

CONTROLLING LED USING HAND GESTURES INTERDISCIPLINARY PROJECT

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Technology degree in Information Technology

by

JEGADEESH K (41120076)



DEPARTMENT OF INFORMATION TECHNOLOGY

SCHOOL OF COMPUTING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

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MAY 2024



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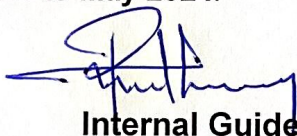
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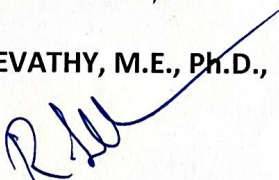
BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **JEGADEESH K (41120076)** who carried out the project entitled **"Controlling LED using Hand Gestures"** under my supervision from **January 2024 to May 2024**.



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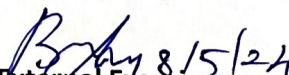
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DECLARATION

I, **Jegadeesh K** hereby declare that the Project Report entitled "**Controlling LED using Hand Gestures**" done by me under the guidance of Dr. **S. REVATHY, M.E., Ph.D.**, is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in **Information Technology**.

DATE: 08-05-24



PLACE: CHENNAI

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ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to **Board of Management** of SATHYABAMA **INSTITUTE OF SCIENCE AND TECHNOLOGY** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

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I wish to express my thanks to all Teaching and Non-teaching staff members of the **Department of Information Technology** who were helpful in many ways for the completion of the project.

CERTIFICATE OF COMPLETION



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CERTIFICATE FOR INTERNSHIP

TO WHOMSOEVER IT MAY CONCERN

This is to Certify that **K JEGADEESH (Reg No: 41120076)** student of Sathyabama Institute of Science and Technology, B. Tech Information Technology, has successfully completed the Internship at Hackwit Technologies from 22nd January to 30th January 2024.

During the internship, **K JEGADEESH** has closely worked as a part of the **Internet of Things** by carrying out the project entitled "**Controlling LED using Hand Gestures**".

He demonstrated good developing and learning skill with self-motivated attitude to learn new things. His contribution to implement the Internet of Things was good. We wish him all the best for his future endeavors.

Best Regards,

A handwritten signature in black ink, appearing to be 'Ravikumar S', is written over a faint, light blue circular stamp.

Ravikumar S
CEO & Managing Director
Hackwit Technologies Pvt Ltd

CERTIFICATE OF COMPLETION



ABSTRACT

Hand gesture-controlled LED system allows users to manipulate the illumination of LEDs using simple hand gestures. Our paper presents a hand gesture-controlled LED system enabling users to manipulate LED illumination through simple gestures. The system integrates a gesture recognition module, a microcontroller unit, and an LED array. Using computer vision and machine learning, the module detects and classifies gestures in real-time, translating them into commands for the microcontroller to adjust LED intensity. Through experiments and user studies, we demonstrate the system's accuracy, responsiveness, and user satisfaction, highlighting its potential for intuitive human-computer interaction in various applications. Throughout the project, key components such as the hand tracking module, gesture recognition module, and LED control module work synergistically to accurately interpret user gestures and translate them into corresponding LED control actions. Real-time feedback mechanisms enhance user awareness and responsiveness, ensuring a smooth and intuitive interaction with the LED display. The versatility and adaptability of the system allow for a wide range of applications, including interactive displays, entertainment systems, educational tools, and assistive technologies. By providing customization options and personalization features, users can tailor their experience to suit their preferences and needs. Gesture control taps into natural human behavior, making it easy for users to interact with the LED system without the need for complex interfaces or input devices.

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LIST OF ABBREVIATIONS

ABBREVIATION	EXPANSION
LED	- Light Emitting Diode
BB	- Bread Board
3D	- Three Dimensional
CV2	- Computer Vision
SDK	- Software Development Kit
UI	- User Interface
CPU	-Central Processing Unit
LOD	- Level of Detail

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CHAPTER 1

INTRODUCTION

Gesture control taps into natural human behavior, making it easy for users to interact with the LED system without the need for complex interfaces or input devices. By providing a hands-free and gesture-based control mechanism, the system offers an enhanced user experience, particularly in scenarios where manual input or physical controls may be impractical or cumbersome. The system can be programmed to recognize a wide range of gestures, allowing for customizable control options tailored to different user preferences and applications.

Hand gesture-controlled LED systems can seamlessly integrate into various environments and applications, including smart homes, interactive displays, entertainment systems, and public spaces, enhancing their functionality and user engagement. Hand gesture-controlled LED system enabling users to manipulate LED illumination through simple gestures. The system integrates a gesture recognition module, a microcontroller unit, and an LED array. Using computer vision and machine learning.

The module detects and classifies gestures in real-time, translating them into commands for the microcontroller to adjust LED intensity, color, and pattern. Through experiments and user studies, we demonstrate the system's accuracy, responsiveness, and user satisfaction, highlighting its potential for intuitive human-computer interaction in various applications.

This project seeks to explore the potential of gesture recognition technology in enhancing user interaction with electronic devices and IoT systems. By leveraging sensors to detect and interpret hand gestures, the system aims to provide a hands-free method for controlling LEDs, offering convenience, accessibility, and novel user experiences. Additionally, the project aims to investigate the feasibility of integrating gesture-based control into various applications, such as smart homes, wearable devices, interactive installations, and educational tools.

The Arduino IDE is a cross-platform application that allows users to write and upload code to Arduino boards. It features a text editor for writing code, a toolbar for managing projects and uploading sketches, and a serial monitor for debugging and communication with the Arduino board. The IDE supports the Arduino programming language, which is based on C/C++, making it easy for beginners to learn and use.

Arduino programming involves writing sketches, which are programs written in the Arduino programming language. Sketches consist of two main functions: `setup()` and `loop()`. The `setup()` function is called once when the Arduino board starts up, while the `loop()` function runs continuously in a loop until the board is powered off or reset. Arduino

A user-friendly interface to visualize detected hand gestures and provide feedback to the user. This could include displaying recognized gestures on a screen or providing auditory or visual feedback through connected devices. Optimize the system for real-time performance to ensure minimal latency between hand gesture detection and device control. This involves efficient processing of video data, as well as optimizing communication with the Arduino board.

1.1 PROBLEM STATEMENT:

In many human-computer interaction scenarios, there is a growing demand for intuitive and hands-free control methods, particularly in environments where traditional input devices may be impractical or cumbersome. This project aims to address this need by developing a system that allows users to control LEDs or lighting systems using hand gestures.

The primary objective is to design and implement a robust gesture recognition system that can accurately interpret hand movements captured by a camera in real-time and translate them into commands to control the illumination of LEDs. Key challenges include developing algorithms for hand gesture detection and classification, ensuring robustness against variations in lighting conditions and hand poses, and minimizing latency to provide responsive control. Additionally, the system should be user-friendly and accessible to individuals with diverse hand morphologies and abilities.

The proposed LED control system has the potential to enhance user experience in various applications, such as smart homes, interactive displays, and entertainment systems, while also offering energy-efficient and environmentally friendly lighting solutions.

Intensive processing requirements can result in increased latency, causing delays in recognizing and responding to hand gestures. Intensive computational tasks associated with hand gesture recognition can generate heat, potentially leading to thermal throttling and reduced performance of the device. Over time, prolonged usage at high temperatures can degrade the device's components and shorten its lifespan.

1.2 OBJECTIVES

To develop a hand gesture recognition system that interacts with an Arduino board. This system aims to detect specific hand gestures captured by a webcam or camera, process the data using computer vision techniques, and then control external devices or perform actions based on the recognized gestures.

To Develop the Hand Gesture Detection:

Develop algorithms to accurately detect and recognize hand gestures in real-time from live video streams or images.

To Integrate with Arduino:

Interface the hand gesture recognition system with an Arduino board using PyFirmata, allowing for bi-directional communication between the Python code and the Arduino hardware.

To Control External Devices:

Implement functionality to control external devices, such as LEDs, motors, or actuators, based on the detected hand gestures. This could involve adjusting the brightness of an LED, moving a robotic arm, or triggering other actions.

To develop User Interaction:

Design a user-friendly interface to visualize detected hand gestures and provide feedback to the user. This could include displaying recognized gestures on a screen or providing auditory or visual feedback through connected devices. Optimize the system for real-time performance to ensure minimal latency between hand gesture detection and device control. This involves efficient processing of video data, as well as optimizing communication with the Arduino.

CHAPTER 2

METHODOLOGY

The systematic approach or set of principles, procedures, and techniques used to conduct research, solve problems, or achieve specific objectives in a particular field of study or practice. The outlines and the steps of processes involved in carrying out in project experiment, investigation, analysis in a structured and organized manner has been explained in this chapter thoroughly.

2.1 PROJECT REQUIREMENTS

Windows/ Mac/ Linux System

Windows, Mac or Linux based operating system for personal computers or any other internet of things devices. Integrating the hardware and software components into a cohesive system and conducting thorough testing to ensure functionality, accuracy, and reliability. Testing should involve evaluating the system's performance under various conditions and refining algorithms or parameters as needed.

PYCHARM

Integrated Development Environment (IDE):

PyCharm offers a powerful IDE specifically designed for Python development, providing features such as code completion, syntax highlighting, and code navigation to streamline the development process.

ARDUINO

Arduino boards are designed to be accessible to beginners and experts alike, providing a simple yet powerful platform for building interactive projects. With a wide range of boards available, from the beginner-friendly Arduino Uno to more advanced models like the Arduino Mega or Arduino Due, there's an Arduino board suitable for every project.

BREAD BOARD

A breadboard is a fundamental tool used in electronics prototyping and experimentation. It provides a convenient way to build and test circuits without the need for soldering.

A breadboard is a rectangular plastic board with numerous holes arranged in a grid pattern. These holes are used to insert electronic components such as resistors, capacitors, LEDs, and integrated circuits (ICs). The holes are typically connected internally in a predefined manner, allowing components to be interconnected to form circuits.

Breadboards typically consist of two main sections: the main area and the power rails. The main area is where components are inserted and connected to each other. It consists of rows of holes, usually labeled with numbers and letters for easy reference. The power rails are long strips of conductive metal that run along the edges of the breadboard. They are used to provide power (usually 5 volts and ground) to the components on the breadboard.

WIRES

Jumper Wires:

Jumper wires are commonly used for making temporary connections between electronic components on breadboards, prototyping boards, or circuit modules. They come in different lengths, colors, and connector types (such as male-to-male, male-to-female, and female-to-female) to facilitate easy wiring and prototyping.



Fig 1.1: JUMPER WIRES

USB Cables:

USB cables are commonly used for connecting IoT devices, microcontrollers, and peripherals to computers, power sources, or other USB-enabled devices. They come in various types, including USB-A to USB-B, USB-A to USB-C, and USB-C to USB-C, with different connector types on each end.

Power Cables

Power cables are used to supply electrical power to IoT devices, microcontrollers, sensors, and actuators. They come in different types and connector formats, including barrel connectors, screw terminals, and JST connectors, depending on the power requirements of the device

LED

Compact Size:

LEDs are available in various sizes and form factors, ranging from miniature surface-mount LEDs to high-power LEDs used in lighting applications. LEDs are available in a wide range of colors, including red, green, blue, white, and multicolor RGB LEDs. The color of the emitted light depends on the semiconductor material and the doping elements used in the LED.

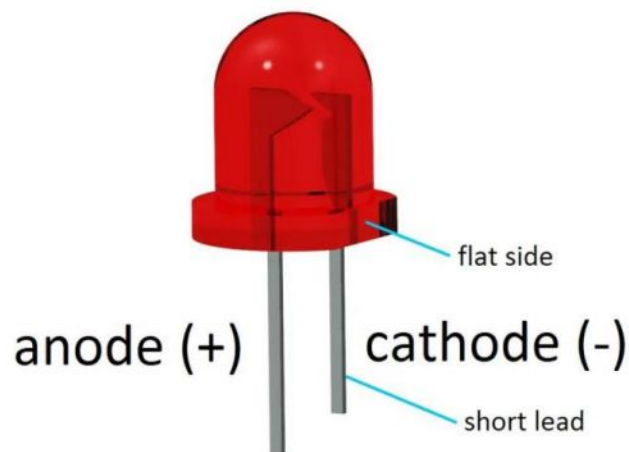


Fig 1.2: LED (LIGHT EMITTING DIODE)

2.2 PROPOSED SYSTEM ARCHITECTURE

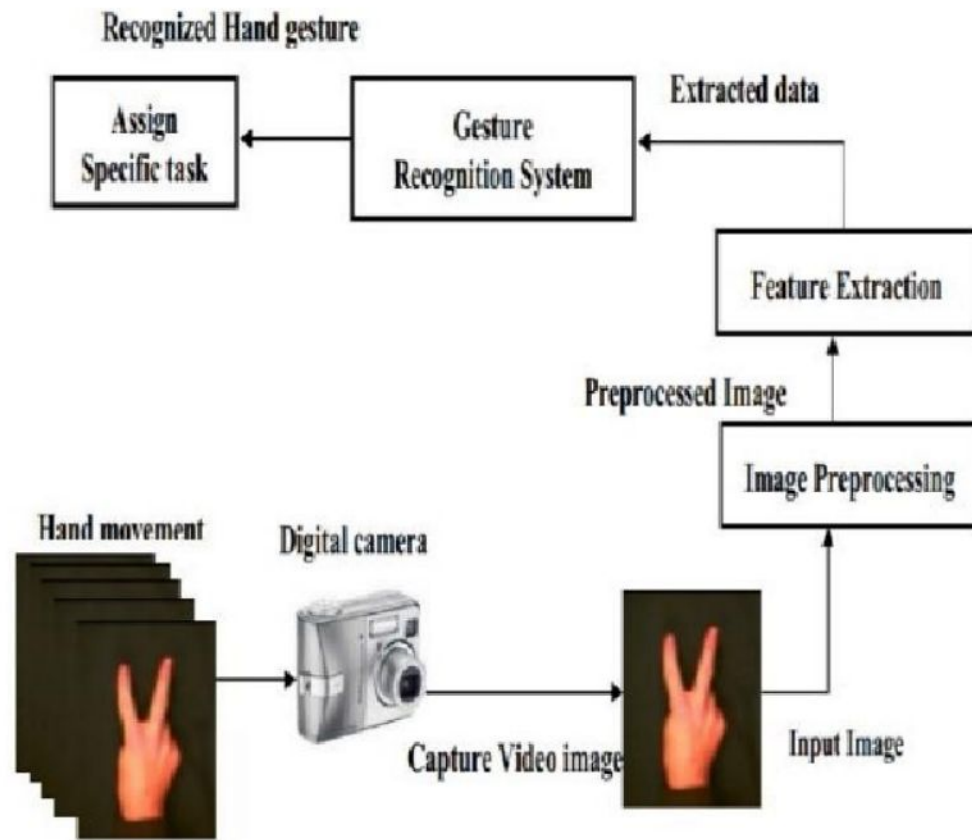


Fig 2.1: PROPOSED GESTURE ARCHITECTURE

The following steps are used to describe Fig 2.1 Gesture Architecture:

1. Hand Movement:

Hand movement recognition refers to the process of detecting and interpreting the movements of a person's hand or hands using sensors, cameras, or other sensing devices.

2. Camera Capture:

Computer vision techniques use cameras or depth sensors to capture images or depth maps of hand movements. Image processing algorithms analyze the captured data to detect hand keypoints, track motion trajectories, and recognize gestures.

3. Image Preprocessing:

Image preprocessing is a critical step in computer vision tasks, including hand movement recognition, as it helps enhance the quality of images, extract relevant features, and improve the performance of subsequent processing steps, such as object detection and classification.

4. Data Extraction:

Extracting data from a camera involves capturing images or video frames using the camera sensor and then processing the acquired data to extract relevant information.

5. Gesture Recognition:

Gesture recognition algorithms analyze the temporal sequence of hand movements to recognize predefined gestures or gestures learned from data.

6. Assigning Task:

Pattern matching algorithms compare observed hand movements with templates or models of known gestures to determine the closest match. Techniques such as dynamic time warping (DTW), template matching, and shape analysis are used for pattern recognition.

7. Feedback and Visualization:

This module provides feedback to the user to indicate the system's status and responses to detected gestures. It may include visual or auditory feedback, such as displaying messages or animations on a screen or emitting sounds or alerts.

2.3 ALGORITHM

STEP 1 - Setup Arduino:

Connect your Arduino board to your computer using a USB cable. Open the Arduino IDE and upload the Standard Firmata sketch to your Arduino board.

STEP 2 - Install Python Libraries:

Ensure you have Python installed on your computer. You can download it from the official Python website. Install the pyfirmata library, which allows Python to communicate with the Arduino board.

STEP 3 - Write Python Code:

Open a text editor or an IDE and start writing your Python script. Import the pyfirmata module at the beginning of your script. Establish a connection to the Arduino board using the pyfirmata Arduino class.

STEP 4 - Access Arduino Pins:

Once the connection is established, you can access and control the digital and analog pins of the Arduino board from your Python script.

STEP 5 - Implement Functionality:

Write the main logic of your Python script, defining how you want to interact with the Arduino board. This could include reading sensor data, controlling actuators, or responding to external events.

STEP 6 - Distance Formula:

$$\sqrt{(X2 - X1)^2 + (Y2 - Y1)^2} \text{ ----- eq 2.1}$$

To measure the distance between your fingers using a distance formula, you'll need to first detect the positions of your fingers using a suitable method such as computer vision. Once you have the coordinates of the fingertips, you can then calculate the distance between them using the Euclidean distance formula.

STEP 7 - Run Python Script:

Save your Python script with a .py extension. Open a terminal or command prompt, navigate to the directory containing your script, and run it

STEP 8 - Finger Detection:

Use a computer vision library such as OpenCV to detect and track the positions of your fingertips in an image or video frame.

You can use techniques like hand detection, keypoint detection, or object tracking to identify the fingertips.

STEP 9 - Coordinate Extraction:

Extract the coordinates (x, y) of the detected fingertips from the image or video frame. You'll typically have the coordinates of each fingertip, allowing you to calculate the distances between them.

STEP 10 - Test and Debug:

Test your Python script to ensure it interacts correctly with the Arduino Board.

Repeat for Multiple Finger Pairs:

If you're interested in measuring the distances between multiple finger pairs e.g., between index and middle finger, middle and ring finger, etc. repeat the distance calculation for each pair of fingertips.

Visualization or Analysis:

By following these steps and leveraging computer vision techniques along with the Euclidean distance formula, you can accurately measure the distances between your fingers in real-time. This approach is commonly used in applications such as gesture recognition, sign language interpretation, and virtual reality interactions.

2.4 FLOW DIAGRAM

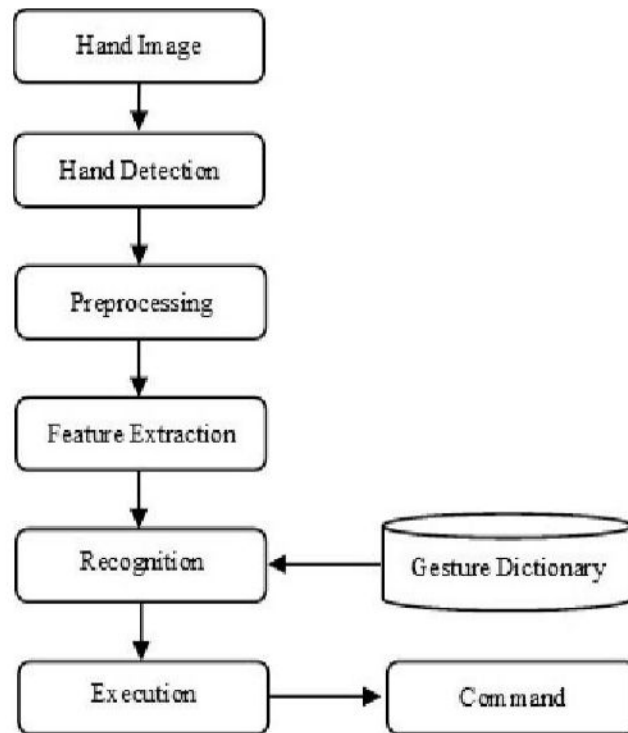


Fig: 2.2: HAND GESTURE CONTROLLED STRUCTURE

The following steps are used to describe the fig 2.6 Flow Diagram:

- 1) First the user shows hand and camera captures hand as image.
- 2) Hand is being detected in camera where it should be processed.
- 3) Images which is captured is preprocessed inside computer
- 4) The finger indexes features are being extracted from user fingers.
- 5) Fingers are being recognized as thumb, fore finger, middle finger, ring finger, little finger.
- 6) The commands of giving output is executed based on analysis.

2.5 MODULES

2.5.1 HAND TRACKING MODULE

1. Initialize Hand Detection Module:

Load a pre-trained hand detection model or module (e.g., MediaPipe Hands) that is capable of detecting hands in images or video frames.

2. Capture Video Frames:

Initialize a video capture device (e.g., webcam) to capture video frames in real-time.

3. Read Frame:

Continuously read frames from the video capture device.

4. Preprocess Frame (Optional):

Preprocess the frame if necessary (e.g., resize, convert to grayscale) to improve processing efficiency or accuracy.

5. Detect Hands:

Pass the preprocessed frame to the hand detection module to detect hands within the frame. The detection module should return the coordinates or bounding boxes of detected hands.

6. Extract Features:

For each detected hand region, extract relevant features such as hand keypoints (e.g., finger tips, palm center) or hand landmarks.

7. Track Hand Movement:

If tracking hand movement across frames is required, use motion estimation techniques (e.g., optical flow) to predict the trajectory of hand movements and update the hand positions.

2.5.2 GESTURE RECOGNITION MODULE:

The gesture recognition module processes the hand key points provided by the hand tracking module to recognize specific hand gestures. It may employ algorithms such as machine learning classifiers or rule-based systems to map detected hand poses or movements to predefined gestures

1. Capture Video Frames: Video frames are continuously captured from a video source (e.g., webcam) to provide a stream of images for hand detection and gesture recognition. Initialize a video capture device using OpenCV's Video Capture class to access the video stream from the camera.

2. Read Frame: Read each frame from the video stream to process the video data and perform hand tracking and gesture recognition operations. Continuously read frames from the video capture device using the read() function of the Video Capture object.

3. Detect Hands: Detect hands within each video frame using the hand tracking module. The detection process identifies regions of interest (ROIs) or bounding boxes containing hand shapes or hand-like features. Pass each frame to the hand tracking module to detect and localize hands. Retrieve the coordinates or bounding boxes of the detected hands.

4. Extract Hand Features: Extract relevant features from the detected hand regions, such as hand key points (e.g., finger tips, palm center) or hand landmarks. These features provide descriptive information about the hand's shape, pose, and movement.

2.5.3 LED CONTROL MODULE:

1. Initialize LED Control Module:

Set up the necessary hardware components to control the LEDs, such as an Arduino board connected to LEDs via GPIO pins.

2. Connect to Arduino Board:

Establish a connection between the Python script and the Arduino board using a serial communication interface (e.g., PySerial).

3. Define LED Pins:

Define the GPIO pins on the Arduino board to which the LEDs are connected. Assign unique identifiers to each LED pin for easy reference.

4. Set Pin Modes:

Configure the defined GPIO pins as output pins on the Arduino board to enable LED control.

5. Initialize LED States:

Set the initial states of the LEDs (e.g., ON or OFF) based on the application requirements.

6. Read User Input:

Continuously monitor user input (e.g., keyboard input, sensor readings) to determine LED control actions.

7. Control LEDs:

Based on the user input or external triggers, control the states of the LEDs by sending commands to the Arduino board via serial communication.

2.5.4 FEEDBACK MODULE

A feedback and visualization module is a software component or library that facilitates the presentation of data and feedback to users in a meaningful and understandable manner. It enables the visualization of complex information, analysis results, system status, and user interactions through graphical representations, charts, diagrams, and other visual elements.

1. Data Visualization:

Interactive Features: Supports interactive features like zooming, panning, tooltips, and data point selection to enhance user engagement and exploration of data.

2. Real-time Feedback:

Enables real-time updating and rendering of visualizations to reflect changes in data or system status dynamically. Live Supports live data streaming and visualization, allowing users to monitor and analyze data as it arrives in real-time.

3. User Interface Components:

Includes widgets and controls for displaying feedback elements such as progress bars, status indicators, alerts, notifications, and messages. Offers dashboard components for organizing and presenting multiple visualizations and feedback elements in a unified interface.

4. Data Analysis and Insights:

Data Aggregation: Aggregates and summarizes data to provide insights and trends through visual representations like averages, totals, distributions, and trends. Performs statistical analysis and calculations to generate visualizations such as histograms, box plots,

and probability distributions for data exploration.

5. Accessibility and Usability:

Ensures accessibility by providing features like screen reader compatibility, keyboard navigation, and high-contrast modes for users with disabilities. Implements responsive design principles to optimize visualizations for different screen sizes and devices, enhancing usability across desktop and mobile platforms.

6. Export and Sharing:

Offers options to export visualizations and feedback elements in various formats such as images, PDFs, or CSV files for sharing and collaboration. Supports embedding visualizations and feedback components in external applications, websites, or reports using embeddable code or APIs.

7. Integration and Extensibility:

Integrates with data sources and APIs to retrieve and visualize data from databases, APIs, files, and streaming sources. Provides APIs and frameworks for extending and customizing visualizations, feedback components, and functionality to meet specific application requirements.

8. Performance and Scalability:

Optimizes rendering performance and efficiency to handle large datasets and complex visualizations without compromising responsiveness. Implements caching and preprocessing techniques to minimize data processing overhead and improve performance.

A feedback and visualization module empowers developers to create informative, interactive, and visually appealing feedback mechanisms and visualizations that enhance user understanding, decision-making, and engagement with software applications.

2.6 DEVELOPMENT AND DEPLOYMENT SETUP

1. DEVELOPMENT ENVIRONMENT:

Arduino, Standard Firmata, pyfirmata, Pycharm, Python to be installed for developing Hand gesture recognition software for coding.

Breadboard, LED, wires, resistor, Arduino to be acquired to deploy hardware setup.

2. DEPLOYED BOARD SETUP:

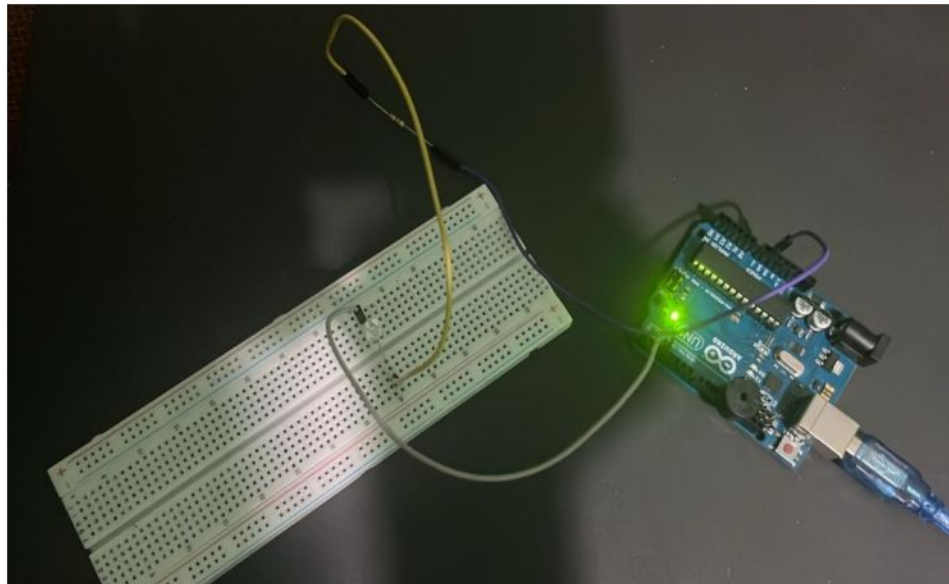


Fig 2.3 DEPLOYED BOARD SETUP

Fig 2.3 shows connections connected from board – Arduino to get the controls from gestures to be responded. Where the gestures from system camera is recognized and sends the controller to Arduino a microcontroller.

3. STANDARD FIRMATA

Standard Firmata is uploaded to the Arduino board using the Arduino IDE or another compatible development environment. Once uploaded, the Arduino board runs the Firmata firmware, establishing a serial communication link with the computer. Software running on the computer (e.g., Python script, JavaScript application) communicates with the Arduino using the Firmata protocol, sending commands and receiving responses.

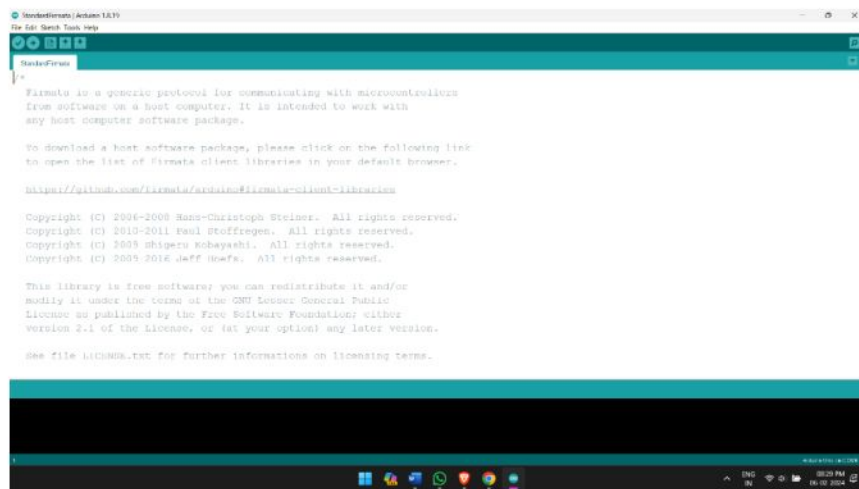
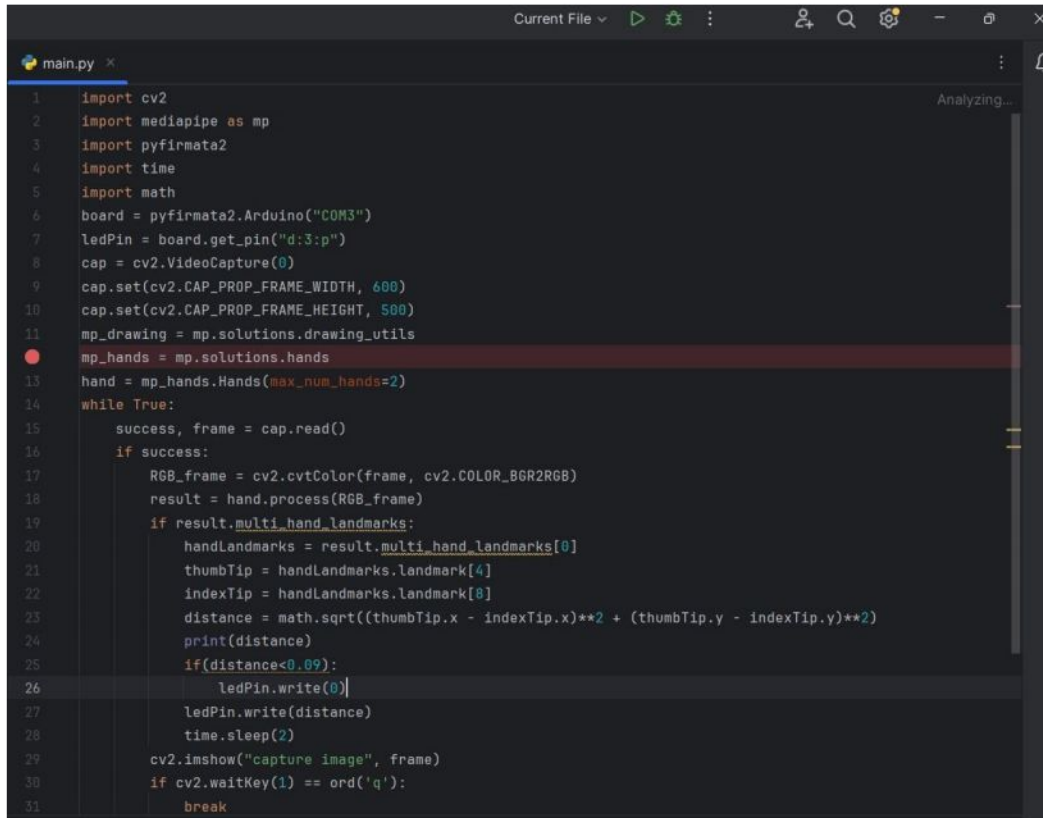


Fig 2.4 STANDARD FIRMATA

The Fig 2.4 Standard Firmata is a firmware sketch for Arduino boards that allows them to communicate with software running on a computer. It establishes a standardized protocol for bidirectional communication, enabling the computer to control and monitor the Arduino's digital and analog pins, PWM outputs, servo motors, and other features remotely.

4. PYTHON CODE



```
1 import cv2
2 import mediapipe as mp
3 import pyfirmata2
4 import time
5 import math
6 board = pyfirmata2.Arduino("COM3")
7 ledPin = board.get_pin("d:3:p")
8 cap = cv2.VideoCapture(0)
9 cap.set(cv2.CAP_PROP_FRAME_WIDTH, 600)
10 cap.set(cv2.CAP_PROP_FRAME_HEIGHT, 500)
11 mp_drawing = mp.solutions.drawing_utils
12 mp_hands = mp.solutions.hands
13 hand = mp_hands.Hands(max_num_hands=2)
14 while True:
15     success, frame = cap.read()
16     if success:
17         RGB_frame = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
18         result = hand.process(RGB_frame)
19         if result.multi_hand_landmarks:
20             handLandmarks = result.multi_hand_landmarks[0]
21             thumbTip = handLandmarks.landmark[4]
22             indexTip = handLandmarks.landmark[8]
23             distance = math.sqrt((thumbTip.x - indexTip.x)**2 + (thumbTip.y - indexTip.y)**2)
24             print(distance)
25             if distance < 0.09:
26                 ledPin.write(0)
27                 ledPin.write(distance)
28                 time.sleep(2)
29                 cv2.imshow("capture image", frame)
30                 if cv2.waitKey(1) == ord('q'):
31                     break
```

Fig 2.5 PYTHON CODE

The Fig 2.5 the python code explains that hand gesture recognition package, camera package, math, and time has been imported. The pin has been initialized to 3 in Arduino and the Arduino com has been selected to COM 3. The fingers in hand has been recognized and stored in as thumb and index finger tips.

The tips have a landmark code as 4 for thumb and 8 for index finder. The distance between thumb and index finger is calculated by distance formula square rooting the sum of difference squares. The distance is then proposed in led pin. write(distance) where the current passing in 3rd pin should be the rate in distance. So where the current passing is fluctuated by the finger distance the LED also starts to emit in a particular intensity variation.

CHAPTER 3

RESULTS AND DISCUSSION

The results chapter of document serves as a bridge between the previous chapters, such as the literature review, methodology, and data analysis, and the presentation of the findings. It sets the stage for what the reader can expect in terms of the results of the study.

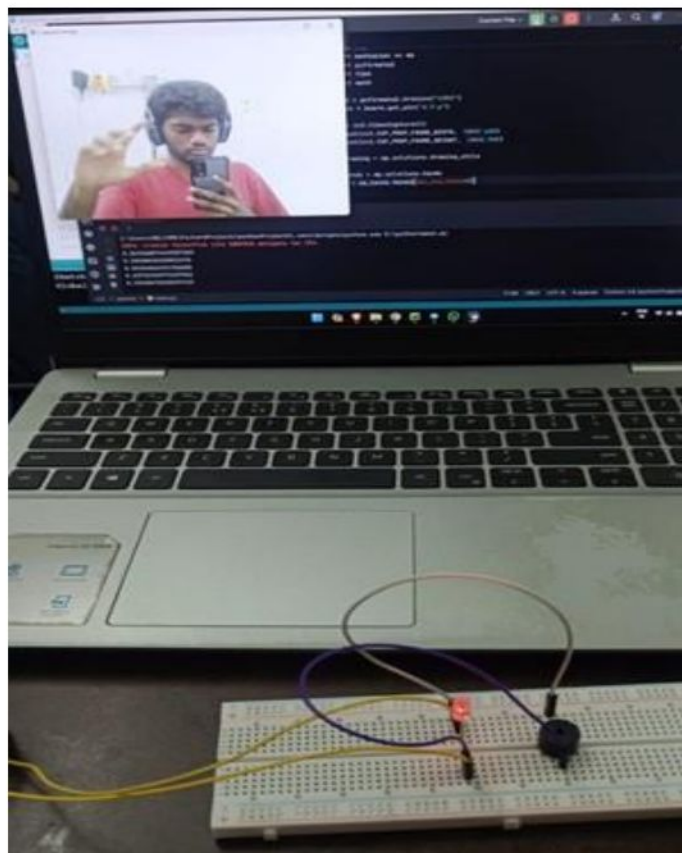


Fig 3.1 LED EMITTING LIGHT ACCORDING TO GESTURES

The Fig 3.1 recognizes hand gestures and emits lights according to movements

Gesture Recognition: Once hand gestures are detected or tracked, gesture recognition algorithms classify these gestures into predefined categories. Classification approaches include rule-based methods, template matching, Hidden Markov Models (HMMs), and machine learning models like Support Vector Machines (SVMs), Random Forests, and deep neural networks.

Traditional Computer Vision Techniques: Traditional computer vision techniques use methods such as color segmentation, edge detection, contour analysis, and template matching to detect hands and recognize gestures. These methods often rely on hand-crafted features and heuristics to distinguish between different gestures. Brightness dynamically as the user performs different gestures. Display live statistics or metrics related to hand gesture.

Customizable Lighting Effects: Users can personalize their lighting experience by defining custom gestures and mapping them to specific lighting effects or scenes, allowing for creative expression and customization according to individual preferences.

Enhanced User Experience: Users will benefit from a more intuitive and engaging way to control LED lighting, leading to increased satisfaction and enjoyment in interacting with the system. Provide visual feedback to the user to indicate successful hand gesture recognition. For example, display a message or an icon on the screen when a specific gesture is recognized. Highlight the detected hand landmarks or draw bounding boxes around the detected hand regions to make it visually clear to the user.

3.1 PERFORMANCE ANALYSIS

Table 3.1 Gesture Recognition Accuracy

S.No	Gesture	Accuracy percentage
1	Gesture 1	95%
2	Gesture 2	87%
3	Gesture 3	92%
4	Gesture 4	96%
5.	Gesture 5	90%

In Table 3.1 the accuracy measures of each trial, where from series of 1 to 5 there are 5 trials made, and the measures varies according to each time the gesture recognition happens

Innovative Interaction Paradigm: The project showcases an innovative approach to human-computer interaction by integrating gesture recognition technology with LED lighting systems, demonstrating the potential for novel interaction paradigms in various applications.

Led Control Response Time (In Milliseconds)

Table 3.2 RESPONSE TIME OF LED

S.No	Trial	LED Control Response Time (in milliseconds)
1	Trial1	120
2	Trial 2	115
3	Trial 3	122
4	Trial 4	118
5.	Trial 5	121

In Table 3.2 the response time from gesture recognition to led emitting time has been displayed. Where the trial 1 has response time of 120ms, trial 2 has 115ms, trial 3 has 122ms, trial 4 has 118ms, trial 5 has 121ms response time.

System Response Time: The time taken by a computer system or software application to process a user's request and generate a response. This includes processing time, network latency, and any delays caused by system overhead.

User Response Time: The total time elapsed between a user initiating an action (e.g., clicking a button) and receiving feedback.

Power Consumption Measurements

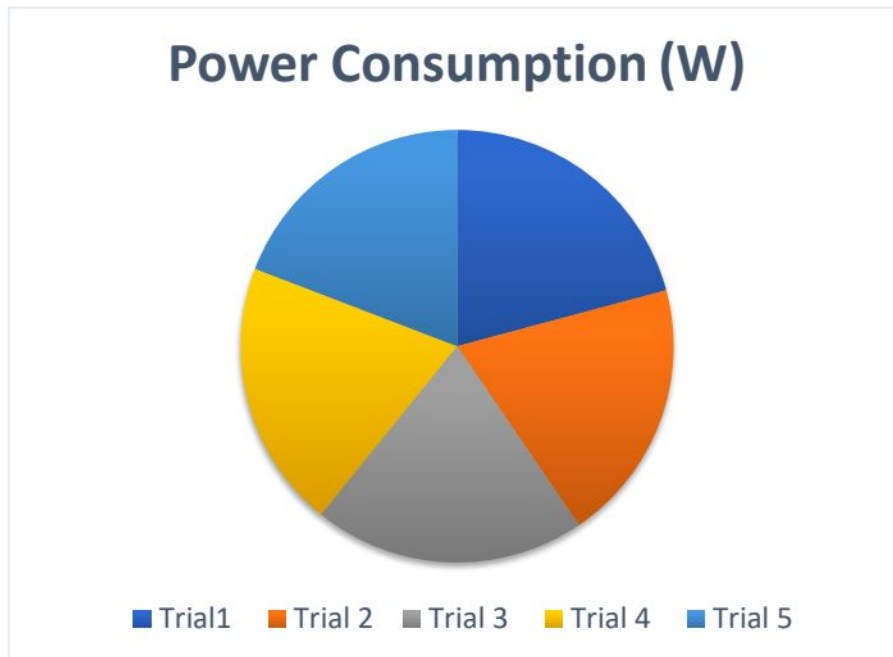


Fig 3.2 POWER CONSUMPTION CHART

The Fig 3.2 visualizes the pie chart of Power consumption rates of each trial of gesture recognition.

Each gesture is mapped to a corresponding action, such as turning an LED on or off, or adjusting its brightness. Once calibrated and tested, users can interact with the LEDs by performing specific hand gestures, initiating the programmed responses. By turning off and on the variations of power consumption rates can be differed by increasing rate of decreasing rate.

Educational and Demonstrative Tool: The project serves as an educational tool for demonstrating the capabilities of computer vision, machine learning, and embedded systems in real-world applications.

Integration with Smart Environments: The project lays the groundwork for integrating gesture-controlled LED lighting systems with smart home environments, IoT devices, and interactive displays, contributing to the development of intelligent and responsive living.

Convenience and Accessibility: The project enables users to control LED lighting effortlessly using natural hand gestures, eliminating the need for physical switches or remote controls. This accessibility feature can be particularly beneficial for individuals with mobility impairments or disabilities. Provide real-time feedback to the user during hand gesture recognition. For example, update the LED brightness dynamically as the user performs different gestures.

Potential Commercial Applications: The project's results may have commercial applications in industries such as entertainment, hospitality, retail, and interior design, where immersive lighting experiences and interactive installations are valued by customers

Research and Development Opportunities: The project opens avenues for further research and development in areas such as gesture recognition algorithms, real-time signal processing, energy-efficient lighting solutions, and user-centered design principles.

A feedback and visualization module empowers developers to create informative, interactive, and visually appealing feedback mechanisms and visualizations that enhance user understanding, decision-making, and engagement with software applications.

It plays a crucial role in conveying complex information in a digestible format, enabling users to derive insights and take informed actions based on data and system feedback.

User Interaction

User interaction refers to the process by which users engage with and manipulate a computer system or application to accomplish tasks, convey information, or receive feedback. It encompasses various forms of input, feedback, and communication between users and the system, ultimately shaping the overall user experience.

Gestures: Hand gestures, body movements, and facial expressions. Hand landmark detection involves identifying key points or landmarks on the hand, such as fingertips, knuckles, and palm center. Techniques like Mediapipe, Open Pose, and HandKeypoint3D leverage CNNs to localize hand landmarks accurately in real-time.

Users will benefit from a more intuitive and engaging way to control LED lighting, leading to increased satisfaction and enjoyment in interacting with the system. Provide visual feedback to the user to indicate successful hand gesture recognition. For example, display a message or an icon on the screen when a specific gesture is recognized.

Highlight the detected hand landmarks or draw bounding boxes around the detected hand regions to make it visually clear to the user hand gestures are detected or tracked, gesture recognition algorithms classify these gestures into predefined categories. Classification approaches include rule-based methods.

Optimizes rendering performance and efficiency to handle large datasets and complex visualizations without compromising responsiveness. Implements caching and preprocessing techniques to minimize data processing overhead and improve performance

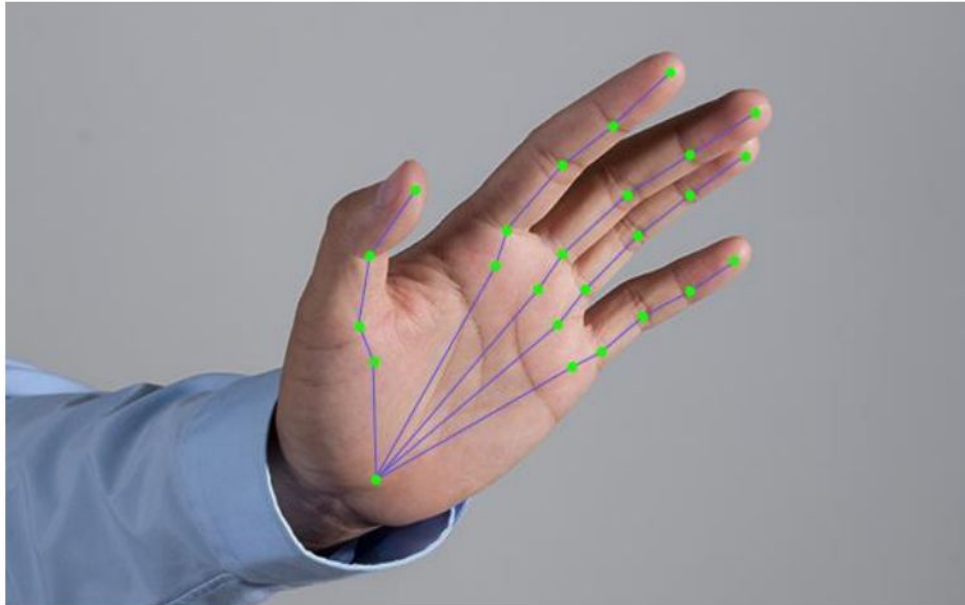


Fig 3.3 HAND GESTURES

Fig 3.3 displays the hand gestures to be identified to give feedback where the feedback mechanisms interact with hand and computer

Feedback Mechanisms: Systems provide feedback to users to convey information, acknowledge actions, and guide interactions. Feedback mechanisms include n Graphical elements, animations, and changes in interface state. Sound effects, notifications, and speech synthesis. Vibrations, tactile sensations, and force feedback.

Interaction Paradigms: Interaction paradigms define the patterns and models of interaction between users and systems. Common paradigms include Users directly interact with objects in the interface (e.g., dragging and dropping). Navigation through hierarchical menus and options. Inputting data through forms and fields. Conversational interfaces and chatbots. Control and manipulation through gestures and body movements.

CHAPTER 4

CONCLUSION AND FUTURE WORK

4.1 CONCLUSION

In conclusion, the hand gesture-controlled LED project represents a successful integration of advanced technology and interactive design to create a novel and intuitive interface for controlling LEDs using hand gestures. Through the utilization of technologies such as MediaPipe for hand tracking and gesture recognition, combined with hardware components like Arduino or Raspberry Pi for LED control, the project offers a seamless and engaging user experience.

Throughout the project, key components such as the hand tracking module, gesture recognition module, and LED control module work synergistically to accurately interpret user gestures and translate them into corresponding LED control actions. Real-time feedback mechanisms enhance user awareness and responsiveness, ensuring a smooth and intuitive interaction with the LED display.

The versatility and adaptability of the system allow for a wide range of applications, including interactive displays, entertainment systems, educational tools, and assistive technologies. By providing customization options and personalization features, users can tailor their experience to suit their preferences and needs.

Looking ahead, the hand gesture-controlled LED project holds promise for further development and refinement. Future iterations may explore enhancements such as additional gesture recognition.

4.2 FUTURE WORK

In future iterations of the hand gesture-controlled LED project, several areas of improvement and expansion could be explored to enhance functionality, performance, and usability. Here are some potential avenues for future work:

Advanced Gesture Recognition: Enhance the gesture recognition module to support a wider range of gestures and movements, including complex gestures, dynamic gestures, and multi-step interactions. Explore machine learning techniques, such as deep learning, to improve accuracy and robustness in gesture recognition.

Multi-User Interaction: Implement support for multi-user interaction, allowing multiple users to control the LED display simultaneously using their hand gestures. Develop algorithms for distinguishing between different users' gestures and assigning control privileges accordingly.

Gesture Customization and Training: Introduce features for gesture customization and training, enabling users to define their own gestures or train the system to recognize personalized gestures. Provide tools for recording and labeling custom gestures and incorporating them into the gesture recognition model.

Integration with Voice Control: Integrate voice recognition capabilities alongside hand gesture control, allowing users to control the LED display using voice commands in addition to gestures.

Enhanced Feedback Mechanisms: Implement richer feedback mechanisms, such as augmented reality overlays, sound effects, or tactile feedback, to enhance user engagement and immersion. Provide dynamic visualizations of recognized gestures and LED control actions in real-time.

Optimization for Low-Power Devices: Optimize the software and algorithms for deployment on low-power devices, such as embedded systems or IoT platforms, to enable energy-efficient operation in battery-powered applications. Minimize resource usage and optimize processing pipelines for real-time performance on resource-constrained hardware.

Integration with IoT Platforms: Extend the system's capabilities to integrate with IoT platforms and smart home ecosystems, enabling seamless integration with other connected devices and services. Develop APIs and protocols for interoperability with popular IoT platforms and cloud services.

Accessibility Features: Incorporate accessibility features to support users with disabilities or special needs, such as alternative control methods, voice guidance, or screen readers. Ensure compatibility with assistive technologies and adherence to accessibility standards and guidelines.

Community Engagement and Collaboration: Foster a community of developers, enthusiasts, and users around the project to encourage collaboration, knowledge sharing, and contributions. Establish forums, documentation, and resources for sharing ideas,

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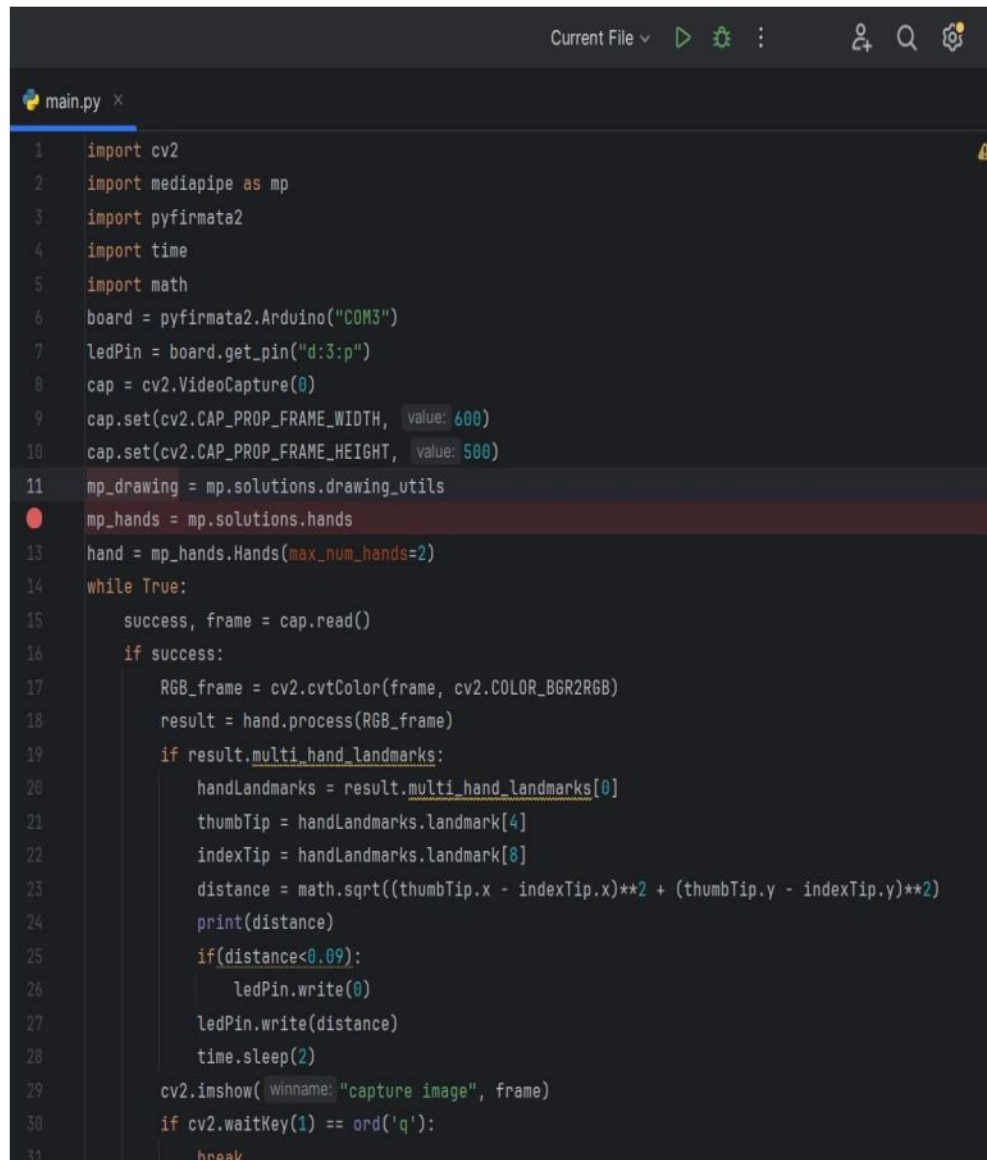
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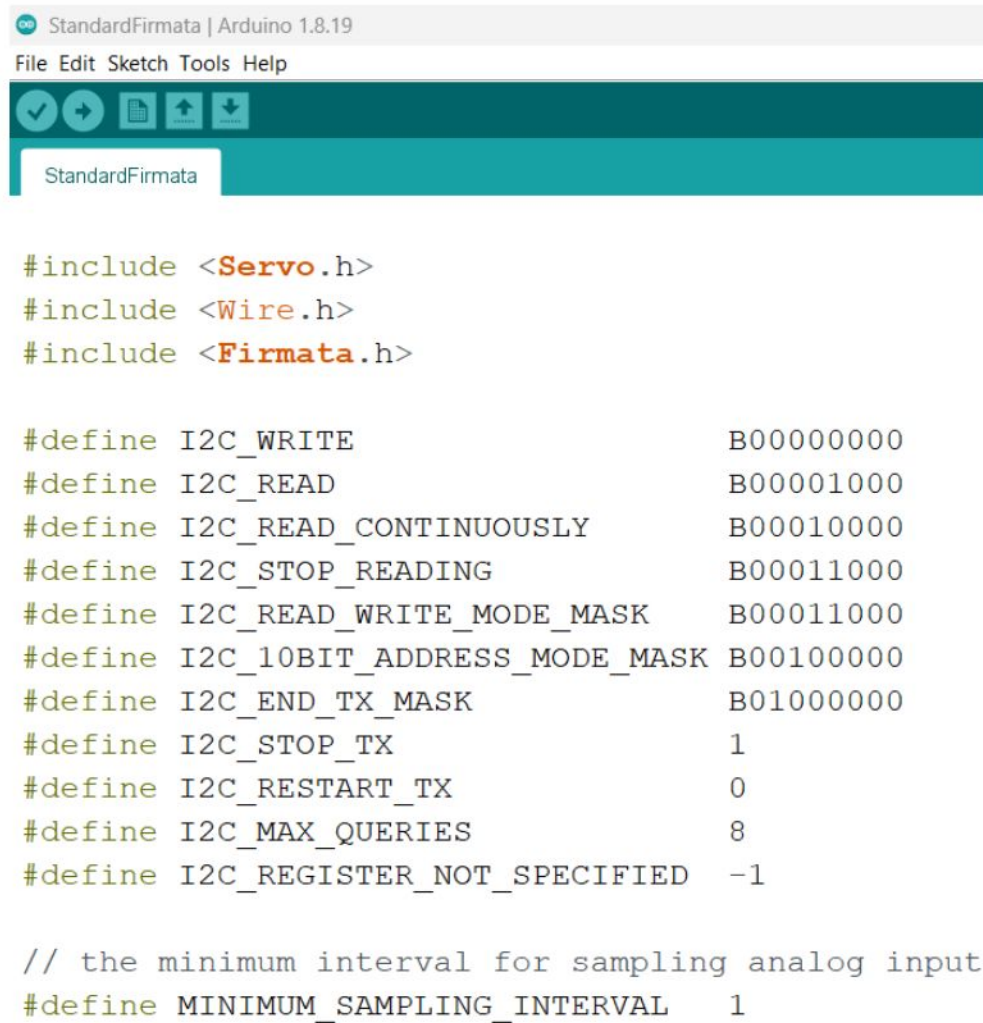
APPENDICES

A.SAMPLE CODE



```
1 import cv2
2 import mediapipe as mp
3 import pyfirmata2
4 import time
5 import math
6 board = pyfirmata2.Arduino("COM3")
7 ledPin = board.get_pin("d:3:p")
8 cap = cv2.VideoCapture(0)
9 cap.set(cv2.CAP_PROP_FRAME_WIDTH, value: 600)
10 cap.set(cv2.CAP_PROP_FRAME_HEIGHT, value: 500)
11 mp_drawing = mp.solutions.drawing_utils
12 mp_hands = mp.solutions.hands
13 hand = mp_hands.Hands(max_num_hands=2)
14 while True:
15     success, frame = cap.read()
16     if success:
17         RGB_frame = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
18         result = hand.process(RGB_frame)
19         if result.multi_hand_landmarks:
20             handLandmarks = result.multi_hand_landmarks[0]
21             thumbTip = handLandmarks.landmark[4]
22             indexTip = handLandmarks.landmark[8]
23             distance = math.sqrt((thumbTip.x - indexTip.x)**2 + (thumbTip.y - indexTip.y)**2)
24             print(distance)
25             if(distance<0.09):
26                 ledPin.write(0)
27                 ledPin.write(distance)
28                 time.sleep(2)
29             cv2.imshow( winname: "capture image", frame)
30             if cv2.waitKey(1) == ord('q'):
31                 break
```

Fig 3.4 SAMPLE PYTHON CODE



```
#include <Servo.h>
#include <Wire.h>
#include <Firmata.h>

#define I2C_WRITE          B00000000
#define I2C_READ          B00001000
#define I2C_READ_CONTINUOUSLY B00010000
#define I2C_STOP_READING  B00011000
#define I2C_READ_WRITE_MODE_MASK B00011000
#define I2C_10BIT_ADDRESS_MODE_MASK B00100000
#define I2C_END_TX_MASK   B01000000
#define I2C_STOP_TX       1
#define I2C_RESTART_TX    0
#define I2C_MAX_QUERIES   8
#define I2C_REGISTER_NOT_SPECIFIED -1

// the minimum interval for sampling analog input
#define MINIMUM_SAMPLING_INTERVAL 1
```

Fig 3.5 FIRMATA CODE

B. LIVE CAPTURE

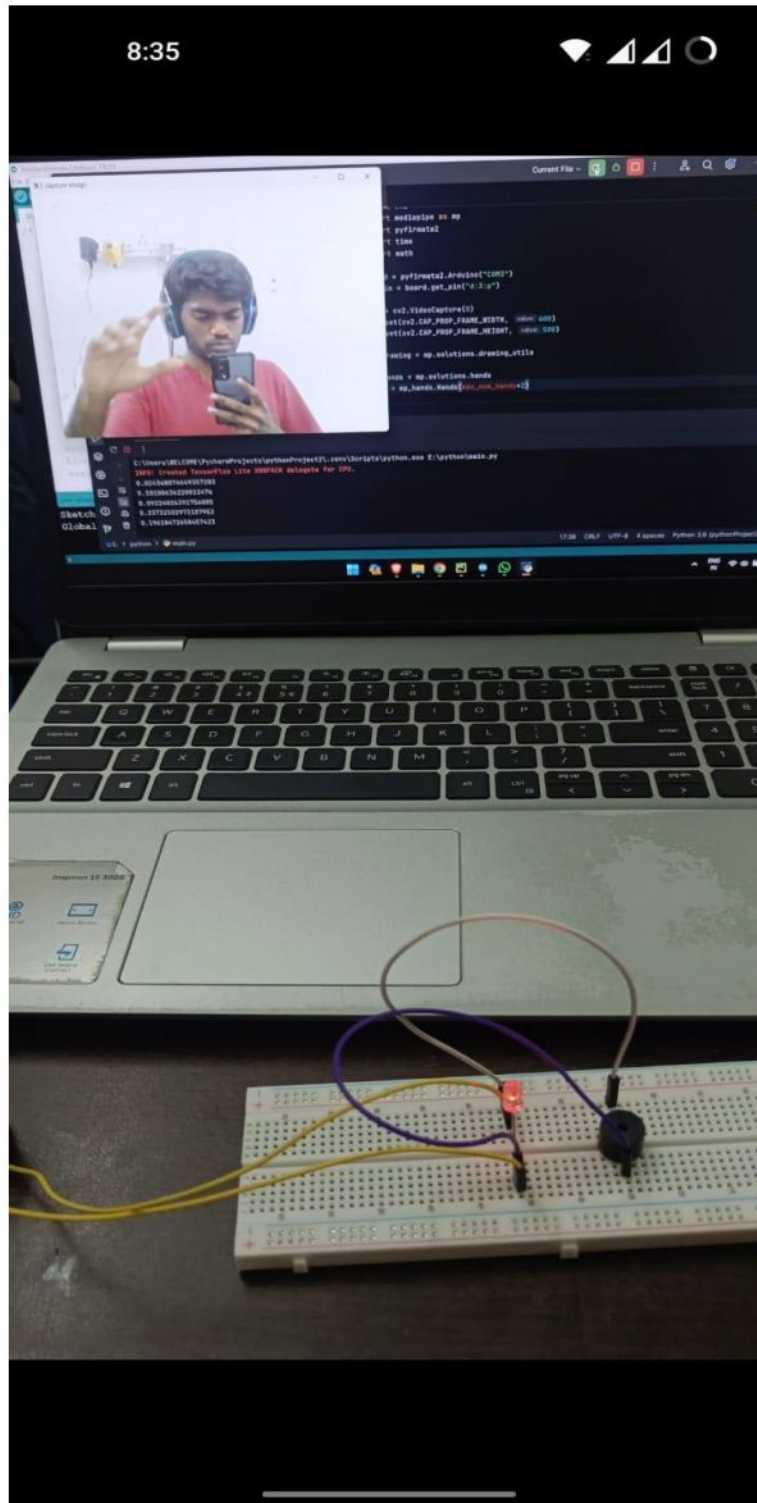


Fig 3.6 REAL TIME HAND GESTURES RESPONSES