Rubik's Cube Simulator with Gesture Controls

1 Introduction

This project is a **Rubik's Cube Simulator** that allows users to interact with a virtual cube using **hand gestures**. It integrates **OpenGL** for rendering, **OpenCV** for camera input, and **MediaPipe** for hand gesture recognition. The simulator provides a **realistic visualization** of a Rubik's Cube and allows users to **rotate its faces** using predefined gestures.

2 Dependencies

To run this project, install the following Python libraries:

- **OpenCV** (`opencv-python`)
- **MediaPipe** (`mediapipe`)
- **PyOpenGL** (`PyOpenGL`)
- **NumPy** (`numpy`)
- **Pygame** (`pygame`)

Install them using the command:

```
pip install opencv-python mediapipe PyOpenGL numpy pygame
```

3 Working of the Code

3.1 Rendering the Cube

- The cube is represented using **OpenGL**, where each face consists of 9 smaller squares.
- OpenGL functions handle **drawing and coloring** of the cube's faces.
- The camera and lighting are configured to provide a **clear visualization**.

3.2 Capturing Hand Gestures

- **OpenCV** accesses the webcam to capture video frames.
- **MediaPipe** processes the frames to detect **hand landmarks**.
- Specific hand gestures are mapped to **cube rotations**.

3.3 Interpreting Gestures

The detected landmarks are analyzed to recognize movements based on the following hand gestures:

Right Hand:

- **4 fingers closed** → Change the face of the Rubik's Cube on the x-plane (horizontally) to the left.
- **3 fingers closed** → Change the face of the Rubik's Cube on the x-plane (horizontally) to the right.
- **Index finger closed** → First row of the cube shifts left.
- **Index and middle fingers closed** → First row of the cube shifts right.
- **Middle finger closed** → Second row of the cube shifts left.
- **Middle and ring fingers closed** → Second row of the cube shifts right.
- **Ring finger closed** → Third row of the cube shifts left.
- **Ring and pinky fingers closed** → Third row of the cube shifts right.

Left Hand:

- **4 fingers closed** → Change the face of the Rubik's Cube on the y-plane (vertically) up.
- **3 fingers closed** → Change the face of the Rubik's Cube on the y-plane (vertically) down.
- **Index finger closed** → First column goes up.
- **Index and middle fingers closed** → First column goes down.
- **Middle finger closed** → Second column goes up.
- **Middle and ring fingers closed** → Second column goes down.
- **Ring finger closed** → Third column goes up.
- **Ring and pinky fingers closed** → Third column goes down.

3.4 Updating the Cube State

- The program updates the **cube's state** based on recognized gestures.
- Rotations are applied to the appropriate **face or the entire cube**.
- The **new state is rendered** in real time.

4 How to Run the Project

4.1 Ensure the dependencies are installed

```
pip install opencv-python mediapipe PyOpenGL numpy pygame
```

4.2 Run the main script

```
python main.py
```

4.3 Interact with the Cube

- Use **predefined hand gestures** to rotate the cube.
- The **webcam must be enabled** for gesture detection.

5 Future Improvements

- Adding more **intuitive gestures** for better control.
- Enhancing **rendering performance** with shader optimizations.
- Implementing **AI to assist** in solving the cube based on the detected state.