Grenze International Journal of Engineering and Technology, January Issue

Air Canvas: Smart White Board

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***Abstract*— Technology is reshaping the way we interact with computers at a rapid pace, and touch-free interfaces are opening up new possibilities. Air Canvas is a creative and intuitive system that lets users draw, write, and annotate in the air—using only hand gestures, with no need for a stylus or touchscreen. Built with OpenCV, MediaPipe, and Python, it accurately tracks fingertip movements and translates them into real-time digital strokes. Unlike traditional methods that require physical contact, Air Canvas is contactless, easy to use, and eco-friendly, reducing paper waste and reliance on external tools. The system detects hand gestures using a simple webcam, allowing users to choose colours, adjust brush sizes, and erase with natural movements. This makes it especially useful for education, design, and interactive learning, where engaging digital tools are becoming essential. Whether in classrooms, remote learning, or creative projects, Air Canvas offers a fun, accessible, and smart way to interact with technology. By making digital drawing and writing more intuitive, it bridges the gap between traditional and modern methods, enhancing creativity and making e-learning more relevant in the virtual world.**

***Index Term*— Air Canvas, Finger-tip, OpenCV, HCI, Hand Tracking, etc.**

I. INTRODUCTION

In today's tech-driven world, Human-Computer Interaction (HCI) plays a pivotal role in daily life, transforming how we learn, work, and communicate. Inspired by the idea of a "dustless classroom," this paper envisions a shift from traditional teaching methods to a more advanced, digital approach. By harnessing the power of OpenCV and Python, we aim to develop an interactive, AI-driven system that transforms the way students learn and teachers instruct. This technology-driven solution will not only enhance engagement but also create a more seamless, dynamic, and immersive educational experience. OpenCV is a powerful open-source library that brings computer vision and machine learning to life, offering over 2,400 algorithms for tasks like face recognition, object detection, and even 3D modelling. Its ability to process images and videos in real time makes it a perfect tool for building responsive and interactive digital applications.

Paired with Python—a flexible and beginner-friendly programming language—OpenCV becomes even more accessible. Python's simplicity and vast ecosystem of libraries make it easy to integrate advanced vision algorithms into functional and user-friendly systems.

This paper explores the vision for a digital art and teaching platform that leverages these technologies. With features like real-time drawing, gesture recognition, and interactive tools, the system aims to create an engaging and dynamic learning experience.

Grenze ID: 01.GIJET.12.1.307

By merging education with modern technology, it has the potential to transform traditional classrooms into smart, tech-driven spaces that foster creativity and innovation.
Embracing these advancements is a step toward the future of education—one where technology enhances learning, making it more interactive, intuitive, and inspiring.

II. Literature Review

In recent years, Air Canvas technology has made significant strides, leading to the development of advanced hand-tracking and virtual sketching systems. Researchers have explored various approaches to implementing Air Canvas, with a strong emphasis on OpenCV, MediaPipe, and AI-driven gesture recognition.
Early studies primarily focused on basic implementations using OpenCV to recognize hand gestures. However, as technology evolved, hand-tracking algorithms became more refined, dramatically improving precision and efficiency [1]. The integration of artificial intelligence has been a game-changer, enhancing real-time tracking performance and reducing the latency issues that were common in earlier models [2].
One of the most critical aspects of Air Canvas is its ability to accurately detect and interpret hand movements. MediaPipe has emerged as a leading tool for real-time hand tracking, efficiently detecting multiple hand positions at once [3]. Additionally, AI-powered deep learning models have been extensively explored to enhance gesture recognition accuracy and reliability [4]. Some researchers have also leveraged OpenCV in combination with NumPy to optimize computational efficiency, ensuring smooth and responsive real-time interaction in Air Canvas applications.
Air Canvas technology has found practical applications across various fields, including education, creative arts, and assistive technology. In educational settings, researchers have developed systems that allow students to virtually sketch and annotate content, making learning more interactive and immersive. Another key area of research focuses on assisting individuals with motor impairments by providing alternative communication methods [5]. Additionally, advancements in this technology have enabled air-drawn sketches to be converted into digital text or images, fostering innovation in digital art and smart documentation [6].
Despite its impressive progress, Air Canvas still faces challenges. One of the main issues is its sensitivity to environmental factors, such as changes in lighting and background noise, which can impact tracking accuracy [7]. Latency in AI-driven hand tracking also remains a concern, particularly for real-time applications. Researchers suggest that optimizing AI models and incorporating hardware acceleration techniques could help address these challenges .
However , colour-based tracking systems have been explored to reduce complexity and cost by detecting and following a coloured fingertip using OpenCV and HSV colour space. These systems, while less sophisticated than deep learning models, offer effective real-time drawing with contour detection and morphological processing — making them suitable for classroom environments or low-resource settings [8] . .
New implementations have integrated MediaPipe's hand landmark detection to achieve pinpoint fingertip accuracy and effortless mode switching via gesture recognition. All these advances have greatly minimized the necessity of external accessories like gloves or markers [9]. Additionally, systems are designed using natural gestures — such as using one finger for drawing and two for selection — that are in line with natural hand movement, making interaction more natural and expressive. Other frameworks also prioritize accessibility through the incorporation of drawing, shape picking, and even canvas clearing solely through gesture control, without any physical buttons or hardware peripherals [9]. This has particularly benefited the systems in terms of making them more inclusive and accessible to people with limited mobility. At the same time, researchers involved in real-time gesture recognition have also been investigating fingertip tracking through deep learning for customized data. The models were very accurate on diverse backgrounds and lighting settings. Through algorithms such as SSD and Faster R-CNN, they enhanced fingertip detection and reduced noise in tracking outputs. Such developments also enabled gesture-controlled operations such as writing, backspace, space insertion, and even text prediction [10].

III. Problem Statement

The widespread use of smartphones among children has become a growing concern, often diverting their attention from education to social media or gaming. Excessive screen time can contribute to issues such as depression, mental health challenges, and even physical risks like accidents. Prolonged exposure to screens at close range may also pose potential health risks. At the same time, paper wastage remains a pressing environmental issue. Many people use paper for trivial tasks like casual writing or doodling, only to discard it

shortly after. The production of paper requires cutting down large numbers of trees, contributing to deforestation and environmental degradation.
Air Canvas technology presents a sustainable and innovative solution to these challenges by replacing the need for paper with digital memory . By reducing paper waste, it promotes eco-friendly practices while also keeping students engaged in their education. Moreover, since Air Canvas allows users to interact from a safe distance, it helps prevent eye strain and encourages healthier screen habits. This technology has the potential to transform learning environments, making education more interactive, sustainable, and accessible for all .

IV. METHODOLOGY

The system to be proposed makes use of a combination of user-friendly interface design, computer vision, and deep learning to provide an unbroken, gesture-based air canvas drawing experience. The main aspects of the method are as follows:

A. System Installation and Initialization

A typical webcam is employed continuously to record live video frames. The system is initialized with required libraries such as OpenCV for image processing and MediaPipe for hand tracking. A canvas is generated utilizing Python libraries (OpenCV and Tkinter) where the user input will be displayed.

B. Hand Detection and Landmark Recognition

The Hand Landmarks model of MediaPipe is used to find the hand and find 21 distinctive points (landmarks) on it, such as finger tips, palm base, and finger joints. These landmarks are monitored to estimate the finger position and movement from one frame to another.

C. Fingertip Tracking and Gesture Mapping

The index fingertip (landmark 8) is employed in drawing movements. The system computes the fingertip coordinates for every frame and draws them onto the canvas to paint. Finger combinations are defined for control modes:
One finger up (Index) → Drawing Mode
Two fingers up (Index + Middle/Ring) → Selection Mode

D. Gesture-Based Functional Control

A hand posture recognition module translates the user hand posture to pre-defined commands:

- ➢ Beginning and ending lines of drawing
- ➢ Switching between drawing and selection tools.
- ➢ Enabling canvas clearing

These movements are continuously monitored with MediaPipe and conditionally executed depending on landmark locations.

E. Drawing and Canvas Interaction

During Drawing Mode, the fingertip's movement is traced and drawn as solid lines by OpenCV's line() function. Smoothing techniques (e.g., calculating a moving average of points) are employed to deliver smoothness and preciseness of stroke. Users may select colours, shape (e.g., rectangles and circles), and stroke width dynamically using GUI buttons or gesture toggles.

F. User Interface (UI)

Tkinter provides the GUI framework, including tool select buttons and setting adjustment buttons. The interface shows the live cam stream together with the air canvas. Mode changes are shown in colour or text format for improved user visibility.

G. System Workflow

Start video recording. Detect and identify hand landmarks. Recognize gestures for mode selection. Track fingertip movement for line drawings. Make marks directly on the canvas. Update the UI and provide feedback.

V. COMPONENTS

The Air Canvas system relies heavily on two essential hardware components: the camera and the screen. The camera is responsible for capturing your hand movements in real time and sending the live video feed to the

system for gesture detection and processing. It can be a built-in laptop webcam, an external webcam, or even a phone camera, as long as it provides a clear and steady view of your hands. Proper lighting and camera positioning are crucial, as poor visibility can lead to inaccurate gesture detection. Maintaining an appropriate distance ensures the system accurately tracks your hand gestures. The screen, on the other hand, serves as the visual interface that displays the live camera feed and reflects your virtual drawings as they occur. It allows you to monitor your gestures, view drawing outputs in real time, and interact with on-screen elements such as the toolbar, colour options (blue, green, red, yellow), and the "Clear All" button. A laptop or desktop screen is commonly used for this purpose, ensuring an intuitive and responsive user experience.
The Air Canvas platform is driven by a number of core software elements that cooperate to provide an interactive and seamless user experience. Python, a popular programming language with a reputation for simplicity, cross-platform compatibility, and the ability to support robust libraries, is at the centre. Python facilitates efficient video processing, hand tracking, and drawing with minimal code. Complementing Python is OpenCV, an open-source computer vision library that takes centre stage in recognizing and tracking hand gestures, finding coloured pointers, and allowing real-time interaction with the virtual canvas. NumPy operates behind the scenes to handle the virtual canvas as a grid of pixels, allowing for rapid mathematical operations on images and efficient processing of binary masks that indicate the detected pointer or hand. Another essential piece of the puzzle is MediaPipe, created by Google, which delivers real-time, high-accuracy hand tracking with its Hands module that recognizes 21 3D landmarks. MediaPipe allows for smooth gesture recognition and drawing even in difficult situations such as low lighting or overlapping hands. Trackbars also increase system versatility by enabling users to manually adjust HSV (Hue, Saturation, Value) settings for precise colour detection, making it versatile for varying lighting conditions and marker colours. Jointly, these tools facilitate a dynamic and responsive Air Canvas system.

VI. HOW TO USE

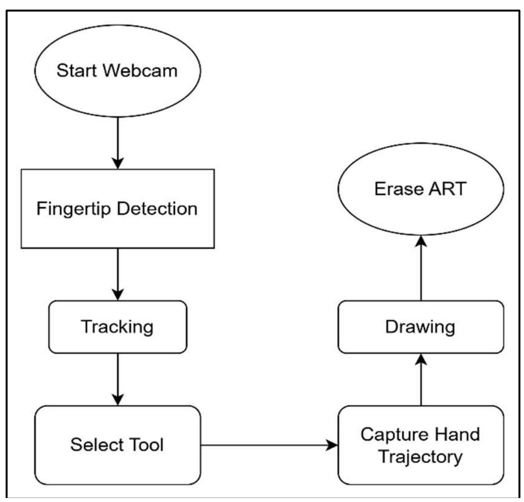

Figure 1: Block Diagram of Proposed System

Steps for using Air Canvas are as follows:
Step 1: Start the application on a portable device that has a good camera or an attached external camera.
Step 2: Be at a distance from the camera where your hand and fingers can be easily detected.
Step 3: Learn the hand movements required to perform actions such as selecting tools or changing tools and drawing shapes.
Step 4: Select the required brush from the device screen and start writing.

VII. RESULTS AND FINDINGS

The system's method is divided into four parts as follows:
- Recognition of finger cap.
- Writing with free hand.
- Erasing with choosing option(clear).

The Air Canvas Application is built step by step using four main modules. In this system, a camera captures input, and a screen shows the output. We use our fingers to draw what we want on the screen, and the app tracks the precise movement of our fingertips. Additionally, specific hand gestures are used to choose and write, based on the functions provided by the included modules and libraries.

A. Recognition of Finger Cap.

This part of the system is designed to detect and understand hand gestures accurately. It tracks key points on the hand, like the cap, what the colour of cap you selected. It uses tools like OpenCV and MediaPipe for real-time hand tracking and recognizing gestures.

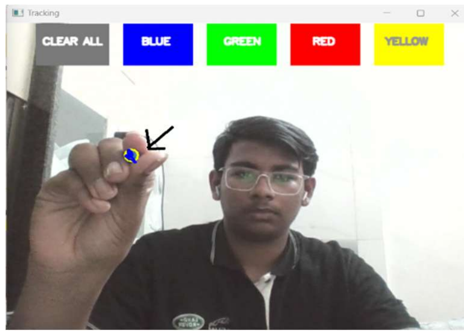

Figure 2: Recognition of finger cap

B. Palm Detection and Writing with Free Hand

If you read [13] , [14] and [15] it does a great work to explain us that this part allows users to draw or write in the air using simple hand gestures in front of a webcam. It uses MEDIAPIPE to improve hand tracking accuracy. When the user points their index finger with wearing cap at the drawing tool, they can start drawing or writing as needed. The name of the selected tool is displayed on the screen when the user points to it.

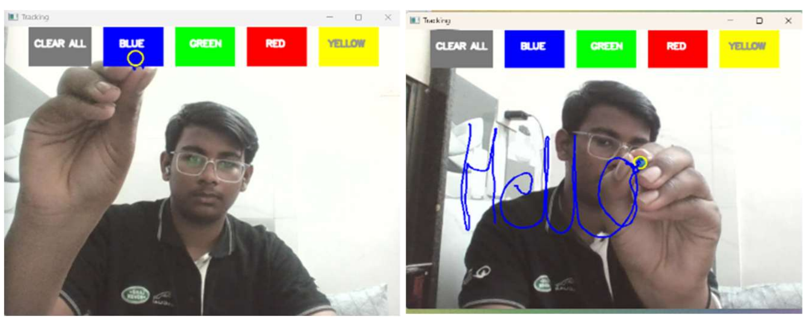

Figure 3 Selecting colour and drawing

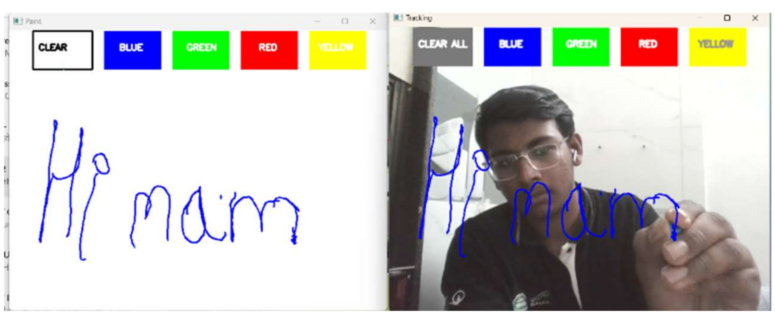

Figure 4. Writing using cap.

C. Erasing with choosing option (clear)

The Air Canvas application lets users switch to erase mode by selecting the eraser tool from the toolbar. It clears all drawing which user inputs.

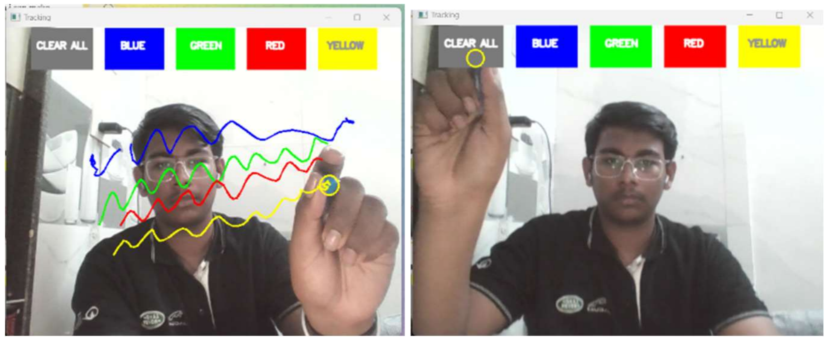

Figure 5: Erasing with choosing option(clear).

This paper aims to create a motion-to-text converter that can be used in smart wearable devices for writing in the air. It works by using computer vision to track finger movements and convert them into text. The generated text can be used for tasks like sending messages or emails. This tool can be especially helpful for the deaf and provides an easy way to communicate while reducing the need for mobile or laptop usage.

VIII. Future Scope of Air Canvas

- The paper aims to produce an effective communication tool that reduces the need for laptops and mobile phones.
- The main goal is to use it in the teaching field to provide a more immersive experience for both online and on-screen teaching.
- Air Canvas can easily be implemented on screen without the need for a mouse or markers.
- It will be used in the design process to create immersive and interactive designs

IX. Conclusion

This paper demonstrates an innovative approach to creating a virtual drawing platform, leveraging computer vision techniques. The application utilizes the webcam to detect a coloured pointer, enabling users to draw on a digital canvas without physical contact. Key features include colour detection for which trackbars allow fine-tuning of HSV colour ranges for accurate pointer recognition. This paper offers real-time interaction with user, they can choose colours (blue, green, red, yellow) or clear the canvas by interacting with a control panel displayed on the live video feed. It provides efficient drawing mechanism for which the system tracks and draws smooth, continuous lines by maintaining a queue of points for each colour. Another feature of this system is dynamic mask creation, the system uses image processing techniques like erosion, dilation, and contour detection to identify the pointer. It proposes a user-friendly design: intuitive controls and real-time feedback make it accessible for interactive applications such as teaching, gaming, or virtual art. this air canvas exemplifies the application of computer vision in creating engaging, touch-free

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