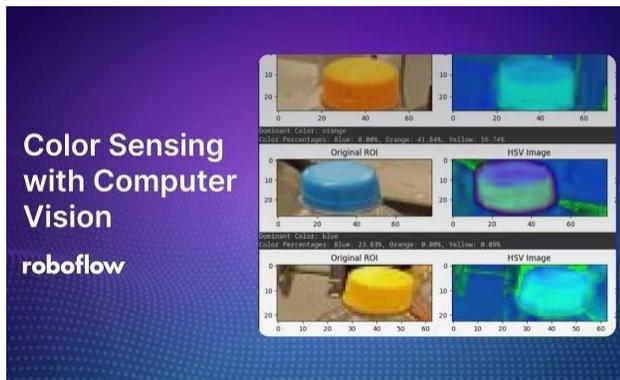
Source: Roboflow Blog[1]

FIGURE 1: visual representation of HSV detects the color.

I.   LITERATURE SURVEY

The referenced project Air Writing: Redefining Digital Canvases [2] primarily focuses on motion-to-text conversion through air writing, leveraging gesture recognition to trace finger paths and translate them into textual output. This approach is geared towards enhancing communication, especially for individuals in the deaf community, by reducing reliance on traditional devices for messaging or email composition. In contrast, **AirCanva** diverges from this goal, focusing on transforming hand gestures into digital strokes on a virtual canvas. This real-time interaction emphasizes creativity and accessibility, integrating advanced features like dynamic color calibration, robust object tracking, and interactive canvas management to redefine how users interact with digital tools.

Both projects utilize computer vision techniques, but while the motion-to-text system is tailored for efficient textual communication, **AirCanva** offers a broader application as a creative medium and an interactive tool for various user groups. The versatility of AirCanva makes it equally useful for artistic purposes and accessible communication, complementing the practical benefits of air-writing solutions like the one presented in [2].

The Virtual Air Canvas Project Using Image Processing [3] focuses on utilizing object tracking and image processing techniques to convert motion into text, offering applications in wearable intelligent devices and communication for the deaf. Similar to your approach, it leverages computer vision to track finger paths and generate corresponding text output. However, your methodology distinguishes itself by emphasizing simplicity, resource efficiency, and enhanced accessibility. Your implementation avoids complex object identification and behavior analysis steps, instead focusing on gesture detection for drawing paths and directly converting them into meaningful outputs like messages or drawings. While the Virtual Air Canvas expands its scope to applications like autonomous surveillance and video indexing, your approach prioritizes practical usability, especially in scenarios requiring rapid and intuitive human-computer interaction. Both projects align in addressing the needs of the hearing-impaired community but differ in their technical depth and target use cases.

II.   METHODOLOGY

The AirCanva methodology is structured to convert real-time hand gestures into digital strokes on a virtual canvas through the application of sophisticated image processing techniques. The procedure initiates with dynamic color calibration, wherein users designate a region of interest (ROI) within the live camera feed to specify the color they intend to track. The system then transforms the ROI into the HSV (Hue, Saturation, Value) color space, enhancing its adaptability to fluctuations in lighting conditions, and computes the upper and lower HSV thresholds to maintain consistent detection. Subsequently, a binary mask is created for the chosen color, which is refined through morphological operations, including dilation and erosion, to reduce noise and enhance detection precision.

Following this, the system engages in real-time detection and tracking of the marker. Contour detection is utilized on the binary mask to identify the marker, with its position ascertained by calculating the centroid of the most prominent contour. The marker's trajectory across frames facilitates the rendering of digital strokes on a blank virtual canvas, with lines drawn between successive positions to ensure a smooth and continuous drawing experience. To bolster robustness, smoothing algorithms, such as Kalman filtering, may be implemented to mitigate jitter resulting from swift hand movements. Furthermore, Gaussian blur is applied to the mask to guarantee consistent performance across varying conditions. The completed drawing can be saved for future reference, and the entire application is compiled into an executable file using PyInstaller, allowing users to access it without the need for Python installation. This thorough methodology promotes adaptability, interactivity, and user-friendliness for a diverse audience.
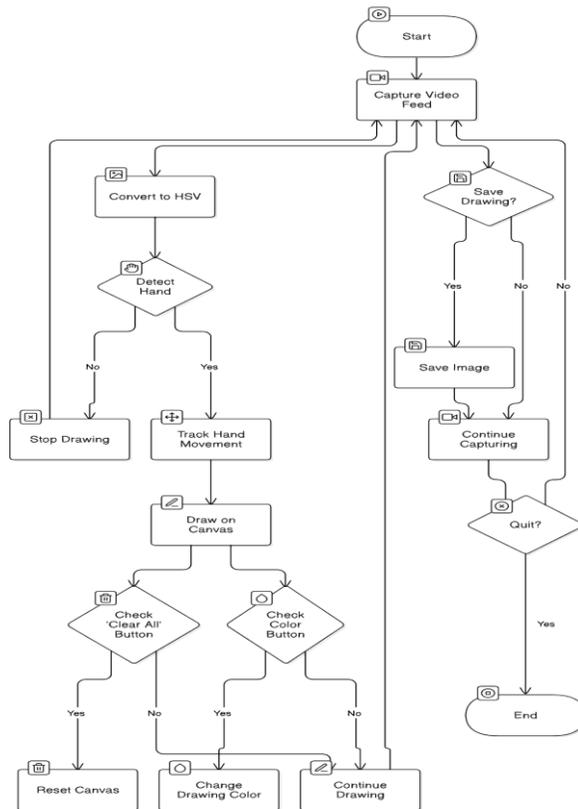
features aim to make the app user-friendly and versatile, providing a creative environment for artistic expression and practical tasks, including education and accessibility for those with disabilities.

FIGURE 3:different buttons the user can interact with in AirCanva exe file, in the figure we can see clear function different colors for the marker on canvas.

III. Implementation

AirCanva focuses on creating an air-writing system that translates real-time hand gestures into digital strokes on a virtual canvas, making it an interactive and dynamic tool for creative expression and communication. The methodology is divided into several stages, incorporating advanced image processing and computer vision techniques to ensure accuracy and user adaptability.

In the implementation of this project, OpenCV is utilized extensively to process video frames captured by the webcam[11]. The library is employed to perform essential tasks such as background subtraction, color space conversion, and contour detection. For instance, the fingertip is identified by analyzing the contours of the hand, while the trajectory of the motion is drawn on a digital canvas by updating pixel positions in real-time. Additionally, OpenCV's functionality for creating GUI elements is used to design interactive buttons for color selection and canvas clearing. This efficient integration of OpenCV [10]modules ensures seamless performance, making the air-writing application responsive and intuitive.

Dynamic Color Selection and Calibration

AirCanva introduces dynamic color selection, enabling users to select their preferred marker color in real time. The process starts with color calibration, where the user defines a region of interest (ROI) containing the target color. The system analyzes this ROI in the HSV (Hue, Saturation, Value) color space for better lighting adaptability compared to RGB. The system then computes the upper and lower HSV bounds to ensure consistent detection of the selected color. These bounds are stored for creating a binary mask in subsequent frames.

```
hsv_roi = cv2.cvtColor(roi, cv2.COLOR_BGR2HSV)
lower_bound = np.array([h_min, s_min, v_min])
upper_bound = np.array([h_max, s_max, v_max])
```


FIGURE 2:Representation of workflow of the AirCanva in a flowchart

AirCanva app lets users make digital art and interact with a canvas using simple hand movements. Its primary features include:

- Clear function: This button clears the canvas, giving users a fresh start for new drawings or writings.
- Color Change function: Users can change the drawing tool's color by picking from a set of colors or using gestures to switch them.
- Save function: Users can save their artwork in formats like PNG or JPEG for later use, sharing, or printing.
- Drawing Mode: The app turns hand gestures into drawing actions, allowing users to create sketches, designs, or text freely on the canvas.
- Undo function: This feature lets users reverse their last action, making it easy to fix mistakes without starting over.
- Zoom and Pan: Users can zoom in and out or move around the canvas, giving them better control and more space for creativity.These

Real-Time Object Detection and Tracking

This stage focuses on isolating and tracking the marker. A binary mask is generated using the HSV bounds, isolating the target color in each frame. Morphological operations such as dilation and erosion are applied to minimize noise. The mask is created and cleaned with morphological transformations:

```
mask = cv2.inRange(hsv_frame, lower_bound,
upper_bound)
kernel = np.ones((5, 5), np.uint8)
cleaned_mask = cv2.morphologyEx(mask,
cv2.MORPH_CLOSE, kernel)
```

Contours are identified, and the centroid of the largest contour is used to track the marker:

```
contours, _ = cv2.findContours(cleaned_mask,
cv2.RETR_TREE, cv2.CHAIN_APPROX_SIMPLE)
largest_contour = max(contours,
key=cv2.contourArea)
M = cv2.moments(largest_contour)
if M["m00"] != 0:
    cx, cy = int(M["m10"] / M["m00"]),
int(M["m01"]        /M["m00"])
```

Drawing on the Virtual Canvas

The tracked marker's position is used to draw on a blank virtual canvas. A line is rendered between consecutive points to visualize the marker's path. This canvas is then overlaid on the live video feed to provide instant user feedback.

Robustness and Accuracy

AirCanva employs smoothing techniques like a Kalman filter to stabilize the drawing process and minimize jitter caused by rapid hand movements. Additionally, Gaussian blur is applied to the mask to enhance noise reduction and maintain robustness in varying lighting conditions.

Saving the Output

Once the drawing is complete, users can save their work as an image file for further use. OpenCV's[10] image writing function is employed for this purpose:

```
cv2.imwrite("drawing_output.png", canvas)
```

Application Packaging

To make AirCanva accessible, the entire application is packaged as a standalone executable using PyInstaller. This process bundles the Python script and all necessary dependencies, ensuring the system runs without requiring Python installation.

```
pyinstaller --onefile --windowed AirCanva.py
```

The resulting file is placed in the dist folder, making it easy to distribute and run the application across different systemsThis approach combines advanced image processing, dynamic user interaction, and practical deployment strategies to create a robust and accessible air-writing system for creative and communicative purposes.
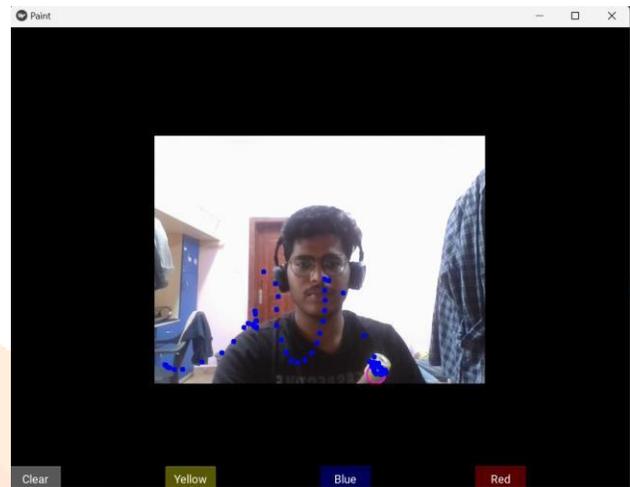

FIGURE 4: Demonstration of the Air Canvas project in execution, showcasing hand gesture tracking for drawing on a digital canvas. The application dynamically detects finger movements to create patterns in real time, with color selection options and a clear button for canvas management.

The image captures the execution of the Air Canvas project, a real-time drawing application that uses hand tracking and object detection through OpenCV[11]. In this demonstration, the system detects the user's finger and tracks its movement across the screen, rendering the trajectory in blue on a digital canvas. The interface includes buttons for color selection (Yellow, Blue, Red) and a 'Clear' button to reset the canvas. The project leverages computer vision techniques to identify and process gestures from live video input, allowing the user to draw intuitively in the air. This technology offers a robust and interactive platform for creative expression and demonstrates its potential as a human-computer interaction tool. The execution highlights the system's accuracy and responsiveness, contributing to advancements in gesture-based applications[9].

IV. CONCLUSION

AirCanva demonstrates the transformative potential of gesture-based interaction systems, emphasizing innovation in human-computer interaction. By integrating computer vision techniques, including color detection in the HSV space and motion tracking algorithms, this system enables intuitive digital canvas manipulation. The use of Python-based image processing ensures real-time responsiveness, while the implementation of gesture recognition bridges the gap between human creativity and technology. AirCanva has significant implications for various domains, including education, art, accessibility, and communication. The scalable and cost-effective design highlights its practical application in creating user-friendly tools for individuals with disabilities and enhancing artistic and educational engagement. Future iterations could expand on integrating advanced machine learning models for gesture recognition, improving accuracy and expanding functionality across diverse user environments. Thus, AirCanva serves as a foundational step toward more inclusive and interactive digital platforms.

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