School

of

Electronics and Communication Engineering

Minor Project-1 Report

on

Low-light Image Enhancement towards Gesture Recognition

By:

1. **Chinmayee BL** 01FE21BEC246
2. **Rakshita K Joshi** 01FE21BEC042
3. **Vinaya Shetti** 01FE21BEC232
4. **A S V Dheeraj** 01FE21BEC161

Semester: VI, 2023-2024

Under the Guidance of

Ramesh Ashok Tabib

K.L.E SOCIETY'S
KLE Technological University,
HUBBALLI-580031
2023-2024

SCHOOL OF ELECTRONICS AND COMMUNICATION ENGINEERING

CERTIFICATE

This is to certify that project entitled **"Low-light image enhancement towards gesture recognition"** is a bonafide work carried out by the student team of **"Chinmayee B L (01FE21BEC246), Rakshita K Joshi (01FE21BEC042), Vinaya Shetti (01FE21BEC232), A S V Dheeraj (01FE21BEC161)"**. The project report has been approved as it satisfies the requirements with respect to the minor project-1 work prescribed by the university curriculum for BE (VI Semester) in School of Electronics and Communication Engineering of KLE Technological University for the academic year 2023-2024

Ramesh Ashok Tabib **Guide**	**Suneetha Budihal** **Head of School**	**B.S. Anami** **Registrar**

External Viva:

Name of Examiners **Signature with date**

1.

2.

ACKNOWLEDGMENT

We would like to express our sincere gratitude towards all those who helped us understand, and work towards the completion of this project. Firstly, the team wishes to express its sincere gratitude to Sunita Budihal, Head of the School of Electronics and Communication, for providing us with this opportunity to utilise our knowledge and skills in this project. Special thanks to Ramesh Ashok Tabib for providing useful suggestions that helped us to make our project more successful. We would also like to thank Kaushik.M for providing useful insights and guiding us throughout the entire project. Additionally, we also appreciate CEVI team for providing all the computational resources and facilities needed. We are truly thankful for each and every individuals that played an important role to help us successfully complete this project.

By:

1. **Chinmayee BL** 01FE21BEC246
2. **Rakshita K Joshi** 01FE21BEC042
3. **Vinaya Shetti** 01FE21BEC232
4. **A S V Dheeraj** 01FE21BEC161

ABSTRACT

This project presents the development of an integrated system combining a gesture recognition model with low-light image enhancement techniques to accurately capture and interpret hand gestures in dim lighting conditions. The primary objective is to enhance the quality of images taken in low light, ensuring that the gesture recognition model can reliably identify the hand gestures. Once captured, these enhanced images are processed to detect the specific gesture represented by the hand. The identified gesture is then translated into a corresponding digit count, which is displayed on a seven-segment display. This process involves several key steps, including image capture, enhancement, gesture detection, and digit display, each optimized for speed and accuracy. The project focuses heavily on improving the image enhancement algorithms to ensure clear and distinguishable gesture inputs, even in suboptimal lighting conditions. Additionally, the system is designed to deliver rapid outputs, making it suitable for real-time applications. The successful implementation of this project demonstrates the effectiveness of combining advanced image processing techniques with gesture recognition models, offering potential applications in areas such as assistive technologies, smart home controls, and low-light security systems. The results showcase the feasibility and practicality of the approach, providing a reliable solution for gesture recognition in challenging lighting environments.

Contents

List of Figures

Chapter 1

Introduction

In environments characterized by low light conditions, human-computer interaction (HCI) faces significant challenges, particularly in scenarios where precise hand gestures need to be detected and interpreted. This challenge is particularly pronounced in applications such as gesture-based counting systems, where accurate recognition of hand gestures is paramount for effective communication between users and machines. The project at hand addresses this challenge by proposing an integrated solution that combines low-light image enhancement techniques with advanced gesture recognition algorithms, implemented on the versatile Raspberry Pi platform. The primary objective is to enable robust and reliable recognition of finger gestures in low-light conditions, thereby facilitating seamless interaction in environments where traditional methods may fail.

1.1 Motivation

Surveillance Systems: Enhancing low-light images can significantly improve surveillance systems effectiveness, enabling better recognition of gestures even in dim environments. This could be valuable for security purposes in areas like ATM kiosks, parking lots, or public transportation hubs.

Human-Computer Interaction (HCI): Contribute towards the advancement of gesture recognition technology, particularly in HCI systems. Finger gestures in low-light conditions to control smart devices, such as smartphones, tablets, or smart home appliances. This could enhance accessibility for users with limited mobility or in environments where traditional input methods are impractical.

Assistive Technology: For individuals with visual impairments, this system could assist in interpreting gestures made in low-light settings, aiding navigation or communication in dimly lit areas. This could empower visually impaired individuals to interact more effectively with their surroundings.

Automotive Safety: Gesture recognition systems are increasingly integrated into automotive technology for hands-free control of infotainment systems, climate control, and other functions. Enhancing the recognition of gestures in low-light conditions could improve the reliability and safety of such systems, particularly for night-time driving scenarios.

Innovation in Imaging Technology: Pushing the boundaries of image capture in low-light conditions can lead to advancements in camera and sensor technologies, which have applications beyond just hand gesture recognition.

1.2 Problem Statement

Develop a system that captures hand gesture images under low-light conditions, enhances these images for better clarity, identifies the digit represented by the hand gesture, and displays the recognized digit on a seven-segment display.

1.3 Objectives

- To develop a system for gesture recognition
- To develop a system for low-light image enhancement.
- To display the detected finger gesture on seven-segment.

1.4 United Nations Sustainable Development Goals (SDGs)

- The United Nations Sustainable Development Goals (SDGs), also known as the Global Goals, are a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity by 2030.
- The SDGs were established by the United Nations in 2015 as a successor to the Millennium Development Goals (MDGs), with a broader and more comprehensive agenda to address the complex challenges facing the world.

Figure 1.1: SDG's given by UNO

1.5 Alignment with SDGs

- **SDG 9: Industry, Innovation, and Infrastructure:** By enhancing infrastructure (such as vehicle systems) with these technologies, it supports safer transportation and operational capabilities, particularly in challenging conditions.

Figure 1.2: Alignment with SDG 9- Industry, Innovation, and Infrastructure

Figure 1.3: Alignment with SDG

1.6 Causal Loop Diagram

- A causal loop diagram (CLD) is a diagram that aids in visualizing how different variables in a system are causally interrelated. The diagram consists of a set of words and arrows.
- If the lighting conditions are poor, the captured low-light frames are processed through the enhancement procedure to produce enhanced frames, which are then fed into the gesture recognition model. The detected gesture is subsequently displayed.
- If bright light frames are captured then they are directy fed to the gesture recognition model and displayed.

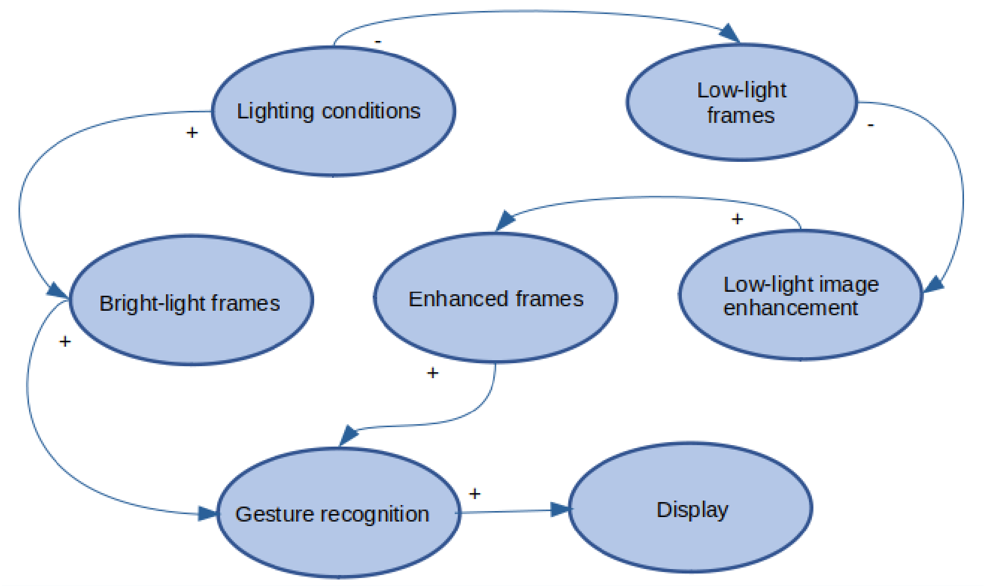


Figure 1.4: Causal loop diagram.

1.7 Literature Survey

- **A Review Paper on Raspberry Pi and its Applications (IJAEM 2020) [1]**

1. **History of Raspberry Pi:** The development of Raspberry Pi started in 2006 with the aim of increasing the number of students opting for Computer Science. The first model, Raspberry Pi Model B, was launched in 2012 with technical specifications including a Broadcom BCM2835 SoC, 512 Mb memory storage, 700 MHz ARM processor, and VideoCore IV GPU.

2. **Technical Specifications:** The latest Raspberry Pi 4 Model B features a Broadcom BCM2711 processor, 8GB LPDDR4 RAM, Bluetooth 5.0, Wi-Fi, USB ports, Gigabit Ethernet, micro-HDMI ports, microSD card slot, and more.

3. **Operating System:** Raspberry Pi initially had its own operating system called Raspbian based on Linux, with various non-Linux OS options available in the market.

4. **Raspberry Pi Boot Process:** The boot process involves stages where the ARM core is initially off, the GPU core is on, and bootloaders are executed to enable SDRAM and load necessary components .

5. **Applications of Raspberry Pi:**

   1. AI Assistant: Integration of voice commands via Google Assistant SDK and Google's Cloud Speech API.

   2. Motion Capture Security Camera: Utilizing Raspberry Pi Camera module for a security system.

   3. Live Bots: Controlling robots based on Raspberry Pi over the internet.

6. **Conclusions:** Suggestions for improvements in internal storage, integration of heat sinks, providing external cases and user guides, integrating GPU for running Windows, and highlighting the flexibility and possibilities of Raspberry Pi for various projects

- **A Survey of Deep Learning-Based Low-Light Image Enhancement (Sensors 2023) [3]**

1. CNN-Based Methods:
   1. Physical Model-based Methods:

      - These methods utilize deep learning techniques alongside physical models to enhance low-light images.
      - LLNet: Introduced by Lore et al., LLNet employs a densely layered sparse denoising autoencoder for contrast enhancement and denoising procedures.
      - MBLLEN: This method, introduced by Lv et al., is an end-to-end multi-branch enhancement network that extracts feature representations across different modules for improved enhancement.
      - Ren et al.: Developed an end-to-end architecture involving an encoder-decoder network and a recurrent neural network to address both image content and edge enhancements.

   2. Non-Physical Model-Based Methods:

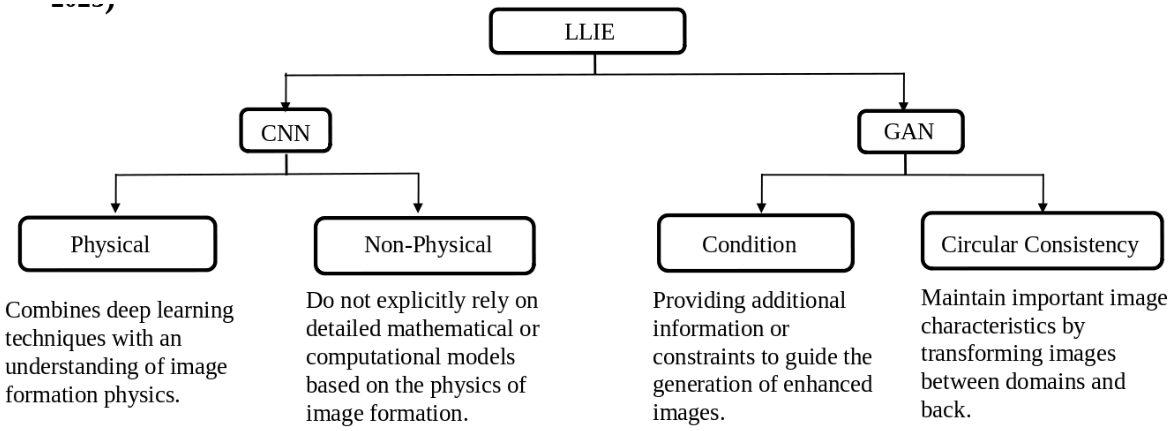


Figure 1.5: Methods

- These methods integrate deep learning techniques without relying on explicit physical models.
- Real-Time Enhancement: Gharbi et al. introduced a real-time image enhancement technique that combines deep learning with the bilateral filter for improved performance.
- MSR-net: Shen et al. proposed MSR-net, which fuses CNN technology with Retinex theory, effectively enhancing low-light images by learning the mapping between low-light and standard-brightness images.
- Retinex-Based Enhancement: Wei et al. developed a deep neural network based on Retinex theory for enhancing low-light images, decomposing images into reflection, intermediate reflection, and shadow components for individualized enhancement.
- Guided Filter-Based Enhancement: Wu et al. proposed a rapid end-to-end trainable image enhancement method based on the guided filter, preserving high-frequency information for efficient enhancement.
- RNN-Based Denoising and Enhancement: Wei et al. introduced an image denoising and enhancement method based on recurrent neural networks, integrating nonlocal mean filters into the RNN architecture for effective denoising and enhancement.

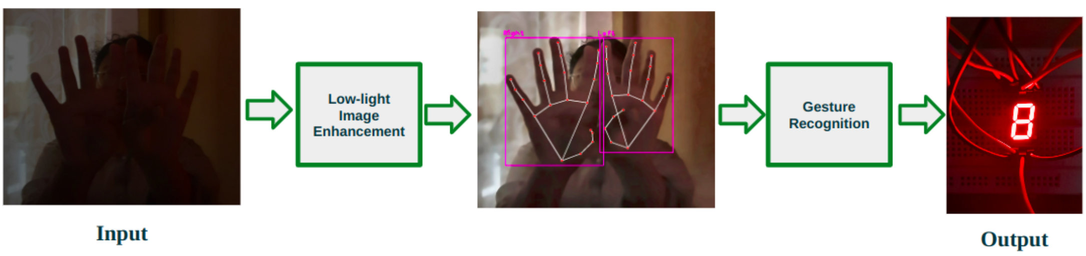
Chapter 2

System Design

In this chapter, we will be looking towards the functional block diagram depicting the flow of the project.

2.1 Functional Block Diagram

- A raspberry pi camera module captures the low-light finger gesture. The captured image is enhanced using image enhancement and the enhanced image is then processed by gesture recognition model to identify the number of fingers being shown. Finally, the detected digit is displayed on seven-segment display.



Chapter 3

Implementation Details

In this chapter, we will be looking towards the specifications details, algorithm/flowchart, model description and experimental setup.

3.1 Specifications of Components

- Raspberry pi 4 - Model b
  1. 64-bit quad-core Cortex-A72 processor
  2. 2GB LPDDR4 RAM
  3. 2 micro HDMI ports
  4. 2 USB 3.0 ports
  5. 2 USB 2.0 ports
  6. Gigabit ethernet port
  7. Bluetooth 5.0

- Raspberry pi Camera V2
  1. Size – Around 25 * 24 * 9 mm
  2. Still resolution – 8 Megapixels
  3. Sensors – Sony IMX219
  4. Sensor resolution – 3280 * 2464 pixels
  5. Focal length – 3.04 mm

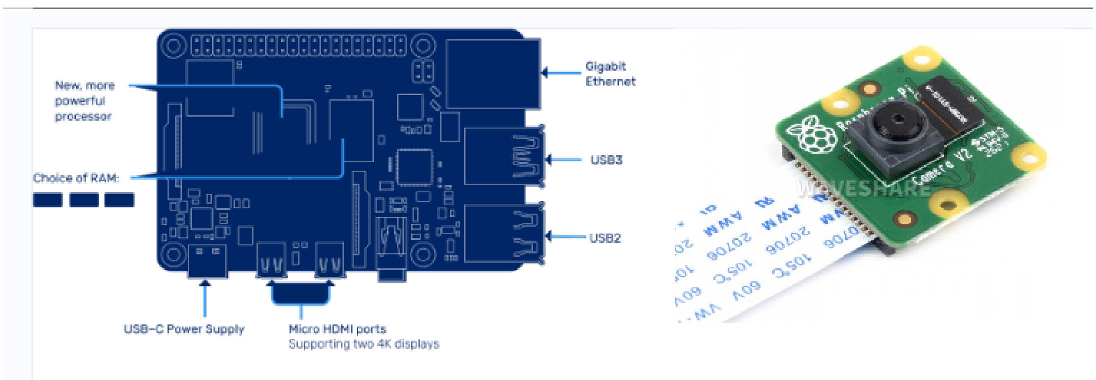


Figure 3.1: Raspberry pi and Raspberry pi camera module

3.2 Algorithm for Low-light Image Enhancement towards Gesture Recognition.

Our project focuses on enabling finger gesture-based counting in low-light conditions. We achieve this through a series of steps:

1. **Low-Light Gesture Capture:** Using a camera, we capture finger gestures in low-light environments.
2. **Low-Light Image Enhancement:** The captured images undergo processing through a specialized low-light image enhancement [2] [4] model or any other model on raspberry pi. This step enhances the visibility and clarity of the gestures, making them suitable for accurate recognition.
3. **Gesture Recognition:** The enhanced images are then analyzed by a gesture recognition model. This model is trained to identify and interpret various finger gestures, including those associated with numerical counting.
4. **Display output:** Finally, the recognized finger count is displayed on a seven-segment display in real-time, providing users with immediate feedback.

3.3 Flowchart of Low-light Image Enhancement towards Gesture Recognition.

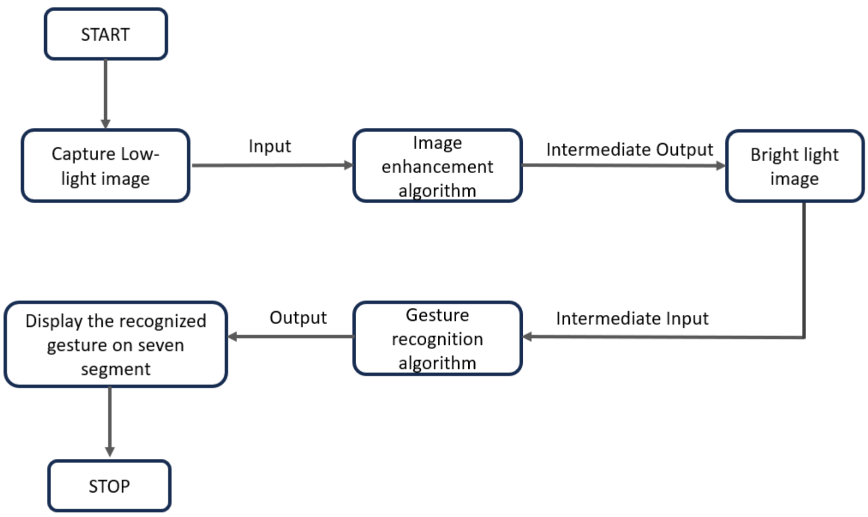


Figure 3.2: Depicting the flow of algorithm

3.4 Gesture Recognition

- MediaPipe Hands: 21 landmarks
- This model gives the count of number of fingers which are up and number of fingers which are down.

- Count of fingers which are up are counted as 1's.
- Count of fingers which are down are counted as 0's.

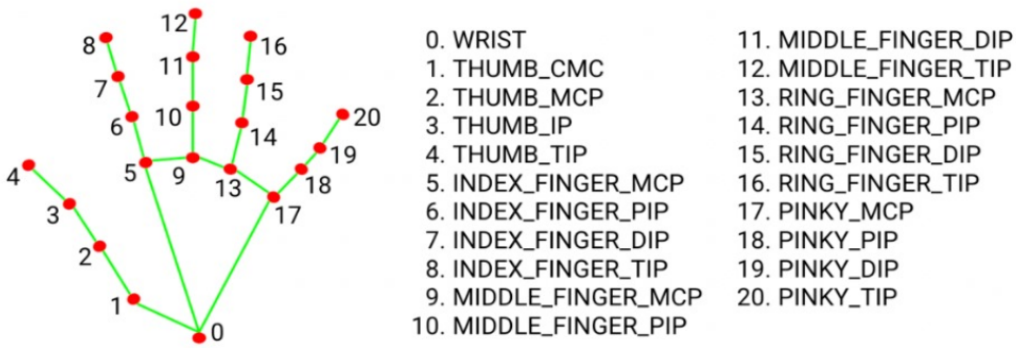


Figure 3.3: MediaPipe hand landmarks

3.5 Low-light Image Enhancement

- To achieve real-time video capture and enhancement using a Raspberry Pi camera module, we will use Python along with the OpenCV library. The steps include capturing the video feed, applying denoising, gamma correction, and bilateral filtering to each frame, and displaying the enhanced video in real-time.
- Captures the video from raspberry pi camera module.
- Enhances each frame in real-time.
- Enhancement includes:
  1. Denoising using open-cv: Reducing noise using Non-Local Means de-noising.
  2. Gamma correction: Adjusting the brightness of the image with the value 1.2
  3. Bilateral filtering using open-cv: Smoothing images while preserving edges.
- Display the results in real-time

3.6 Seven Segment

- A seven-segment display is an electronic display device used for displaying decimal numerals and some alphabetic characters.
- We are using common anode seven-segment display.
- Common Anode: All the anodes (positive terminals) of the LEDs are connected together and to a common positive voltage supply.

3.7 Experimental Setup

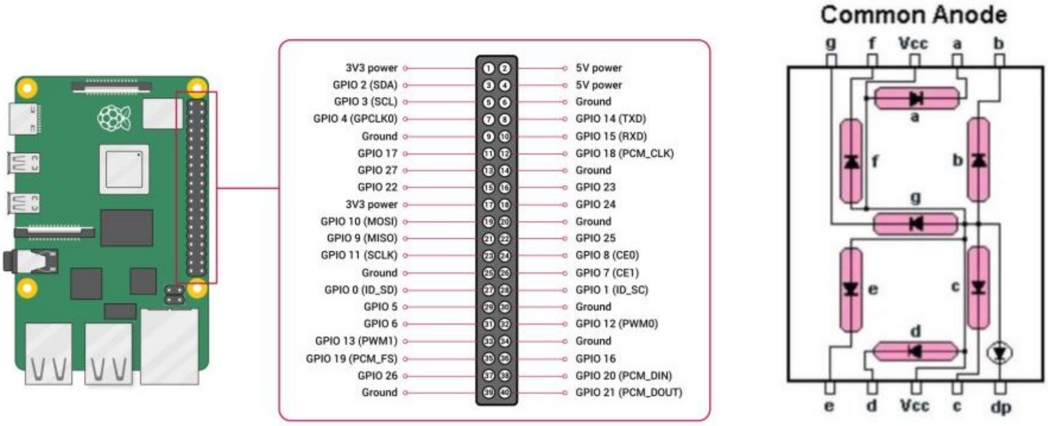


Figure 3.4: Raspberry Pi and seven-segment pin configuration

- To set up the hardware components for this project, we begin with the Raspberry Pi 4 B, the central processing unit. Installing the Raspbian OS on the Raspberry Pi is the first step, providing the necessary operating system for running the project. Once the OS is installed, the Raspberry Pi needs to be connected to a monitor, keyboard, and mouse for initial setup and testing. This ensures that we can interact with the Raspberry Pi and configure its settings as required. Additionally, ensuring internet access for the Raspberry Pi is crucial, as it allows for the installation of necessary libraries and updates, facilitating the smooth execution of the project.

- Next, we focus on the Raspberry Pi Camera Module, which plays a vital role in capturing real-time frames of hand gestures. The camera module is connected to the Raspberry Pi using the CSI (Camera Serial Interface) port, enabling seamless communication between the camera and the Raspberry Pi. It's essential to securely position the camera to capture hand gestures effectively. This involves stabilizing the camera and ensuring it is positioned at an appropriate distance to capture the entire hand frame, optimizing the accuracy of gesture recognition.

- The Common Anode seven-segment display serves as the output interface for displaying the recognized digit gestures. To set up the display, the common anode is connected to the 3.3V pin on the Raspberry Pi, providing the necessary power. Each segment (a-g) of the display is then connected to the GPIO pins on the Raspberry Pi through current-limiting resistors. This wiring configuration ensures that each segment can be controlled individually, allowing for the accurate representation of digits on the display. A breadboard is used for prototyping and making connections between the display and the Raspberry Pi GPIO pins, providing a convenient and organized platform for wiring.

- Additional components such as connecting wires, breadboards, and resistors are utilized to facilitate the connections and ensure the proper functioning of the hardware setup. Jumper wires are used to make all necessary connections, providing flexibility and ease of assembly.

- The breadboard serves as a central hub for organizing and securing connections between the Raspberry Pi and the seven-segment display, simplifying the setup process.

- Appropriate resistors are employed to limit the current to the seven-segment display segments, preventing damage and ensuring reliable performance.
- Overall, the hardware setup encompasses the Raspberry Pi 4 B, Raspberry Pi Camera Module, Common Anode Seven-Segment Display, and additional components, all carefully configured and interconnected to create a functional system for real-time hand gesture recognition and display.

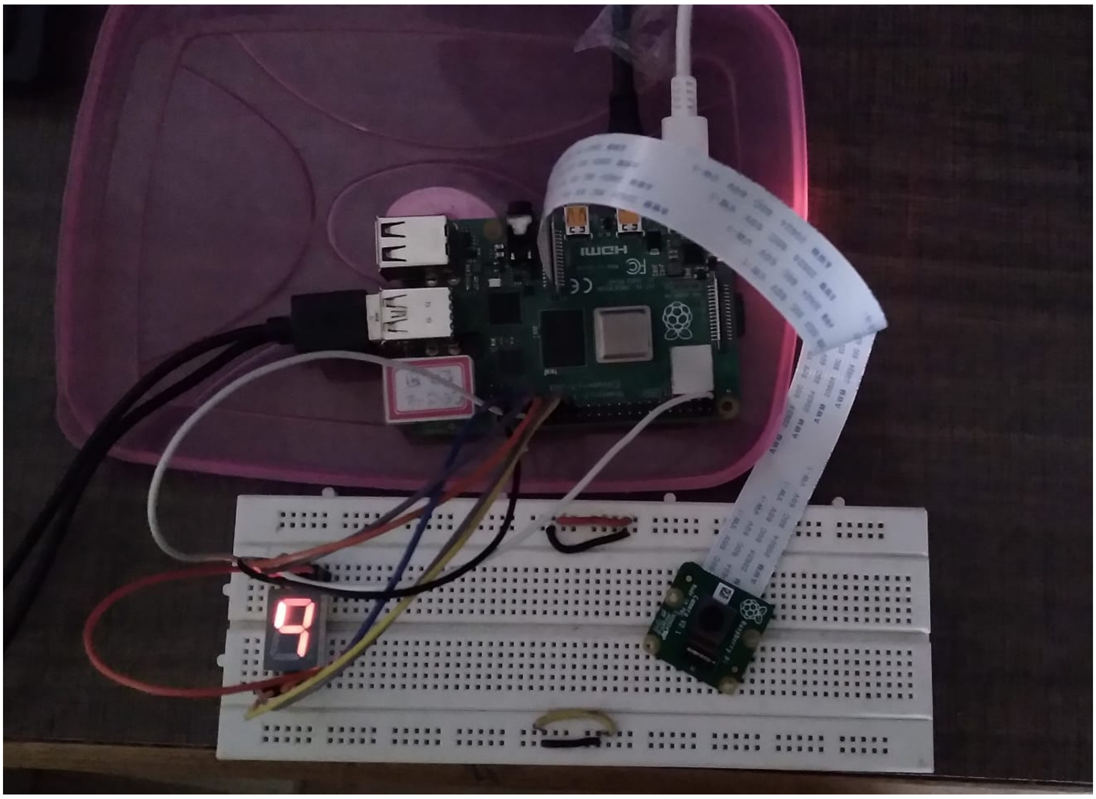


Figure 3.5: Experimental setup for low-light image enhancement towards gesture recognition.

Chapter 4

Results and discussions

In this chapter, we will be looking towards the experimental results and final results.

4.1 Experimental Results of Gesture Recognition

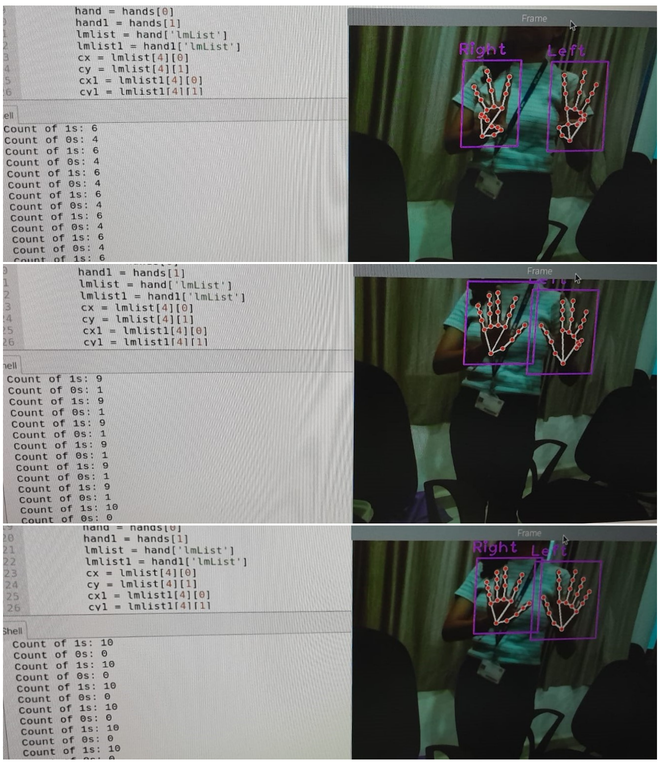


Figure 4.1: Gestures are detected with count of fingers up and down as 1's and 0's respectively. In first image count of 1's is 6 and count of 0's is 4, in second image count of 1's is 9 and count of 0's is 1, similarly in third image count of 1's is 10 and count of 0's is 0.

4.2 Final Results

- In the final results section of our project, we demonstrate the complete workflow of our low-light finger gesture recognition system.
- Initially, we capture images of finger gestures in a low-light environment, highlighting the visibility challenge. We display these images to show the dim lighting conditions.
- Next, we process the images using a low-light image enhancement model on a Raspberry Pi, improving their lighting conditions for better recognition. The enhanced images are displayed alongside the originals to showcase the improvements. These enhanced images are then analyzed by a gesture recognition model which identify finger gestures (numerical counting).
- We overlay or annotate the recognized gestures on the enhanced images to demonstrate the model's accuracy. Finally, the recognized finger count is displayed in real-time on a seven-segment display.
- Integrating a gesture recognition model with low-light image enhancement to capture and enhance finger gestures under low-light conditions at different time followed by detection of the gesture and display the corresponding digit count on a seven-segment display.
- Experimental results around 5:30 pm.
  - Under the lighting condition around 5:30 pm we are able to detect the gesture without enhancement and display the corresponding digit on seven-segment.
- Experimental results around 7:00 pm.
  - Around 7:00 pm, the lighting conditions make it difficult to detect finger gestures without enhancement.
  - To address this, we pass the captured finger gesture through a low-light image enhancement process.
  - This produces an enhanced image, enabling us to detect the finger gesture and display the corresponding digit on a seven-segment display.

Figure 4.2: Around 5:30 pm, the finger gesture is detected and displayed on a seven-segment display without enhancement, where the first column represents the input and second column represents the output.

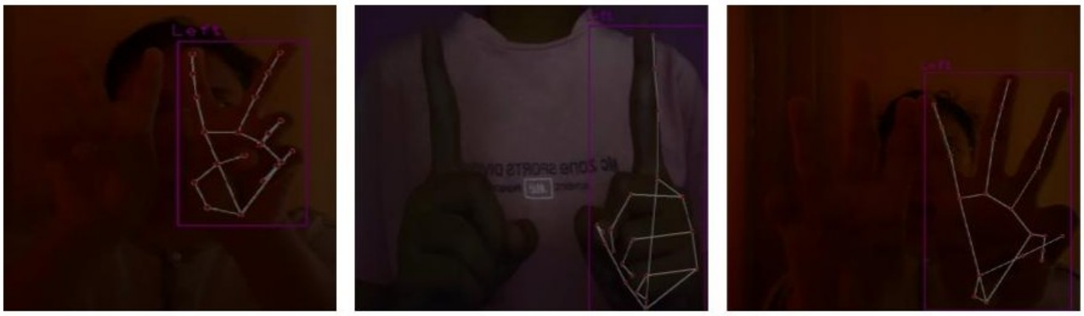


Figure 4.3: In the above figure all three images captured around 7:00 pm, the lighting conditions make it difficult to detect finger gestures without enhancement.

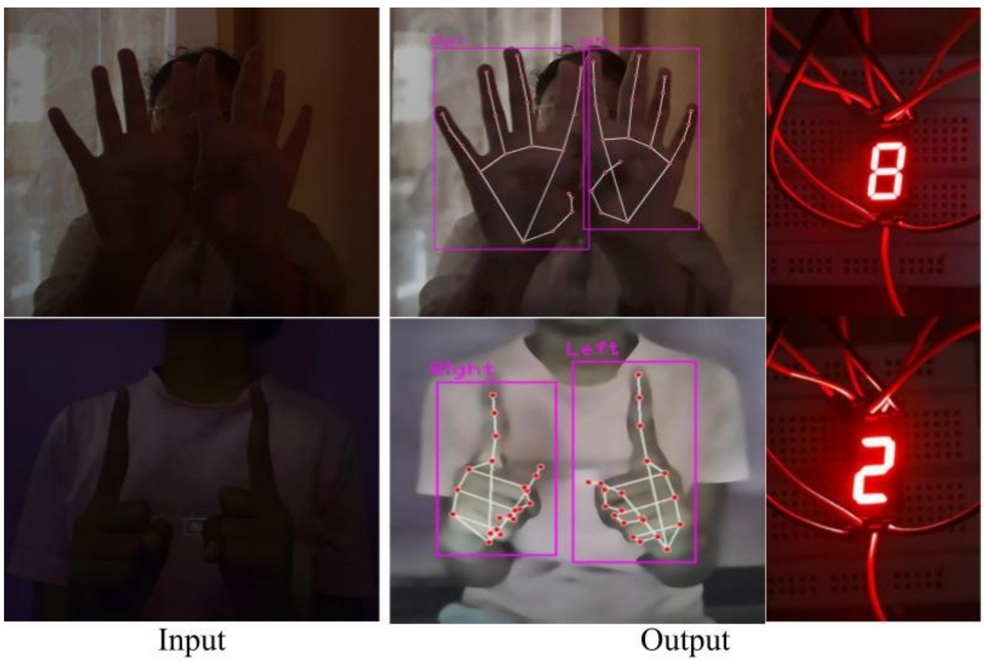


Figure 4.4: Around 7:00 pm, the finger gesture is detected and displayed on a seven-segment display after enhancement, where the first column represents the input and second column and the third column represents the output.

Chapter 5

Conclusions and future scope

In this chapter, we will be looking towards conclusions and future scope.

5.1 Conclusion

This project successfully integrated a gesture recognition model with low-light image enhancement to accurately capture and improve hand gestures in low-light conditions. The system effectively detected the gestures and displayed the corresponding digit count on a seven-segment display, demonstrating both the feasibility and efficiency of our approach.

5.2 Future scope

The focus will be on enhancing image quality and improving the speed of obtaining the output further deploying on any edge device.

Bibliography

[1] Hirak Ghael. A review paper on raspberry pi and its applications. 01 2020.

[2] Yu Guo, Yuxu Lu, Ryan Wen Liu, Meifang Yang, and Kwok Tai Chui. Low-light maritime image enhancement with regularized illumination optimization and deep noise suppression. *arXiv preprint arXiv:2008.03765*, 2020.

[3] Zhen Tian, Peixin Qu, Jielin Li, Yukun Sun, Guohou Li, Zheng Liang, and Weidong Zhang. A survey of deep learning-based low-light image enhancement. *Sensors*, 23:7763, 09 2023.

[4] Chen Wei, Wenjing Wang, Wenhan Yang, and Jiaying Liu. Deep retinex decomposition for low-light enhancement. *arXiv preprint arXiv:1808.04560*, 2018.