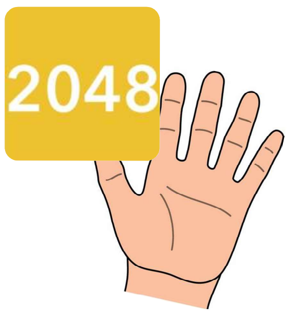
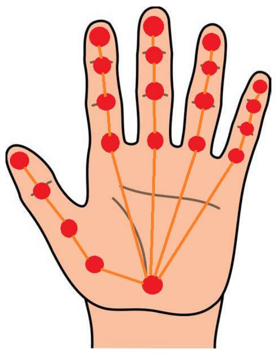


-HAND 2048-



AI LAB PROJECT

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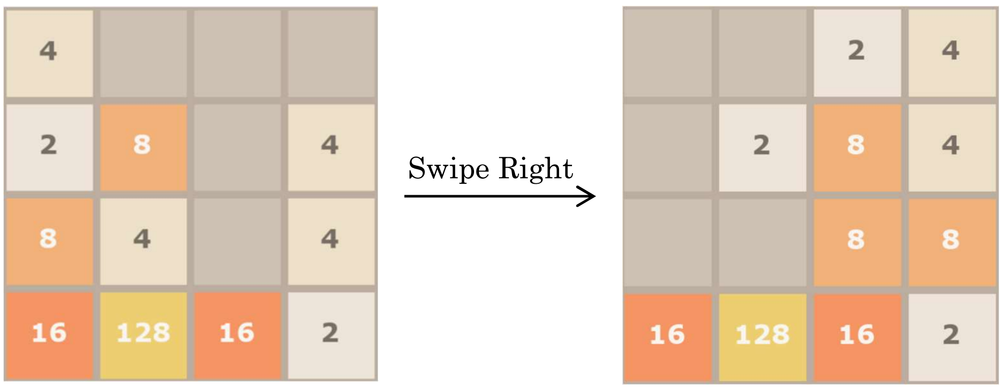
1. INTRODUCTION

With our project, we aimed to combine real-time hand recognition and the popular game 2048, allowing players to use hand gestures captured in real-time by the camera as input. We also implemented a set of commands to interact not only with the game but also with the GUI, offering the possibility to play entirely without the use of a keyboard and mouse.

1.1 Game Description

2048 is a single-player game where the player must combine tiles with the same number to achieve even higher numbers, with the aim of reaching 2048 before running out of space on the grid. The tiles can move in four directions on a 4x4 grid, sliding until they encounter another tile or the grid's edge.



Example of an action in the game

We are aware that there are many projects that employ hand recognition, for instance, in the field of virtual reality, sign language interpretation, or human-computer interaction. Nonetheless, we tried to find a new, original way to exploit this widely known and used model.

2. METHOD

The project consists of three main parts:

1. Hand recognition using MediaPipe and OpenCV
2. Interpretation and translation of gestures into commands
3. Sending commands to the game

2.1 Hand Recognition

In this part of the project, we used the OpenCV and MediaPipe libraries to recognize hands from a video captured in real-time. MediaPipe is an important and powerful library developed by Google, offering real-time tracking solutions for hands and fingers.

Indicating that the model is being used for real-time tracking and not for static images, we started by initializing the MediaPipe hands module, which requires specifying some parameters:

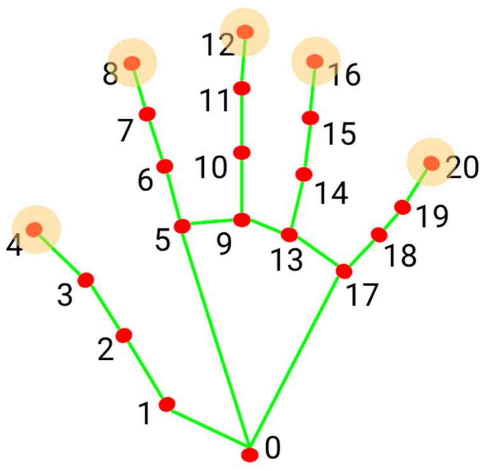
```
with mp_hands.Hands(
        static_image_mode=False,
        max_num_hands=1,
        min_detection_confidence=0.5,
        min_tracking_confidence=0.5) as hands:
```

Indicates that the model is being used for real-time tracking and not for static

The maximum number of hands detected at the same time is 1

Minimum confidence threshold to detect and trace a hand

After capturing the webcam footage via OpenCV, we processed each frame for hand tracking using the **process()** method, which returns information on the detected hands, including the landmarks. The landmark list contains the 21 reference points of the hand, and each point is an (x, y, z) object. The obtained coordinates for each reference point are normalized, meaning they range from 0 to 1, where (0, 0) is the top-left corner of the image and (1, 1) is the bottom-right corner. Since we used a mirrored image to achieve a mirror effect, these coordinates are also mirrored.
Once we have the hand points, we can use them to recognize specific gestures.



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

-List of the 21 hand landmarks. In yellow, those used in the project for gesture recognition-

2.2 Interpretation and Translation of Gestures into Commands

The most challenging part of this project was actually finding unique gestures that could be interpreted by the program as commands and not just simple hand movements. We started by defining the basic movements necessary for the game to understand in which direction to send the tiles. This is done by continuously reading the position of the index finger and, based on the direction the finger moves, converting it into the *Left*, *Right*, *Up*, or *Down* command, which is then sent to the game.

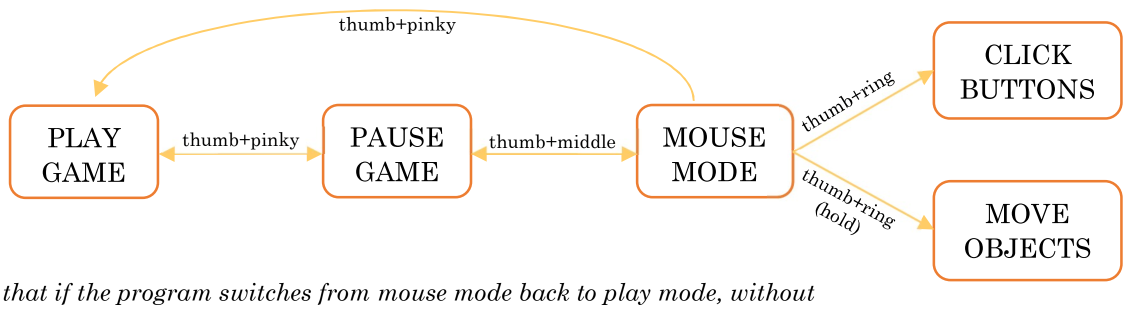
To achieve this, we compared the current position of the index fingertip with its position a moment earlier, and by doing so, while always considering a certain margin of error, we were able to interpret in which direction the hand was moved and thus the game tiles on the grid.

Since our initial idea was to interact not only with the game but also with the GUI, so enabling mouse movement, clicking, and moving windows and objects on the screen, we had to identify unique gestures that would correspond to the various actions mentioned above.

Before implementing this, we decided to add a game pause mode where the hand could be moved freely without movements being interpreted as game commands. We thus associated a gesture with the transition from game state to pause state.

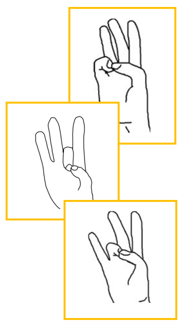
Moreover, since our project aimed not only to interact with the game without the keyboard but also using the entire GUI, we needed a way to distinguish when the index finger would be interpreted as a mouse pointer and when as a reference point for moving the tiles on the grid. We thus identified a second gesture indicating the transition from pause mode to mouse mode, where it would be possible to use the mouse to click and move objects on the screen by defining additional gestures.

-*Flow chart of program states*-



Note that if the program switches from mouse mode back to play mode, without passing through pause mode, it will automatically activate the mouse when it returns to pause mode from play mode.

Below we list all the gestures and corresponding actions:

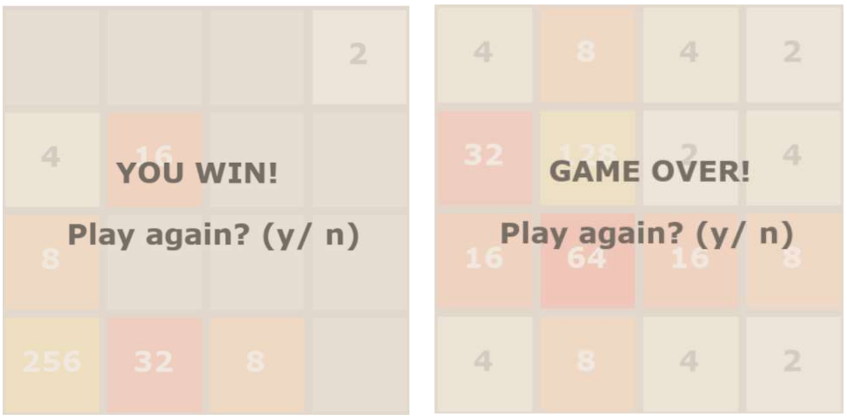


- Thumb tip touches pinky tip: the program enters **PAUSE** mode;
- Thumb tip touches middle finger tip: the program enters **MOUSE** mode, and the index finger, now functioning as a pointer, is marked with a colored circle;
- Thumb tip touches ring finger tip: the program performs a **CLICK**;
- Thumb tip touches ring finger tip for an extended time: the program performs a long click, allowing objects to be moved on the screen.

At the end of the game, when the goal number (which could be 2048, 1024, 512, 256 depending on the game difficulty chosen) is reached, or no more moves are available, the game requires keyboard input (Y or N based on whether the player wants to continue playing a new game or exit). Therefore, we identified two more gestures listed below:

- Thumb tip touches pinky tip: sends the **NO** command to indicate the end of the game;
- Thumb tip touches index tip: sends the **YES** command to indicate the will to continue playing.

Although the first of these gestures is already associated with the pause, there is no problem because, in the final state, the game only interprets the specific movements listed above, ignoring the previous ones.



YOU WIN!

Play again? (y/ n)

GAME OVER!

Play again? (y/ n)

-Victory, Loss, Restart screens -

2.3 Sending Commands to the Game

The 2048 game implemented in Python requires the player to specify the direction to move the tiles by pressing the WASD keys.

To convert the finger movement into actual game movements, we used the *keyboard* library, which simulates key presses using the *press_and_release* method.

Regarding mouse movement, once the program detects the gesture associated with the transition from pause mode to mouse mode, it uses the *pyautogui* library and the *moveTo* method, which moves the mouse pointer to the (x, y) coordinates given by the index fingertip's position at the time of the function call.

To simulate mouse clicks, we used the same library but utilized the *click* method. Furthermore, for moving objects, we used a combination of the *mouseDown* and *mouseUp* methods.

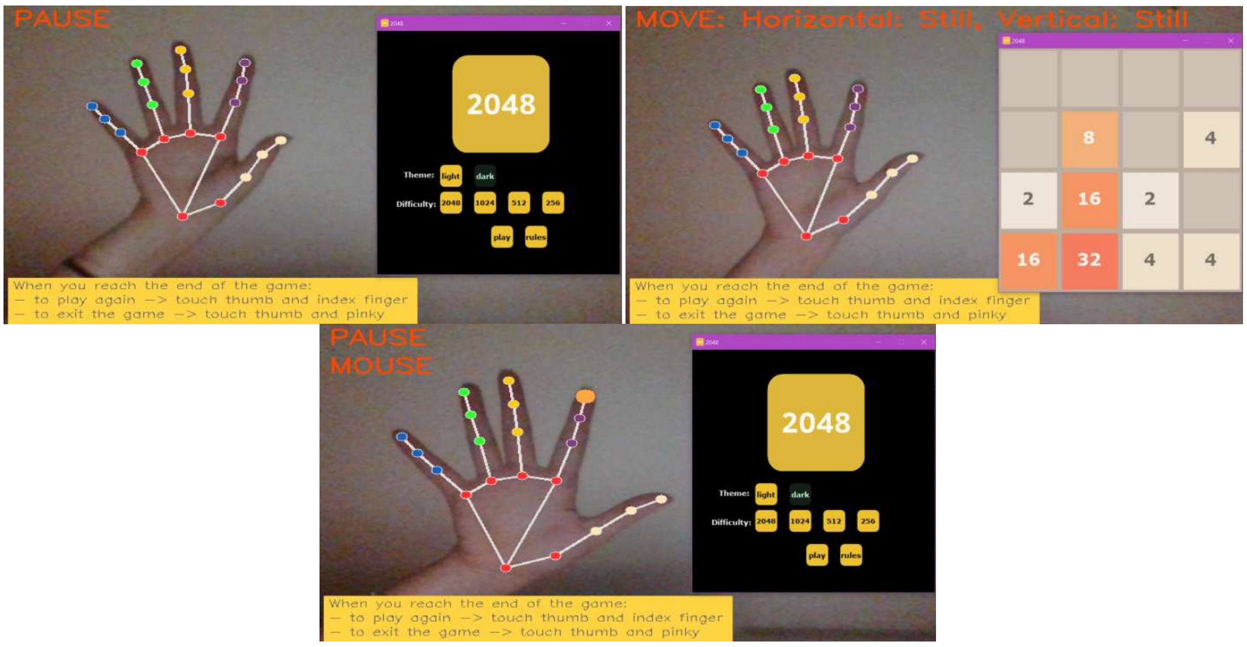
3. RESULTS

3.1 Project Output

The visual output shown to the player when the program is started is:

- Video Capture: real-time video captured from the device's webcam. Text specifying the recognized action will appear overlaid on the video. Additionally, the end-game rules will be displayed at the bottom of the screen to keep them handy at the time of game over or victory.

- 2048 Game: the main menu of the game will appear, where players can choose game options and read the rules.



PAUSE

When you reach the end of the game:
— to play again —> touch thumb and index finger
— to exit the game —> touch thumb and pinky

MOVE: Horizontal: Still, Vertical: Still

When you reach the end of the game:
— to play again —> touch thumb and index finger
— to exit the game —> touch thumb and pinky

PAUSE
MOUSE

When you reach the end of the game:
— to play again —> touch thumb and index finger
— to exit the game —> touch thumb and pinky

-Visual output in the three main parts of the project: Pause, Play and Mouse –

4. CONCLUSION

In conclusion, hand recognition is undoubtedly used for much more significant purposes than a simple computer game. However, we can also confidently say that this small program could easily be used to implement a virtual arcade where, in addition to having the 2048 game, there are many other games that typically use the mouse and WASD keyboard keys. Moreover, this program could be used to operate a computer remotely, since the functions we usually perform on the computer involve using the mouse and keyboard, which we have completely converted to hand use.

5. REFERENCES

For 2048 game implementation in python:
https://github.com/rajitbanerjee/2048-pygame/tree/master?tab=readme-ov-file

Mediapipe documentation:
https://ai.google.dev/edge/mediapipe/solutions/vision/hand_landmarker/python?hl=it