Title: Airbrush: The Digital Finger Painting Experience

Names of group members (in alphabetical order as it appears in iLearn)**:**

1. Md Kaykobad Reza
2. Shahriar M Sakib

Group number (in iLearn)**:** 05

Abstract: The project aims to build a virtual canvas that allows users to draw using a colored marker on their hand. By using a camera to capture a live video stream, the movement of the marker is detected and translated into strokes on virtual canvas. The canvas will have a white background with options to select colors and clear the canvas. The marker stroke color will change upon moving it onto predefined colors, and the canvas will be cleared when the marker is placed on the "Clear All" option. We achieved this by converting each frame into HSV color space and generating a mask using morphological operations to detect the marker position accurately. The movement of the marker is detected by calculating the center point of the contour, which is then used to draw/put color on the canvas. Additionally, our tool provides options for selecting colors and clearing the canvas, enhancing the user experience.

Introduction: The demand for innovative and intuitive digital art tools is on the rise, and this project aims to contribute to this trend by creating a virtual canvas that allows users to draw and paint in real-time using a colored marker on hand. The motivation behind the project is to provide an accessible and user-friendly tool for individuals of all skill levels to express their artistic ideas digitally. The lack of a simple and intuitive virtual canvas tool that enables users to create and modify their art in real-time is the problem that the project is addressing. The project aims to bridge this gap by providing an easy and accessible solution that enables users to express their artistic ideas without any prior knowledge or training. The objectives of the project are to create a virtual canvas with a white background, the option to select colors, and the ability to clear the canvas, using the camera to capture a live video stream, and the movement of the hand as a colored marker to draw on the virtual canvas. The advantages of the project are that it provides an affordable and accessible solution for individuals to express their creativity digitally, an innovative and engaging way to express artistic ideas, and an intuitive and user-friendly interface for users of all skill levels to create their art in real-time. In conclusion, this project is a game-changer in the field of digital art tools, providing a simple, intuitive, and accessible virtual canvas for individuals to express their artistic ideas digitally.

Related work: Object detection and movement tracking in videos is a very common problem that has been studied for a long time which has applications in different fields including surveillance systems, robotics, etc.. Li et. al. [1] proposed a statistical model in HSV space, a multi-criteria decision, a speedup morphological filter, and a connected components labeling algorithm to accurately segment objects in a video under varying lighting and shadows. Summerah [2] presents a strategy to automate the process of recognizing and tracking objects using color and motion in real-time using HSV color space values and OpenCV, resulting in an accuracy of 90% in tracking objects. Ray et. el. [3] proposed a novel approach to an automated visual surveillance system that efficiently detects and tracks moving objects in a video by compensating for pseudo-motion in the background, modeling the background, detecting moving objects through differences, refining object regions, attributing objects, and tracking them with a Kalman filter. Sangale et. al. [4] uses mean shift and particle filters for real-time object detection and tracking in video sequences while Hedayatullah et. al. [5] tracks objects by combining the object's color (using HSV components) and texture features (using Local Binary Pattern). Kang et. al. [6] also uses HSV color space with ROI random sampling and similarity comparison to detect object motion for robot grasping. In this project, we will use object movement tracking using HSV color space and different morphological operations to track the movement of a marker on a variable background and use the path coordinates to draw on a virtual canvas.

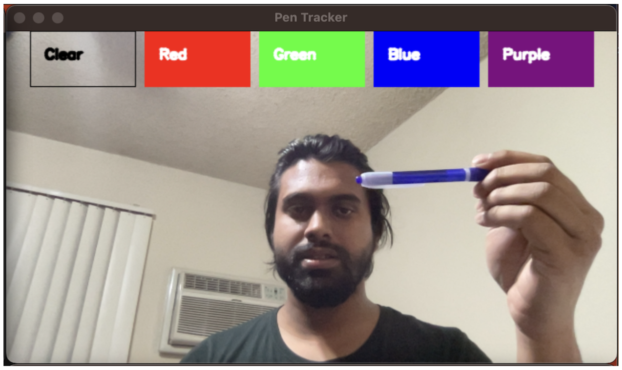
Problem formulation: The problem formulation for our project involves the detection of a moving marker and drawing it's position in a virtual canvas using the selected color. The main challenge we faced was to detect the marker's movement, pinpoint the position in each frame and accurately draw the path on the canvas. The main underlying problem was the detection of a moving object of any shape, size or color and pinpointing its location from a variable background.

To solve this problem, we derived a two-step solution.

- Firstly, we captured the live stream and processed it. We achieved this by capturing the live stream from the camera and converting each frame to the HSV color space. Then we generated a mask using predefined HSV values to detect the marker position and applied morphological operations to the mask to improve the accuracy of the marker detection and tracking. After that we calculated the center of the contour of the marker in each frame.
- Secondly, we focused on drawing on the virtual canvas. We created a white background as the virtual canvas using OpenCV, put the option selection buttons over the canvas, and drew on the virtual canvas by finding the center point of the contour of the regions in the mask that correspond to the marker position. We also performed the selected operation (clear the canvas or change the color) if the marker position goes over any of the option buttons.

Experimental Results: In this section, we will present the procedures and outcomes of different steps of our marker-based virtual canvas project. We have included 6 figures to showcase the different stages of our algorithm and the final result.

Figure 1 shows a single frame from the live stream captured by the camera. This serves as the input to our algorithm. Figure 2 depicts the HSV mask generated for the frame. The mask is generated using predefined HSV values to detect the color of the marker. You can see some small noise and artifacts in the mask image. To remove the small noise and artifacts, we applied erosion, morphological extraction and dilation in sequence. Figure 3 shows the result of applying erosion to the mask to remove small white noises in the mask. Figure 4 depicts the result of applying morphological extraction to the mask to improve the accuracy of marker detection and tracking. Figure 5 shows the result of applying dilation to the mask to fill gaps in the marker contour and produce a smoother boundary. Finally, Figure 6 showcases the drawing on the virtual canvas in real-time based on the center of the contour detected by the mask. We can see that the marker movements are accurately tracked and the drawing is made over the virtual canvas.



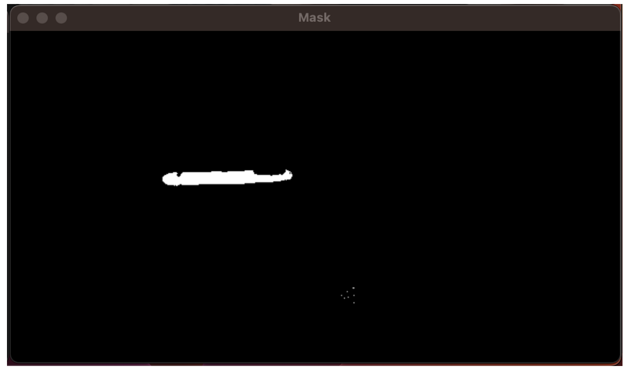
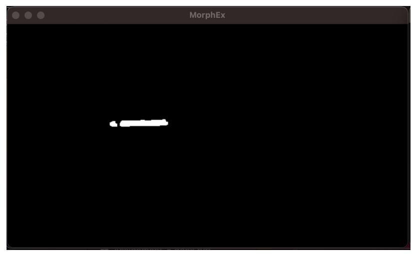


Fig 1: Live stream from the camera

Fig 2: HSV mask



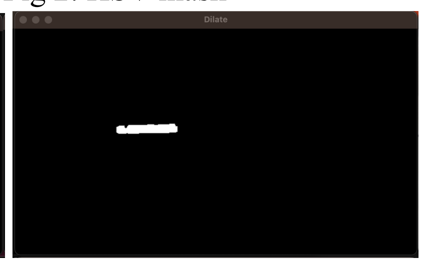


Fig 3: Erosion

Fig 4: Morphological Extraction

Fig 5: Dilation

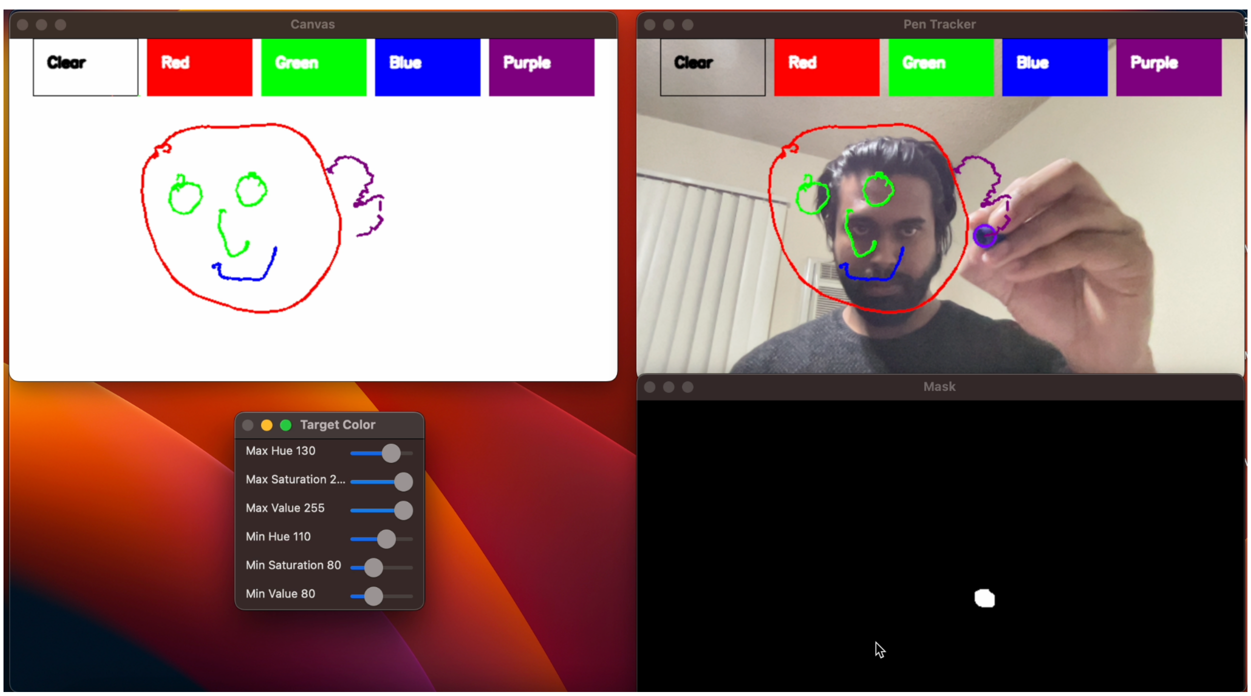


Figure 6: Drawing on the virtual canvas in real-time

Challenges in Marker-based Virtual Canvas: Creating a marker-based virtual canvas presented a few challenges. Firstly, distinguishing the marker from the variable background was difficult due to varying colors and objects in the surroundings. Secondly, accurately tracking the movement of the marker posed a challenge as it involved detecting its speed and direction, especially when it moved unpredictably. Finally, detecting the contour and shape of the marker was also challenging due to variations in its shape, size, orientation, and lighting conditions. We set a target color (can be changed real time using the Target Color selection panel) that can be detected by the system to separate the market from the background and use masking to detect the contour and pinpoint the location. Despite all these challenges, we were able to implement effective solutions to ensure smooth and accurate marker detection of any shape/size/color and movement tracking, resulting in a user-friendly and intuitive virtual canvas tool.

Improvement Scope/ Future Work: As our project progresses, there are several avenues we can explore to improve its functionality and user-friendliness. One potential improvement is adding the feature to change the stroke width of the brush, as currently, the project only supports one stroke width. Additionally, we can work on detecting multiple brushes simultaneously, enabling users to paint with multiple colors at the same time. We can also consider adding the feature to switch between drawing modes and writing modes using hand gestures, making the process more intuitive and user-friendly. Finally, integrating predefined shapes such as circles, rectangles, and triangles can enable users to create more complex drawings with ease. These improvements can enhance the overall experience of using our marker-based virtual canvas and provide users with more tools to express their creativity.

Contributions: Here are the contributions of team members in the project:
Md Kaykobad Reza:

- ❖ Designed the algorithm for the movement tracking and drawing on the virtual canvas.
- ❖ Wrote part of the code (contour detection, center calculation, keeping track of the movement, drawing on the canvas, and performing selected operations) for the virtual canvas using the algorithm.
- ❖ Created the presentation materials for the project.
- ❖ Fixed the bugs that were encountered during the development and testing process.

Shahriar M Sakib:

- ❖ Read multiple papers related to virtual canvases and digital art tools to gather information and inspiration for the project.
- ❖ Wrote part of the code for the virtual canvas (capturing live stream, creating mask, applying morphological operations to generate the final mask) following the algorithm designed by Md Kaykobad Reza.
- ❖ Conducted testing to ensure that the virtual canvas was functioning correctly.
- ❖ Wrote the report detailing the project's methodology and results.

Acknowledgements: This project was motivated by the Air Canvas Project by Jastin Joco. They used RaspberryPi, PiCamera, PiTFT Screen, OpenCV and PyGame for their project. The key difference is that they designed a hardware device and algorithm for hand gesture recognition and digital drawing while we used an existing webcam inbuilt in a laptop and designed an algorithm for moving object tracking via masking.

We used Python, OpenCv and Numpy for this project and used their documentation and tutorials for different parts of the implementation. We acknowledge the use of the following documentations, tutorials and blogs while implementing different parts of the code and solving issues that arose in different stages:

- Numpy basic documentation: https://numpy.org/doc/stable/user/basics.html
- OpenCV Tutorial: https://docs.opencv.org/4.x/d9/df8/tutorial_root.html
- Trackbar Tutorial: https://docs.opencv.org/3.4/da/d6a/tutorial_trackbar.html
- Drawing Over Frames: https://docs.opencv.org/4.x/dc/da5/tutorial_py_drawing_functions.html
- Morphological Operations: https://docs.opencv.org/4.x/d9/d61/tutorial_py_morphological_ops.html
- Camera and Video: https://docs.opencv.org/3.4/dd/d43/tutorial_py_video_display.html
- We took help from different stackoverflow questions for solving some issues.

References: (11pt font size in MLA style)

1. Li, Na & Bu, Jiajun & Chen, C.. (2002). “Real-time video object segmentation using HSV space.” Proceedings / ICIP . International Conference on Image Processing. 2. II-85 . 10.1109/ICIP.2002.1039893.
2. Sheikh Summerah (2021). “An Efficient Real Time Object Tracking Based on HSV Value.” International Journal for Research in Applied Science and Engineering Technology, Vol-9(11) pp. 1197-1203 10.22214/ijraset.2021.38975
3. Ray, Kumar S., and Soma Chakraborty. "An efficient approach for object detection and tracking of objects in a video with variable background." arXiv preprint arXiv:1706.02672 (2017).
4. S. P. Sangale and S. B. Rahane, "Live object monitoring, detection and tracking using mean shift and particle filters" 2016 International Conference on Inventive Computation Technologies (ICICT), Coimbatore, India, 2016, pp. 1-6, doi: 10.1109/INVENTIVE.2016.7830143.
5. Hidayatullah, Priyanto; Zuhdi, Miftahuddin. ”Color-Texture Based Object Tracking Using HSV Color Space and Local Binary Pattern.” International Journal on Electrical Engineering and Informatics; Bandung Vol. 7, Iss. 2, (Jun 2015): 161-174.
6. Kang, Hyun-Chul, Hyo-Nyoung Han, Hee-Chul Bae, Min-Gi Kim, Ji-Yeon Son, and Young-Kuk Kim. 2021. "HSV Color-Space-Based Automated Object Localization for Robot Grasping without Prior Knowledge." Applied Sciences 11, no. 16: 7593. https://doi.org/10.3390/app11167593