Faculty of Electronics & Computer Technology and Engineering

DEVELOPMENT OF HOME AUTOMATION SYSTEM USING HAND GESTURE

PUGALENTHI A / L MANORING

Bachelor of Electronics Engineering Technology

(Industrial Electronics) with Honours

2025

DEVELOPMENT OF HOME AUTOMATION SYSTEM USING HAND GESTURE

PUGALENTHI A/L MANORING

This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

اونيۏرسيتي تيكنيكل مليسيا ملاك
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electronics and Computer Technology and Engineering

UNIVERSITY TEKNIKAL MALAYSIA MELAKA

2025

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FAKULTI TEKNOLOGI DAN KEJURUTERAAN

Tajuk Projek : Home Automation System using Hand Gesture

Sesi Pengajian : 2024/2025

Saya NAMA PENUH DALAM HURUF BESAR mengaku membenarkan laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (✓):

☐	**SULIT***	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
☐	**TERHAD***	(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan.
☑	**TIDAK TERHAD**	

Disahkan oleh:

(TANDATANGAN PENULIS) (COP DAN TANDATANGAN PENYELIA)

Alamat Tetap: ,

Tarikh : 6 FEBRUARY 2025 Tarikh : 6 FEBRUARY 2025

*CATATAN: Jika laporan ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh laporan ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I declare that this project report entitled Home Automation System using Hand Gesture is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Signature	:
Student Name	: PUGALENTHI A/L MANORING
Date	: 6 FEBRUARY 2025

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours.

Signature :

Supervisor Name : ZULKARNAIN BIN ZAINUDIN

Date : 6 FEB 2025

Signature :

Co-Supervisor :

Name (if any) :

Date :

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEDICATION

I offer this bachelor's degree project as a tribute to my parents, Manoring Muniyandi and Thilagavathi Vengadasalam, whose unwavering support, inspiration, wisdom, knowledge, and understanding have been my guiding force. Their strength has empowered me to see this project through to completion during my academic journey. Additionally, I extend this dedication to my friends, whose constant encouragement urged me to persevere and never surrender. I gratefully acknowledge the support, guidance, and advice bestowed upon me by my friends and lecturers throughout the project, ensuring its success.

UTeM
اونيۏرسيتي تيكنيكل مليسيا ملاك
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ABSTRACT

This project aims to create a prototype that changes how people control their homes, making it easy to access and energy efficient. The main goal is to create a system which promotes energy efficiency and simple hand gestures to control home appliances such as lights and fans. The webcam will play a major role in this project to capture the images. By using Convolutional Neural Network trained model this prototype can make smart decisions to save energy and promote eco-friendly habits. The system uses one main controller which is Raspberry PI4, makes the decision to control the outputs based on presence of hand gestures. Webcam will be used to detect the presence of hand gestures while LED, motor and buzzer will be used as the project's dedicated outputs.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ABSTRAK

Projek ini bertujuan untuk mencipta prototaip yang mengubah cara orang mengawal rumah mereka, menjadikannya mudah diakses dan cekap tenaga. Matlamat utama adalah untuk mencipta sistem yang menggalakkan kecekapan tenaga dan kawalan peralatan rumah seperti lampu dan kipas menggunakan isyarat tangan yang mudah. Kamera web akan memainkan peranan utama dalam projek ini untuk merakam imej. Dengan menggunakan model Convolutional Neural Network (CNN) yang dilatih, prototaip ini boleh membuat keputusan pintar untuk menjimatkan tenaga dan menggalakkan tabiat mesra alam. Sistem ini menggunakan satu pengawal utama iaitu Raspberry PI4, yang membuat keputusan untuk mengawal output berdasarkan kehadiran isyarat tangan. Kamera web akan digunakan untuk mengesan kehadiran isyarat tangan manakala LED, motor dan buzzer akan digunakan sebagai output khusus dalam projek ini.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my exceptional supervisor, Sir Zulkarnain Bin Zainudin, for his invaluable guidance, unwavering support, and patience throughout this project. His words of wisdom and constant encouragement played a significant role in keeping me motivated and focused. I feel truly fortunate to have had him as my supervisor. Without his direction and expertise, completing this thesis would have been a challenging task. I sincerely appreciate all his guidance and advice, which were instrumental in ensuring the success of this project.

I am profoundly grateful to my parents, Manoring Muniyandi and Thilagavathi Vengadasalam, for their unconditional love, support, and prayers during my academic journey. Their constant encouragement and belief in me were the driving forces behind my perseverance. I am blessed to have them as my pillars of strength and am deeply thankful for their continuous support.

I would also like to acknowledge my dear friends, Naavinesh, Tharmein, Vaithis, Kuuberan, and my BERE classmates. Their assistance, encouragement, and motivation have been indispensable in helping me complete this project. The unwavering belief they have shown in me pushed me to keep going, and I am incredibly grateful for their support throughout this journey. You all have truly been my strength, and I cannot thank you enough.

My heartfelt thanks extend to everyone who has helped me in completing this thesis, even if their names are not mentioned here. Your contributions have been invaluable, and I am deeply grateful for your kindness and support.

Lastly, I would like to take a moment to thank myself. I thank myself for believing in my abilities, for dedicating myself to the hard work, for never giving up, and for persevering through the toughest moments. I appreciate the effort I put into this project and for always striving to do my best. I thank myself for choosing the right path and staying true to my principles throughout this journey.

TABLE OF CONTENTS

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF TABLES

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF FIGURES

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF APPENDICES

اونيۆرسيتي تيكنيكل مليسيا ملاك
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 1

INTRODUCTION

1.1 Background

Gestures are actions that people use to communicate information to others without having adiscussion. This project is proposed to study the efficiency of hand signal using Kinect sensor to all kinds of people. The project focuses on individuals who seek to enhance their quality of life through the integration of technology within their home environments. It specifically serves homeowners or tenants that prioritize efficiency, convenience, andpersonalization when it comes to overseeing their living areas. They will have to perform simple hand gestures to control their home appliances such as lights and fans.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

1.2 Societal/Global Issue Through Home Automation System Project

Designing a home automation system based on hand gestures presents an opportunity to address several societal or global issues. One prominent area is accessibility for individualswith physical disabilities. By creating a home automation system that can be controlled through hand gestures, you can empower people with mobility impairments to interact withtheir environment more easily, promoting independence and inclusivity. Additionally,integrating hand gesture-based controls into a home automation system can contribute to energy conservation and environmental sustainability. By allowing users to effortlessly adjust lighting, temperature, and other appliances with simple gestures, the system can encourage more efficient use of resources, reducing energy waste and carbon emissions.

Furthermore, such a project can contribute to the advancement of human-computer interaction technology, paving the way for more intuitive and natural interfaces in various applications beyond home automation. This can have far-reaching implications for improving user experiences and accessibility across different domains, including healthcare, education, and entertainment. Overall, developing a hand gesture-based home automation system not only offers practical benefits for users but also contributes to broader societal goals of accessibility, sustainability, and technological innovation

1.3 Problem Statement

In modern households, the integration of various smart devices often remains fragmented, leading to inefficient control and management of home environments. Traditional methods of controlling household appliances such as lights and fans require direct physical interaction or simple remote control, which may not fully harness the potential of advanced automation technologies. Additionally, current home automation systems may lack intuitive, hands-free interaction that can significantly enhance user convenience and accessibility, especially for individuals with disabilities.

Despite the availability of sophisticated sensors and computing platforms, there is a noticeable gap in leveraging these technologies to create a seamless, efficient, and reliable home automation experience. This gap highlights the need for a system that can accurately and reliably interpret hand gestures to control household appliances, providing a more integrated and user-friendly solution.

1.4 Project Objective

The main goal of this project is to introduce a home automation system that can be controlled with hand gestures. The detailed objectives are as follows:

- To assemble a functional prototype integrating webcam with Raspberry Pi to control LED and motor through hand gestures.
- To conduct testing to evaluate the accuracy and reliability of the gesture recognition algorithms in controlling LED and motor.
- To study the effectiveness of webcam in scope of this project.

By accomplishing these objectives, the project aims to contribute a complete model for an energy efficiency-based home automation system.

اونيؤرسيتي تيكنيكل مليسيا ملاك
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

1.5 Scope of Project

The scope of this project are as follows:

- Detect the motion of hand gesture performed by the house residents.
- Process the image with Python and Raspberry PI OS installed.
- Make decisions according to the user’s command.

Assessing the knowledge about the algorithms used for hand gesture recognition.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss the method and concept that will be used in this project based on the information and the sources that was obtained from books, journals, and website. This section basically guides for preparing the entire report content and the study on existing home automation system using microcontroller was also carried out in this chapter to assessthe characteristics of a home automation system to be taken as a reference.

2.2 Understanding Current Issue in the Home Automation System

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Homeowners often struggle to effectively manage and control their living environments due to the complexity and inefficiency of existing home automation systems. Many current systems are plagued by manual operation requirements and complicated setup procedures, leading to user frustration and suboptimal performance. As a result, homeowners experienceinconveniences and are unable to fully leverage the potential benefits of home automation, such as reduced energy usage, enhanced comfort, and streamlined daily routines. To address these challenges, a user-friendly and effective home automation system is essential. By focusing on user-friendliness and effective integration, developers can create home automation solutions that truly meet the needs of modern homeowners.

2.3 Energy Efficiency in Households and its effect

As energy consumption increasingly contributes to climate change through carbon emissions, attention from both scholars and policymakers has focused on household-level energy-saving behaviors and expenditures. This study aimed to determine whether purchasing energy-saving products reduces greenhouse gas emissions at the household level and whether such behaviors are influenced by changes in household income. From [], has conducted a comprehensive survey across 37 nations, utilizing both internet-based and face-to-face methodologies, resulting in 100,956 observations. Across countries, the author founda positive correlation between household wealth and energy consumption expenditure, indicating that energy usage tends to rise with improved household wealth. Additionally, in27 out of 37 countries, including China, India, the United States, and Germany, households exhibited a positive relationship between energy expenditure and life satisfaction. Furthermore, the study confirms the beneficial effects of household energy-saving behaviors. However, while the purchase of energy-saving products shows some impact on reducing energy consumption expenditure, it is limited compared to energy-curbing behaviors. In conclusion, achieving carbon-neutral households solely through reducing energy consumption expenditure poses challenges.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2.3.1 Understanding Home Automation System

In the modern era of living, the concept of home automation system stands as a beacon of technological advancement and innovation, by their smoothness integration of sensors, actuators, controllers, and communication interfaces that have redefined the way of we interact with our living spaces. This section covers the functionalities, applications, and profound impact of home automation systems.

At the heart of home automation systems lies a plethora of functionalities designed to enhance convenience, comfort, and efficiency within residential settings. Lighting control features allow users to adjust brightness levels, set schedules, and create ambiance with a simple tap on their smartphones. Climate control systems regulate temperature, humidity, and air quality, ensuring optimal comfort while minimizing energy consumption.

Despite the remarkable strides made in the realm of home automation, challenges and opportunities for improvement persist. High initial costs, interoperability issues, and cybersecurity concerns represent notable hurdles that must be addressed to foster widespread adoption and acceptance. Additionally, future research and development efforts should focuson enhancing user experiences, expanding compatibility with emerging technologies, and promoting sustainability through energy-efficient design and operation. Collaboration among industry stakeholders, policymakers, and researchers will be essential in charting thecourse for the future evolution of home automation systems.

In conclusion, home automation systems epitomize the fusion of technology and lifestyle, offering a glimpse into the homes of tomorrow. From humble beginnings to unprecedented sophistication, these systems have evolved to become indispensable assets in modern living, enhancing convenience, efficiency, and security for homeowners worldwide. As we embracethe future of smart living, the transformative potential of home automation systems shines bright, illuminating a path towards a more connected, intelligent, and sustainable future.

2.3.2 Mediapipe and Deep Learning Model

The deep learning model that MediaPipe uses for hand gesture recognition is built for real-time performance. It is optimized to run efficiently on low-power devices by using lightweight neural networks that maintain accuracy while minimizing computational overhead. For instance, MediaPipe utilizes MobileNet, designed specifically for mobile and embedded systems. This optimization allows for real-time processing, even when running on hardware with limited resources. Additionally, MediaPipe uses hardware acceleration techniques, such as GPU support, to further enhance the model's performance. This makes it possible to detect and track hands and fingers at high frame rates, enabling dynamic hand gesture recognition for applications like controlling home automation systems.

The 3D landmark estimation feature of MediaPipe is particularly useful for understanding the depth and orientation of the hand. This is important for distinguishing between different hand gestures and detecting subtle movements or positions, such as pointing or grasping. By processing both the 2D image and 3D spatial information, MediaPipe provides a more comprehensive understanding of hand gestures. The 21 hand landmarks serve as the foundation for gesture recognition, allowing for complex gestures, such as open or closed hands, specific finger combinations, or even dynamic gestures like swiping or pinching, to be detected with high accuracy.

2.3.3 Gesture Recognition Using Webcam

Gesture recognition using webcam technology has emerged as a powerful tool with far-reaching implications across various domains, from healthcare and education to entertainment and security. By enabling users to interact with technology through natural body movements, webcam-based gesture recognition systems offer innovative solutions to address pressing societal and global challenges. This essay explores the multifaceted applications of webcam technology in gesture recognition and its potential to contribute to positive societal impact.

One of the most significant benefits of webcam-based gesture recognition is its potential to enhance accessibility for individuals with physical disabilities. Traditional input devices such as keyboards and mice can pose challenges for people with mobility impairments. However, by utilizing webcams to detect hand gestures, individuals can control devices and interact with technology without the need for physical input devices. This empowers people with disabilities, enabling greater independence and inclusion in both personal and professional settings.

Webcam-based gesture recognition technology holds immense potential to address a wide range of societal and global challenges across various domains. From enhancing accessibility for individuals with disabilities to improving healthcare delivery, education, entertainment, and security, webcam-based gesture recognition systems offer innovative solutions with tangible benefits for individuals, communities, and society as a whole. By harnessing the power of webcam technology, developers and researchers can continue to innovate and create positive societal impact, unlocking new possibilities for human-computer interaction and technology-driven solutions to complex challenges.

2.4 Literature Review based on Several Research Paper

The main goal of a literature review is to make a link between the project idea and the body of information and concepts that already exist regarding a certain topic. Before starting this research, a comprehensive review of the literature was done to learn about the technologies that were used and the approaches that were used in earlier research on the same topic.

For the past five years, Malaysia has emitted about 240 million tons of CO2 emissions [14]. This indicates that the energy consumption has reached higher than what was expected. Energy consumption started to rise in the year 2018 as demand increased. TheSuruhanjaya Tenaga proposed a plan to sustain the non-renewable sources so crisis would be averted. However, in 2020 the whole world was struck by covid-19 when the overuse ofenergy sources was inevitable. By utilizing the Home Automation System, it can detect the presence of owners and act according to their instructions, which is more efficient and convenient.

The main idea is to create a functional prototype which enables hand gesture recognition to control lights, fans, and buzzer. To execute this, information regarding home automation systems from other papers was needed so a level of understanding is met before doing the project. One of the papers by [1] Dong-Luong Dinh proposes an automation system using hand gestures which explores system that utilizes depth imaging sensors to control appliances in smart home settings through hand gestures. This system identifies different parts of the hand within a depth silhouette, allowing for the generation of control commands. This approach involves creating a database of synthetic hand depth silhouettes and their corresponding labeled hand part maps, which is then used to train a random forests classifier. This classifier enables the recognition of hand parts within a depth silhouette, subsequently facilitating the generation of control commands through our interface. Testing on real hand gestures yielded an impressive average recognition rate of 98.50% across five subjects. Withthis interface, users can effortlessly control various smart home appliances like TVs, fans, lighting, and doors, adjusting parameters such as channels, temperature, and volume using simple hand gestures.

In the next study, the paper by[2] Harshitaa A discusses gesture recognition which offers a means for individuals with disabilities to control home appliances. Gestures, definedas movements or motions of the human body, serve as inputs for various applications including sign language recognition, human-computer interactions, and more. Hand gesturesare particularly common for appliance control, enhancing functionality. The author has proposed a system that demonstrates the effectiveness of using hand gestures to effortlessly manage electronic home appliances. Key concepts such as deep learning, artificial intelligence, and automation are integral to achieving this goal. These techniques enable appliance control via camera input, eliminating the need for sensors. Consequently, the project aims to empower disabled individuals to operate their home appliances comfortablyfrom a fixed position using only a camera, leveraging deep learning algorithms and artificialintelligence, all without requiring internet connectivity.

Furthermore, a study made by Troy Malatesta [3], Efforts in residential automation and energy management systems have primarily focused on reducing energy consumption within homes. These systems are designed to align with human behavior, potentially influencing people's energy consumption habits. While energy-efficientbuildings have been heralded as a sustainable solution for optimizing energy usage and generation, several studies have highlighted their limitations. The emergence of the home system of practice, rooted in Social Practice Theory, represents a novel approach to designing these systems. This framework emphasizes the routines and repetitive behaviors inherent in individual lifestyles, shaping the temporal aspects of energy consumption. In a study monitoring an Australian home equipped with renewable energy systems and smart technology, the goal was to assess the performance of automation systems and their interaction with occupants' routines. The paper delves into the efficacy of integrating socialtheories and the home system of practice into the design of energy-efficient buildings and management systems. Employing machine learning techniques, the methodology aimed to identify patterns in energy consumption data and correlate them with occupants' lifestyles and routines. By analyzing these patterns, the study sought to elucidate why the automation system in the home under examination did not function as intended and proposed design modifications to enhance its effectiveness and performance.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Moreover a research by Rung-Ching Chen [4], the author utilized Raspberry Pi astheir development environment. By employing Mediapipe to detect hand nodes, our systemcan identify gestures for controlling light switches. This research serves as a foundation thatcan be expanded to encompass various other smart home applications in the future. This project utilized Mediapipe's gesture nodes for identification purposes. The task involves locating each node based on its name, organizing the node identifications for specific gestures, and implementing these arrangements within the program. Subsequently, the program undergoes debugging to ensure its functionality, followed by assessing the accuracyof gesture recognition.

Followed by a paper from Zhiyong Zou [5], to enhance the efficiency and convenienceof intelligent home control for the elderly, this study introduces a smart home system controller designed around Raspberry Pi. With a simple hardware structure and low development costs, the design utilizes a Raspberry Pi development board and Python language. The fatigue detection algorithm is implemented using OpenCV, Dlib, and the EAR algorithm. Various hardware components such as temperature and humidity sensors, an infrared extended version, and an LCD display screen enable intelligent control of indoor environments. The test results demonstrate accurate fatigue state detection and successful electrical control functionality. This design elevates household control intelligence, meetingthe demand for energy-saving convenience in daily life.

The second main idea was to evaluate and test the reliability of hand gesture recognition. Since Kinect Sensor has, depth sensing by using IR sensor and skeletal trackingsoftware it is important on how accurate the device reads the gesture especially the small joints such as fingers. The study by Truong Quang Vinh [6], presents a novel method for hand gesture recognition utilizing depth images obtained from Kinect sensors. Initially, handregion extraction is achieved by applying thresholds to hand points detected using the NITE2 library from PrimeSense. Subsequently, a feature vector is extracted, encompassingmetrics such as the count of open fingers, angles between fingertips and the hand's horizontalaxis, angles between consecutive fingers, and the disparity between the distance from the hand center to fingertips and the radius of the largest inscribed circle. Finally, a support vector machine (SVM) is employed to distinguish between different gestures. Experimental findings demonstrate that the proposed approach achieves real-time hand gesture recognitionaccuracy of 95%.

In the experiment, the hand gesture recognition system was implemented on an Intel Core i5-560M computer using Visual Studio 2012 and C++ programming language. The interface with the Kinect sensor was facilitated by the OpenNI 2 library, while image processing steps and the SVM classifier were handled by the OpenCV library. To create a database for hand gesture recognition, the author enlisted the participation of five students from the IC-Lab at Ho Chi Minh City University of Technology. They were tasked with performing 11 gestures within a range of 50cm to 1.5m, with each gesture repeated at least 10 times per person. This resulted in a total of 620 samples, which were used to train the SVM classifier. For evaluating the proposed hand gesture recognition method, the author employed two testing approaches: sampling testing and visual testing. In the sampling testing method, they enlisted 10 different individuals, each performing 11 different gestures, with each gesture repeated at least 10 times. This yielded a total of 1926 samples, and the evaluation results were presented in a confusion matrix (Table 1), indicating an accuracy of at least 93%.

The study made by Anagha P. Dhote [7], introduces an innovative system for real-time hand tracking and gesture recognition. The SIFT algorithm is employed to generate image features that exhibit invariance to translation, scaling, rotation, and partial invariance to changes in illumination. By matching the extracted key points with stored key points, the system identifies gestures from captured images. Experimental validation was conducted on the MATLAB platform, resulting in successful recognition of various gestures. To demonstrate the system's adaptability, experiments were conducted under different lighting conditions in real time. The achieved results are both rapid and promising. The scale invariant feature transform (SIFT) algorithm, developed by Lowe [1], is an algorithm for image features generation which are invariant to image translation, scaling, rotation and partially invariant to illumination changes and affine projection. SIFT algorithm can be used to detect distinct features in an image. Computation of SIFT image features is performed through the four consecutive phases which are Scale-Space Local Extrema Detection, Keypoint Localization, Orientation Assignment and Keypoint Descriptor.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Followed by a study Ming Guang Yong [8] the author determines that the requirement for precise and reliable tracking performance in real-time, on-device applications is the main obstacle to hand tracking. Conventional hand tracking techniques are not appropriate for on- device deployment because they may depend on intricate algorithms or demand a large amount of processing power. Furthermore, difficult lighting circumstances, hand posture fluctuations, and occlusions may be problems for the systems now in use. With MediaPipe Hands, these drawbacks should be addressed and a portable, effective, and precise hand tracking solution offered. MediaPipe Hands introduces a deep learning-based hand tracking pipeline that operates efficiently on-device. The pipeline consists of several key components, including a palm detection model and a hand landmark model. The palm detection model identifies the presence and location of hands in the input image, while the hand landmark model detects and localizes key landmarks on the detected hands. These landmarks include points such as fingertips, knuckles, and wrist positions, enabling precise hand tracking and pose estimation.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2.5 The Comparison of Selected Literature Review

Title of Journal	Author	Description
[1] Hand Gesture Recognition and Interface via a Depth Imaging Sensor for Smart Home Appliances (2014)	Dong-Luong Dinh, Jeong Tai Kim, Tae-Seong Kim	A hand gesture recognition system was developed for appliance control in smart home using the labelled hand parts via the trained RFs from a hand depth silhouette. **Advantage**: The state of each finger is directly identified by recognizing the hand parts and then hand gestures are recognized based on the state of each finger. **Disadvantage**: Creating and maintaining the database may require significant effort and resources, including collecting and

		labeling data, training the classifier, and updating the database to accommodate variations in hand gestures over time.
[2] Gesture based Home appliance control system for Disabled People (2021)	Harshitaa A, Hansini P, Dr. P. Asha	The system proposed helps the disabled and elderly people to control the electronic home appliances with ease without any internet connectivity. **Advantage**: The system eliminates the need for physical interaction with appliances, providing a convenient and intuitive interface. **Disadvantage**: Relying solely on camera-based gesture recognition is the risk of limitations in accuracy and reliability, particularly in varying lighting conditions or environments with background clutter.
[3] Systems of social practice and automation in an energy efficient home (2022)	Troy Malatesta, Christine Eon	The author monitored an Australian home that consisted of renewable energy systems, smart technology and automated systems designed to reduce the use of grid electricity. **Advantage**: By understanding the temporal characteristics of energy consumption within the context of daily life, designers can tailor automation systems to better align with the needs and preferences of users. **Disadvantage**: Designing energy efficient buildings and management systems is the complexity of capturing and integrating diverse user behaviors and preferences. Human behavior is inherently dynamic and multifaceted, making it challenging to accurately predict and accommodate individual routines and lifestyles
[4] Using Finger for Smart Home Applications 2023	Rung-Ching Chen	The author developed a hand gesture recognition system to control the lights by using Raspberry PI and a camera.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

		Advantage: Raspberry Pi's versatility allows flexible customization and expansion, accommodating various sensors, actuators, and communication protocols required for smart home applications. **Disadvantage:** While Raspberry Pi offers sufficient capabilities for basic tasks and applications, complex algorithms and real-time processing may strain its performance.
[5] Design of smart home controller based on raspberry PI (2020)	Zhiyong Zou, Ying Wang, Li Wang	The author designed a smart home system controller based on raspberry PI with simple hardware structure and low development cost. **Advantage:** The integration of OpenCV visual library, Dlib library, and EAR (Eye Aspect Ratio) algorithm enables the detection of fatigue states with high accuracy, enhancing the safety and well-being of elderly users. **Disadvantage:** The implementation of fatigue detection algorithms using computer vision techniques may be computationally intensive, potentially impacting the system's overall performance and responsiveness.
[6] Hand Gesture Recognition Based on Depth Image Using Kinect Sensor (2015)	Truong Quang Vinh, Nguyen Trong Tri	The author developed a novel method for hand gesture recognition that performs accurately in real time using depth information from Kinect sensor. **Advantage**: Depth images provide richer information compared to traditional RGB images, allowing for more accurate and robust hand region extraction **Disadvantage**: The reliance on proprietary libraries like NITE 2 provided by PrimeSense for hand region extraction may introduce compatibility issues or licensing

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

		constraints, hindering the flexibility and portability of the system.
[7] A Novel System of Real Time Hand Tracking and Gesture Recognition (2017)	Anagha P. Dhote, Vikramsingh R. Parihar	The author developed a systems which is capable of gesture recognition in real time domain. **Advantage:** The system can effectively track and recognize hand gestures in real-time, providing a seamless and intuitive interface for users. **Disadvantage:** The computational overhead of feature extraction and matching could lead to latency issues or reduced responsiveness, particularly in applications requiring high-speed gesture recognition
[8] MediaPipe Hands: On-device Real-time Hand Tracking [2020]	Ming Guang Yong, Andrew W. Fitzgibbon	The authors introduced a deep learning (CNN) based hand tracking pipeline that operates efficiently. **Advantage:** The system has a built-in palm detection model and hand landmark model that identifies the presence and location of hands in the input image. **Disadvantage:** Struggles with accurately tracking hands in high complex or cluttered environments.

Table 2.1: Literature Review Comparative Analysis

2.6 Summary

The literature review aimed to establish a connection between the project idea and existing knowledge on gesture recognition and home automation systems. Various methods were explored, including a Raspberry PI, a camera, and a Webcam. The importance of hand gesture recognition algorithms was emphasized.

One approach involved a system which proposed Hand Parts Recognition. The system focuses on accurately identifying the various parts of the hand within depth images captured by a depth camera. This process begins with the creation of a synthetic hand database (DB), which contains a vast collection of depth maps paired with corresponding hand parts-labelled maps. These maps serve as training data for the system's machine learning components, specifically Random Forests (RFs), which are trained to recognize different hand parts based on the depth information provided.

The literature review concluded with a comprehensive exploration of various technologies and methodologies, emphasizing the need for an effective system to read hand gestures of the house residents to control the applications.

CHAPTER 3

METHODOLOGY

3.1 Introduction

A comprehensive intro to research methodology offers a thorough examination of numerous scientific frameworks and methods, as well as the related instruments and techniques. This chapter covers the utilization of Raspberry Pi and Webcam to developa home automation system. This chapter covers the approach that entails in choosing the project title and the components that will be required. To do this, a flow chart which contains all of the processes required to execute the project from beginning to end is prepared. Before starting this project, it is important to understand the hardware and software resources that will be used. This chapter seeks only to focus on design techniques.

3.2 Sustainability for The Home Automation System.

. Sustainability is crucial for the project of Home Automation System to ensure long term effectiveness and impact. This involves several key aspects. Firstly, it is important to design the system with energy efficiency in mind, minimizing power consumption to reduce environmental impact. Implementing a smart energy management features such as turning offthe LED lighting and motor usage when there is no human presence will increase energy efficiency. Furthermore, the system uses hand gesture recognition model which willbe the basis for the project. This will allow the system to focus on computational resourceson specific parts of the video feed, rather than processing the entire frame. This selective processing reduces the overall computational load which will lower the energy consumption. The method will also allow real-time gesture recognition, resulting in faster response times for user commands. By integrating these methods, performance and energy efficiency will be enhanced making it more sustainable product.

3.3 Methodology

This project focuses on creating a gesture-based control system that allows users to operate home appliances such as lights, fans, and buzzer through hand gestures using a webcam and a Raspberry Pi. The webcam captures video, which is processed with the help of MediaPipe to recognize hand gestures. When a specific gesture is detected, it triggers the corresponding relay to control an appliance, such as turning on a light or fan when a particular set of fingers are extended. To ensure the system is effective only when the user is present, MediaPipe Pose is employed to detect body movement. If the system detects no body for a specified period, it automatically turns off the devices. Each video frame is analyzed, starting with converting the image into RGB format for compatibility with the gesture recognition model, followed by flipping the frame to simulate a mirror effect for better user interaction. The program identifies different hand gestures, such as extended index or multiple fingers, and associates these with certain actions. The GPIO pins on the Raspberry Pi control the relays, providing real-time switching of appliances based on the user's gestures. The status of these appliances is displayed on an LCD screen, giving clear feedback to the user. One of the major challenges was to ensure the system works efficiently in real-time, minimizing delays, improving accuracy in gesture recognition, handling varying lighting conditions, and avoiding errors where the system might mistakenly activate appliances without the user being present. Key steps in overcoming these issues included fine-tuning the gesture detection algorithm, setting time limits for gestures, and integrating automatic appliance shutdown when no movement is detected. This project successfully integrates gesture recognition, body detection, and home automation, allowing users to control their environment intuitively while optimizing energy use.

3.4 Block Diagram of the Project

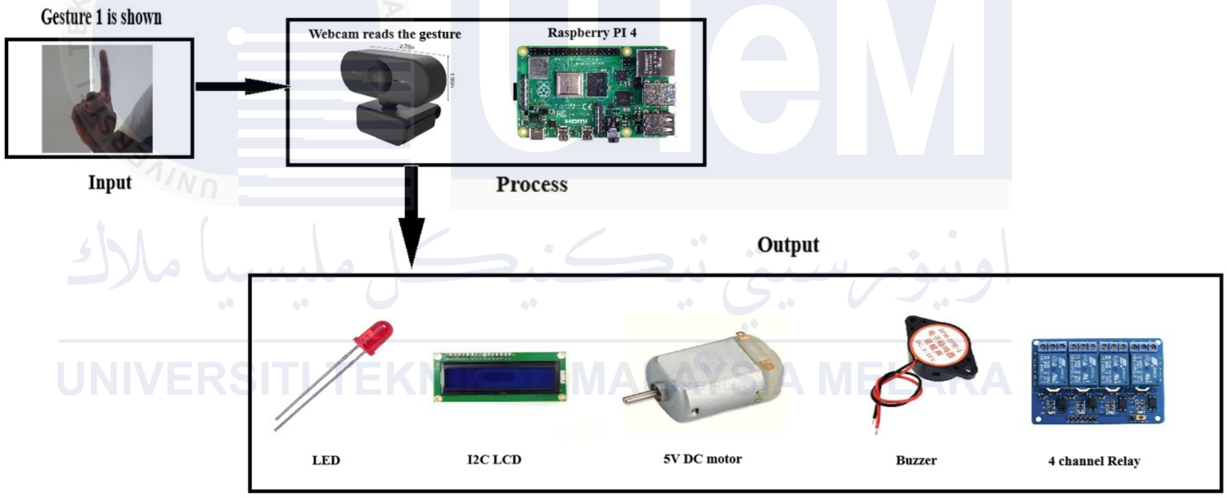


Figure 3.1 Block Diagram of the Project

The block diagram of the project represents the flow of data and control signals from the input to the output. The system starts with the Input stage, which involves capturing a Gesture from the user. This gesture is detected through a webcam, where MediaPipe is used for hand gesture recognition. The Process stage is handled by the Webcam and Raspberry Pi. The Raspberry Pi receives the video feed from the webcam, processes the gesture data, and analyzes it to detect specific gestures. The processing includes image transformations such as RGB conversion and frame flipping to facilitate gesture recognition. Once the gesture is identified, it is translated into actions. The Output stage involves multiple devices: a 4-channel relay for controlling appliances like lights, fans, or other electronics; an LED to provide visual feedback for system activity; a 5V DC motor for tasks that require movement; a Buzzer for alerts or notifications; and an LCD to display the current status of the system (e.g., which appliances are on or off). Each component in the output stage is activated or deactivated based on the user's gestures, creating an interactive and automated environment.

3.5 Flowchart of the Project

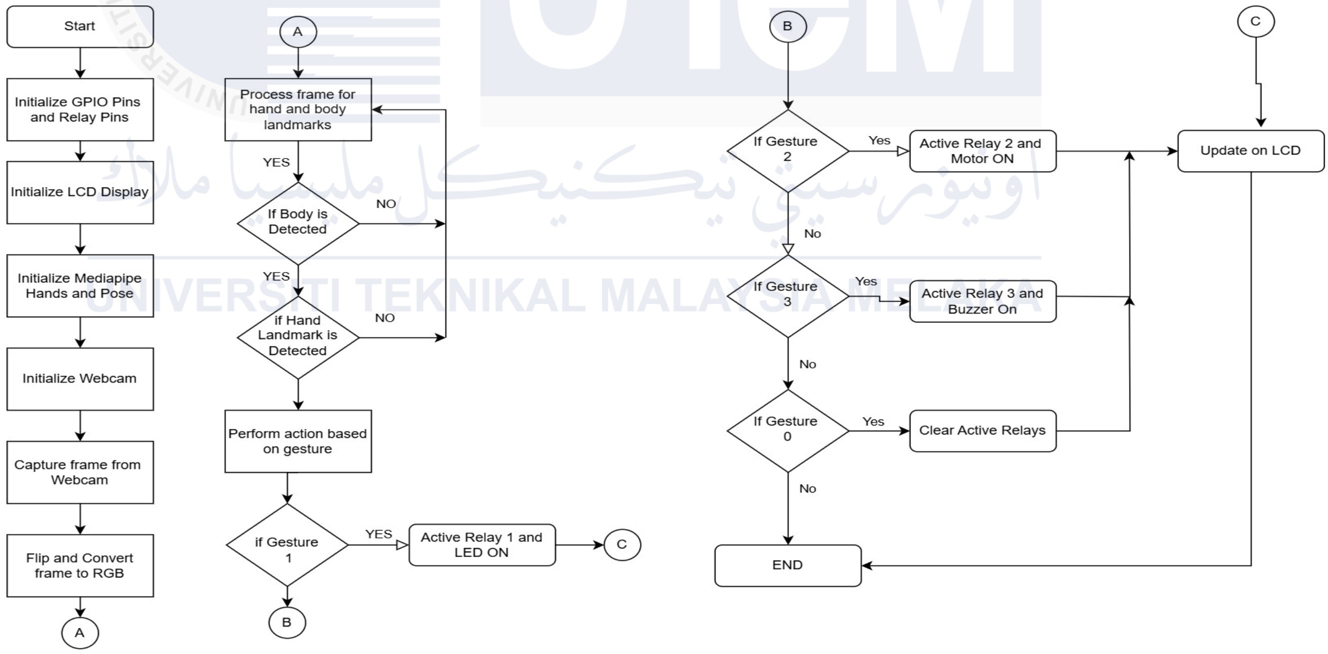


Figure 3.2 Flowchart of the Project

The flowchart illustrates the gesture-based control system workflow. It begins with initializing GPIO pins, relay pins, an LCD display, Mediapipe Hands and Pose models, and the webcam. The webcam captures and processes frames, flipping them to RGB format. If a body is

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

detected, it checks for hand landmarks and identifies gestures. Based on the gesture detected, specific actions are triggered. Gesture 1 activates Relay 1 and an LED, Gesture 2 activates Relay 2 and a motor, Gesture 3 activates Relay 3 and a buzzer, and Gesture 0 clears active relays. Updates are shown on the LCD, and the system loops back to process subsequently frames, ensuring continuous functionality.

3.6 Software Implementation

3.6.1 Python

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Figure 3.3 Python Software

Python is a versatile, high-level programming language known for its simplicity and readability. The python abstracts many complex programming concepts, making it easier to write code compared to lower-level languages like C or assembley. Python's syntax is clear and is very easy to understand which makes it a formidable choice for beginners. The software comes with a variety amount of library that includes modules for many tasks. Since the project depends on visualisation and data analysis, python seems a valid choice as it has the library for hand tracking (Mediapipe) and gesture recognition (OpenCV).

3.6.2 Microsoft Visual Studio Code

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Figure 3.4 Microsoft Visual Studio Code

For the development and management of our gesture recognition and home automation system, we utilized Visual Studio Code (VS Code), a robust and lightweight code editor. As an open-source integrated development environment (IDE), VS Code offers a user-friendly interface along with advanced features that enhance the coding experience, making it particularly suitable for our project on both Raspberry Pi and PC platforms.VS Code supports a variety of programming languages, with Python being the primary language for our gesture recognition system. The Python extension available in VS Code includes functionalities such as syntax highlighting, IntelliSense, and debugging tools, which facilitate the writing and troubleshooting of code. Furthermore, VS Code integrates effortlessly with several version control systems, including Git, allowing us to monitor code modifications and collaborate effectively. Its terminal support enables the execution of scripts directly within the editor, while the integrated Jupyter Notebooks assist in testing and visualizing code outputs throughout the development phase.

3.7 Hardware Implementation

3.7.1 1080P Webcam

Figure 3.5 Webcam Full HD 1080P

For our gesture recognition and home automation system, we have utilized **an** HD CMOS sensor webcam capable of capturing high-definition video with a resolution of 1920x1080P **at** 30FPS. This provides clear, real-time video necessary for accurate gesture detection, especially when tracking hand movements in dynamic environments. The webcam's M-JPEG video output format and compatibility with BMP and JPG photo formats ensure that it can capture both video and still images effectively. The 50Hz blink control improves image quality in different lighting conditions, making it suitable for various room environments in our home automation setup. This webcam is plug-and-play with a USB 2.0 interface, easily connecting to the Raspberry Pi for seamless integration with the gesture detection system. With a 150cm USB cable, it offers flexibility in positioning the webcam in the desired location. It also supports Windows, Mac OS, and Linux, making it a versatile choice for the project. Its focusing range of 20mm ensures precise detection of hand gestures at close distances, which is crucial for accurate control of the home automation system, such as turning lights, fans, and buzzers on or off based on specific hand gestures.

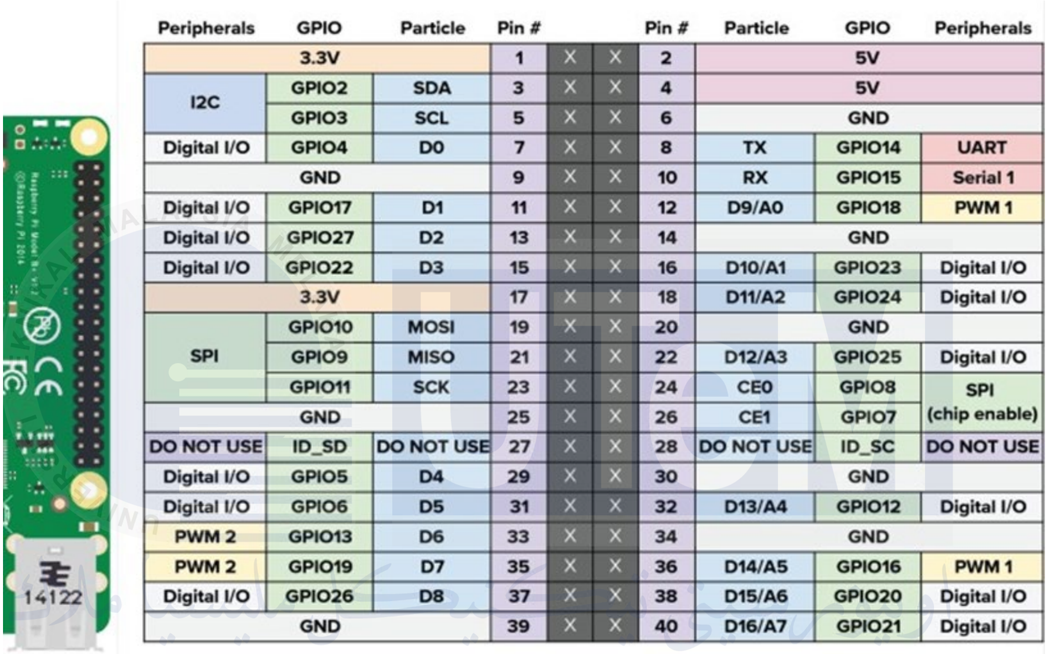
3.7.2 Raspberry PI 4 Model B

Figure 3.6 Figure of Raspberry PI 4 Model B

The Raspberry PI is the fourth generation of the Raspberry PI series of single-board computers developed by the Raspberry Pi foundation. This particular model has improved perfomance, enhanced connectivity and expanded capabilities. It uses a more powerful processor and increased RAM options compared to old models. It has two usb 3.0 ports which can be used for webcam. It has GPIO 40-pins which makes the board to be flexible with input

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

and output connections. The model also has many memory options whichis 2GB,4GB and 8GB to easily meet the specific requirements that project required. The Raspberry Pi is supplied with DC signal which makes it more convenient for the project asit uses DC based output.



Peripherals	GPIO	Particle	Pin #	Pin #	Particle	GPIO	Peripherals
	3.3V		1	2		5V	
I2C	GPIO2	SDA	3	4		5V	
	GPIO3	SCL	5	6		GND	
Digital I/O	GPIO4	D0	7	8	TX	GPIO14	UART
	GND		9	10	RX	GPIO15	Serial 1
Digital I/O	GPIO17	D1	11	12	D9/A0	GPIO18	PWM 1
Digital I/O	GPIO27	D2	13	14		GND	
Digital I/O	GPIO22	D3	15	16	D10/A1	GPIO23	Digital I/O
	3.3V		17	18	D11/A2	GPIO24	Digital I/O
SPI	GPIO10	MOSI	19	20		GND	
	GPIO9	MISO	21	22	D12/A3	GPIO25	Digital I/O
	GPIO11	SCK	23	24	CE0	GPIO8	SPI (chip enable)
	GND		25	26	CE1	GPIO7	
DO NOT USE	ID_SD	DO NOT USE	27	28	DO NOT USE	ID_SC	DO NOT USE
Digital I/O	GPIO5	D4	29	30		GND	
Digital I/O	GPIO6	D5	31	32	D13/A4	GPIO12	Digital I/O
PWM 2	GPIO13	D6	33	34		GND	
PWM 2	GPIO19	D7	35	36	D14/A5	GPIO16	PWM 1
Digital I/O	GPIO26	D8	37	38	D15/A6	GPIO20	Digital I/O
	GND		39	40	D16/A7	GPIO21	Digital I/O

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Figure 3.7 Figure of Pin layout for Raspberry PI 4

3.7.3 Motor

Figure 3.8 3VDC Motor

The 3V motor represents a physical actuator in the system, capable of performing tasks like driving a small mechanism or demonstrating motion-based outputs. Controlled via Relay 2, the motor is activated upon detecting Gesture 2. Its compact size and compatibility with the relay module make it an ideal choice for this project, where gestures directly influence real-world operations.

3.7.4 LED

Figure 3.9 LED

The LED is used as a simple visual indicator for system status or successful gesture recognition. For example, when Gesture 1 is detected, the LED is turned on via Relay 1, providing immediate feedback to the user. Its low power requirements and straightforward integration make it a practical component for testing and real-time operation acknowledgment in this gesture-based control system.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

3.7.5 Buzzer

Figure 3.10 Buzzer

The buzzer adds an auditory feedback element to the system. It is triggered by Relay 3 upon detecting Gesture 3, producing a sound to notify the user of the associated action. This component enhances the user experience by incorporating audio cues, making the system accessible even in scenarios where visual feedback might be insufficient.

3.7.6 LCD

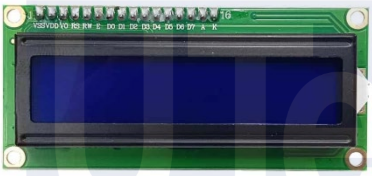


Figure 3.11 LCD

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

The LCD is used to display system updates, such as the detected gesture or the current status of connected devices. It provides clear and concise feedback, enhancing the usability of the system. By integrating this component, the project ensures that users have a real-time understanding of the system's responses, adding a layer of interactivity and transparency to the gesture-based control system.

3.7.7 4- Channel Relay

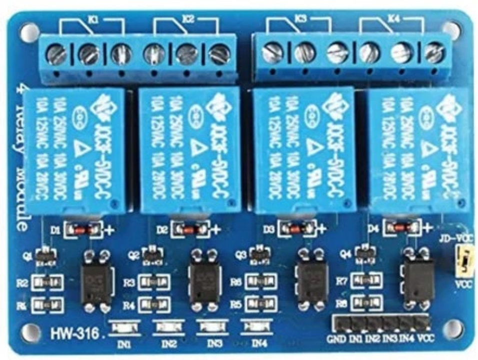


Figure 3.12 4-Channel Relay

The 4-channel relay module serves as the core switching mechanism in the project, allowing the Raspberry Pi to control multiple high-power devices safely. Each relay operates as an electrically controlled switch that can toggle devices like motors, buzzers, or other appliances on or off. By using GPIO signals, the relays isolate the Raspberry Pi from high-voltage circuits, ensuring the system's safety and reliability. In this project, specific gestures detected by the webcam activate individual relays, enabling dynamic control of connected devices.

3.8 Developing the Hand Recognition System

3.8.1 Hand Detection and Tracking

MediaPipe Hands plays a crucial role in detecting and tracking hands for gesture recognition. MediaPipe uses a machine learning-based approach that combines palm detection and landmark localization to achieve real-time hand tracking. Initially, a palm detection model identifies the region of interest containing the hand in the camera feed, generating a bounding box. Following this, a second model predicts the positions of 21 key hand landmarks, including fingertips, joints, and the wrist, represented as normalized 3D coordinates. These landmarks are fundamental for analyzing hand gestures and determining finger states, which are essential for controlling the home automation system.

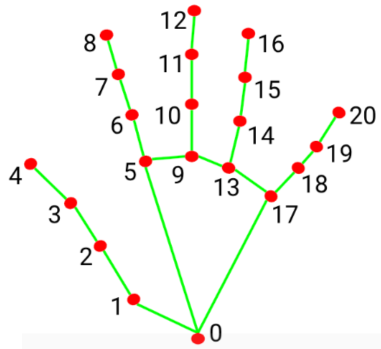


Figure 3.13 21 key hand landmarks

The first stage of the hand gesture recognition pipeline in MediaPipe is hand detection. In this stage, MediaPipe uses a Convolutional Neural Network (CNN) to detect the presence of a hand in the input image. This CNN is trained on large datasets of hand images and is capable of detecting hands under various lighting conditions and hand orientations. The model generates a bounding box around the hand, which is used as a reference for the second stage of the pipeline. This initial detection stage is designed to be lightweight and runs efficiently on devices with limited computational resources, such as smartphones and single-board computers like the Raspberry Pi. The output of the hand detection model is a bounding box that defines the region in the image where the hand is located.

Once the hand is detected, the second stage of the pipeline is landmark estimation. In this stage, MediaPipe's model uses the detected hand region to estimate the coordinates of 21 key landmarks that correspond to various parts of the hand, including the wrist, knuckles, and fingertips. These landmarks are output as (x, y, z) coordinates, where the (x, y) coordinates represent the 2D position in the image and the z-coordinate represents the depth or distance from the camera, providing a 3D representation of the hand. The landmark estimation model is also based on a CNN, trained to learn the spatial relationships between the various parts of the hand and the overall hand pose. This model is capable of handling complex hand gestures and varying hand shapes, as well as detecting multiple hands in a single frame.

3.8.2 Gesture Recognition Algorithm

The hand gesture recognition system in our project was built using a custom logic approach, utilizing the 21 landmarks detected by the Media Pipe Hands library. Each of these landmarks represent specific points on the hand, such as the wrist, joints, and fingertips, and their spatial relationships were analyzed to determine gestures. For instance, the fingertips (Landmarks 8, 12, 16, 20) and their corresponding base joints (6, 10, 14, 18) were essential for identifying whether a finger was extended or folded.

The calculation involved comparing the y-coordinates of the fingertip and its base joint for most fingers. If the y-coordinate of the fingertip was lower (closer to the top of the image), the finger was considered extended. Conversely, if the y-coordinate was higher, the finger was deemed folded. For the thumb, which extends horizontally, the x-coordinate of the thumb tip (Landmark 4) was compared with the x-coordinate of its preceding joint (Landmark 3). If the thumb tip's x-coordinate was greater (for a right hand), the thumb was marked as extended; otherwise, it was folded. This logic was implemented in the code as follows:

```python
def detect_gesture(landmarks):
    """
    Detect the hand gesture based on finger landmarks and return:
    0 for all fingers closed,
    1 for index finger only,
    2 for index and middle fingers,
    3 for index, middle, and ring fingers.
    """
    index_extended = landmarks[8].y < landmarks[7].y and landmarks[7].y < landmarks[6].y
    middle_extended = landmarks[12].y < landmarks[11].y and landmarks[11].y < landmarks[10].y
    ring_extended = landmarks[16].y < landmarks[15].y and landmarks[15].y < landmarks[14].y

    if not index_extended and not middle_extended and not ring_extended:
        return 0  # All fingers closed
    elif index_extended and not middle_extended and not ring_extended:
        return 1  # Only index finger
    elif index_extended and middle_extended and not ring_extended:
        return 2  # Index and middle fingers
    elif index_extended and middle_extended and ring_extended:
        return 3  # Index, middle, and ring fingers
    return -1  # Undefined gesture
```

Figure 3.14 Code for the algorithm

This function assessed the states of individual fingers and mapped them to specific gestures. For example, Gesture 0 represented all fingers folded, Gesture 1 indicated the index finger extended, Gesture 2 represented both index and middle fingers extended, and Gesture 3 involved the extension of the index, middle, and ring fingers. To ensure robust detection, the system incorporated a time threshold and to confirm gestures. A gesture was validated only if it persisted over a specified duration (e.g., two seconds). This was done by maintaining a count of consecutive frames where the same gesture was detected. If the count surpassed the threshold, the gesture was recognized; otherwise, the counter reset. This logic reduced false detections caused by noise or rapid hand movements.

In addition to recognizing hand gestures, the MediaPipe Pose library ensured that the user was within the camera’s range and interacting with the system. MediaPipe Pose provided landmarks corresponding to the user's body posture, such as the shoulders, neck, and torso. The presence of a user was confirmed by tracking the visibility score of specific pose landmarks (e.g., the shoulders). If the visibility of the required landmarks dropped below a threshold or if no user was detected, the

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

system automatically deactivated all outputs. This served as a fail-safe to ensure the system responded only when a user was actively present.

```python
# Timer and gesture threshold
GESTURE_THRESHOLD = 2  # Time in seconds to confirm gesture
BODY_PRESENCE_THRESHOLD = 5  # Time in seconds to turn off outputs if no body is detected
last_body_detection_time = time.time()
```

Figure 3.15 Pose Threshold and Timer

Once confirmed, the gestures triggered corresponding actions, such as controlling GPIO pins to activate relays. For example, Gesture 1 turned on a light, Gesture 2 activated a fan, and Gesture 3 operated a buzzer. The relay states were updated on an LCD to provide real-time feedback to the user. The integration of gesture recognition, noise filtering, and system control in a single pipeline ensured reliable operation. By combining the spatial analysis of hand landmarks with time-based validation, the system provided a robust and accurate solution for gesture-based control.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

3.8.3 System Control and Feedback

Once a gesture was recognized, the system activated or deactivated the appropriate relay connected to external devices, such as light, fan, and buzzer. The LCD displayed the current status of the devices in real-time. To prevent accidental triggering, a gesture confirmation threshold of 2 seconds was implemented. This required the user to maintain a gesture for a specified duration before the system acted on it. The GPIO library was used to control the relays, ensuring reliable operation of the external devices.

3.8.4 Testing and Optimization

The system was tested extensively under various lighting conditions and with different hand positions and orientations to ensure robust performance. Adjustments were made to the gesture recognition logic to minimize false positives, such as misinterpreting background objects or partial hand views as gestures. Additionally, the computational load on the Raspberry Pi was reduced by limiting frame processing to grayscale mode and optimizing the gesture detection algorithm.

3.8.5 Error Handling and Logging

Error handling mechanisms were implemented to manage issues such as lost camera connections or incorrect gestures. Logging functionality recorded system events, including recognized gestures, relay actions, and errors, to a log file stored on the Raspberry Pi. This helped identify and address issues during development and testing.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

3.8.6 Integration and Final Deployment

The hand recognition system was integrated with the rest of the home automation system, allowing gestures to control multiple devices. The entire setup was deployed in a headless configuration to optimize space and usability, with the Raspberry Pi handling all processing and control operations. The final system achieved real-time gesture recognition and device control with high accuracy and reliability.

3.9 Circuit Design

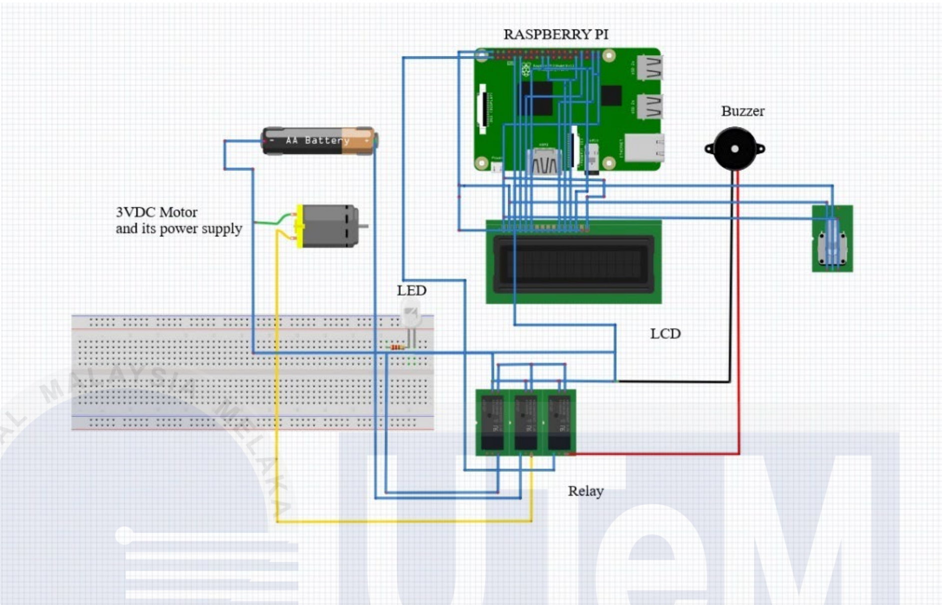


Figure 3.16 Circuit Design of the components

اونيورسيتي تيكنيكل مليسيا ملاك
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

The circuit design consists of a Raspberry Pi connected to a USB webcam for visual monitoring and a 4-channel relay module for controlling various devices. The relay module is controlled through GPIO pins 14, 15, and 18 of the Raspberry Pi, with Relay 1 controlling an LED powered by the 3.3V rail, Relay 2 controlling a 3V motor powered by a 3.7V battery, and Relay 3 controlling a buzzer powered by the 5V supply. Additionally, an I2C LCD display is connected to the Raspberry Pi to provide a user interface for monitoring the status of the devices. This setup enables the Raspberry Pi to manage multiple devices with visual and auditory feedback, creating a simple automation system.

3.10 Summary

This chapter presents a comprehensive approach to building an efficient and effective gesture-controlled home automation system using a webcam and Raspberry Pi. A flow chart has been created to visualize the project's progress, ensuring smooth execution throughout the development stages. Prior to implementation, careful consideration was given to selecting both hardware and software components, which are crucial for ensuring the system's success, ease of development, and cost-effectiveness. By choosing reliable components such as MediaPipe for hand and body detection and ensuring their compatibility with the Raspberry Pi, the project aims to minimize potential challenges. Additionally, the system's performance is continuously monitored, allowing for quick identification and resolution of any hardware or software issues. The project has successfully advanced to the final stages, with all critical aspects integrated to provide a functional and responsive home automation solution.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results and analysis of developing a gesture-controlled home automation system using a webcam for hand detection and a Raspberry Pi for processing and control. It also discusses the necessary steps undertaken to implement the project and ensure its functionality and efficiency. The data collection and testing process were conducted based on predefined criteria to evaluate whether the project's objectives and scope were successfully achieved. Furthermore, the final outcomes of the project, including an analysis of system performance and the integration of a functional prototype, will be detailed in this chapter.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

4.2 Result and Analysis

The development of the system demonstrates that the prototype integrates a variety of components to collect and analyze gesture data effectively. It utilizes a webcam for hand detection and gesture recognition, operating seamlessly under predefined conditions to control the connected devices.

4.2.1 System Design

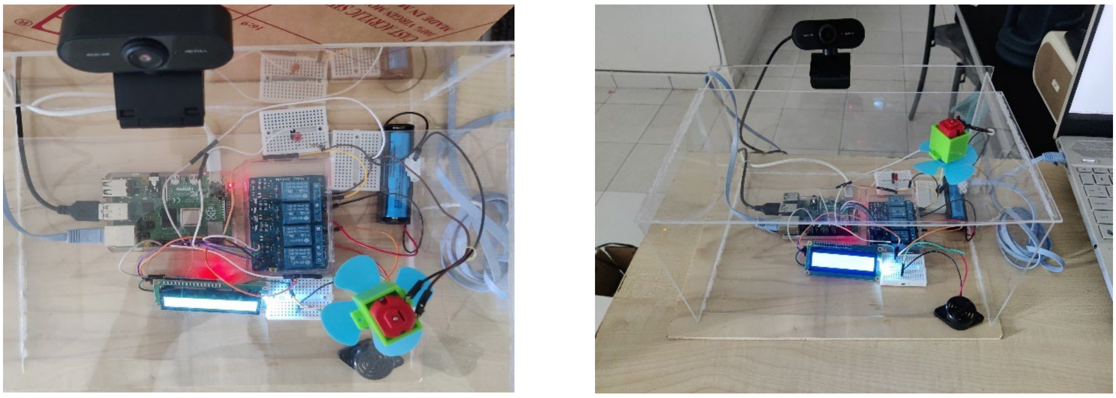


Figure 4.1

Figure 4.1 illustrates the components of the system used for the gesture recognition process. The webcam actively detects hand gestures under specific conditions, such as the recognition of predefined gestures, which trigger the system. The data captured by the webcam is then processed by the Raspberry Pi to activate the corresponding relays, controlling devices like the light, fan, or buzzer as an output response.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

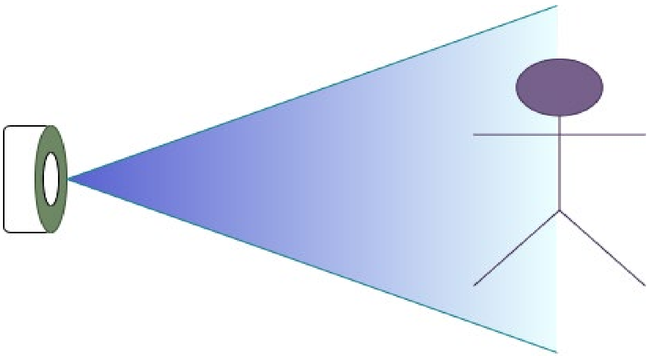


Figure 4.2 Human Presence Detected by Camera using Pose Detection

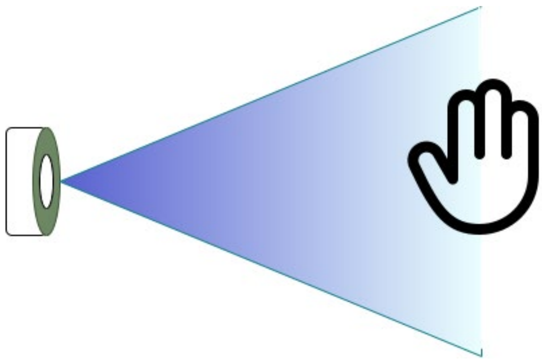


Figure 4.3 Hand Region Detected by Camera

4.2.2 Testing and Result

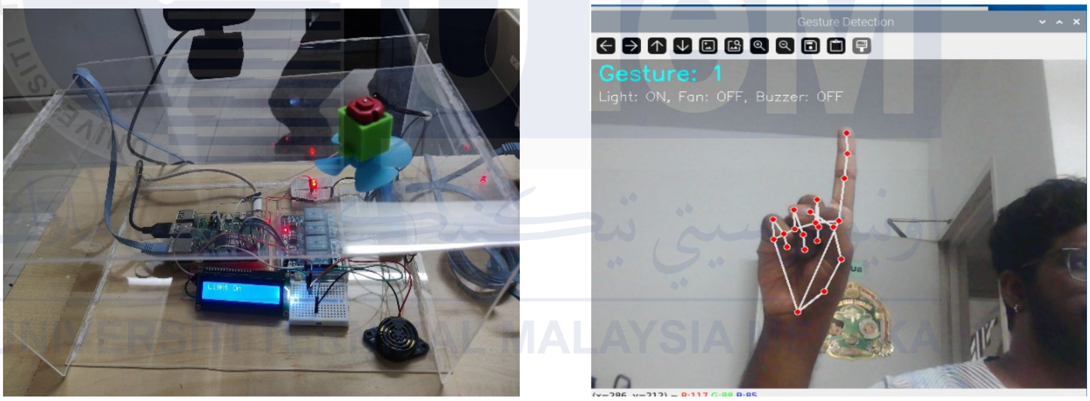


Figure 4.4 Condition for Gesture 1

When the index finger is the only one extended, the system recognizes this gesture and turns on the light by setting the relay for the light (RELAY_1_PIN) to LOW (on). The LCD display will show "Light On" to indicate that the light has been activated.

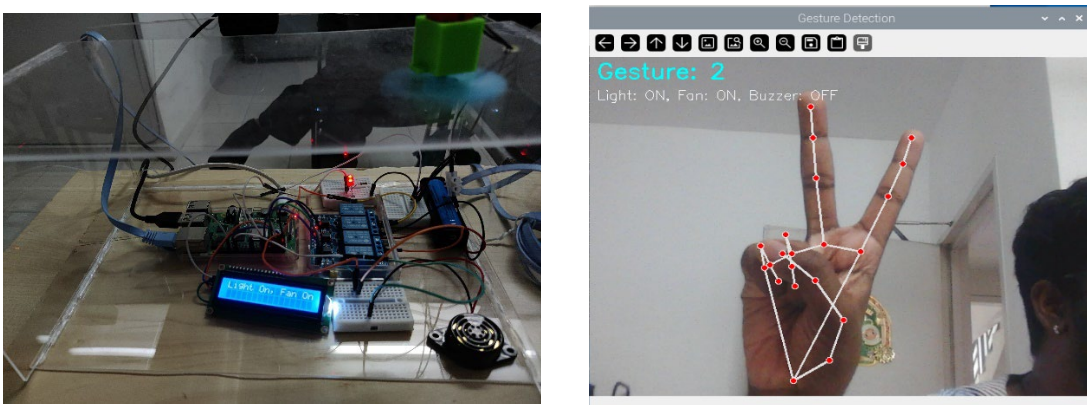


Figure 4.5 Condition for Gesture 2

In this gesture, both the index and middle fingers are extended while the rest of the fingers remain closed. The system interprets this as a signal to turn on the fan by setting the relay for the fan (RELAY_2_PIN) to LOW (on). On the LCD, the status will show "Fan On" to indicate that the fan has been powered on.

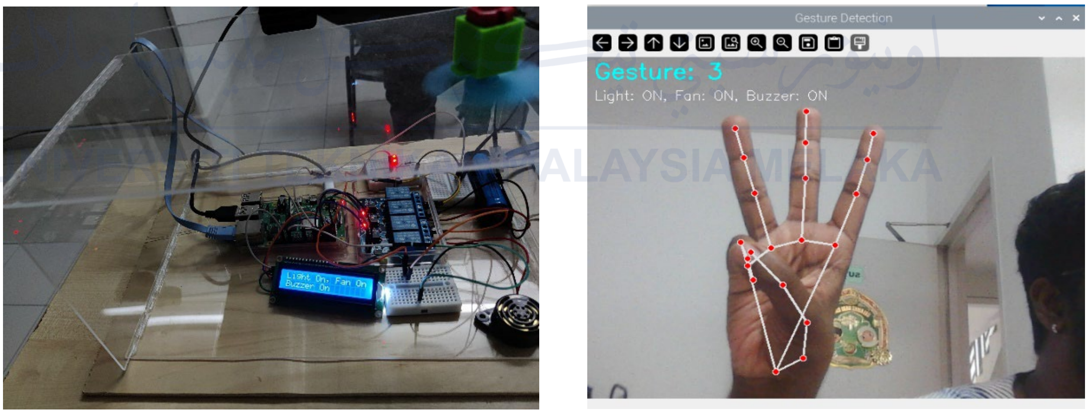


Figure 4.6 Condition for Gesture 3

When the index, middle, and ring fingers are extended, the system triggers the buzzer by setting the relay for the buzzer (RELAY_3_PIN) to LOW (on). The LCD display will update to show "Buzzer On" to indicate that the buzzer has been activated.

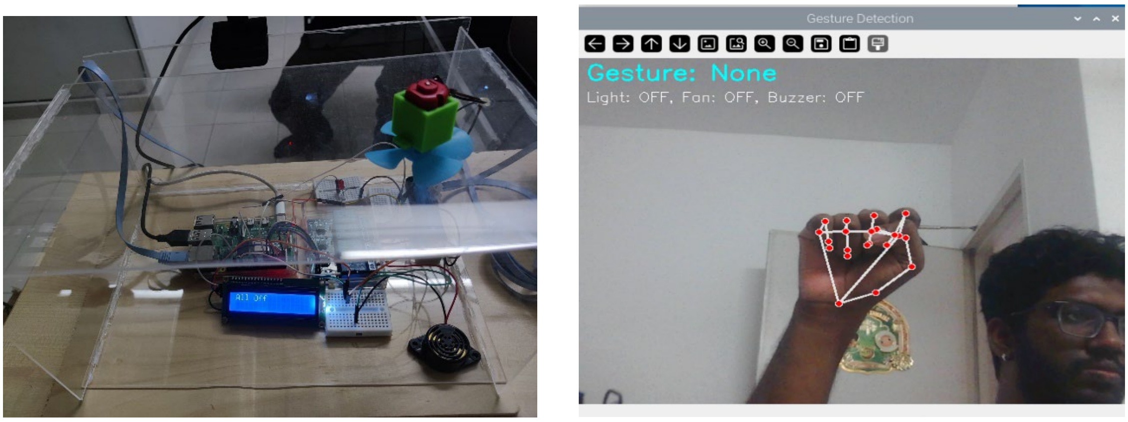


Figure 4.7 Condition for Gesture 0

When all the fingers are closed, the system detects this gesture as a signal to turn off all the activated devices. Specifically, it shuts off the light, fan, and buzzer by setting the respective relay pins to HIGH (off). The LCD display updates to show that all devices are off, displaying "All Off" on the screen.

4.2.3 Sampling Test

Prediction / Actual	Gesture 1	Gesture 2	Gesture 3	Gesture 0
Gesture 1	16	0	0	0
Gesture 2	0	18	4	0
Gesture 3	0	5	20	9
Gesture 0	0	0	4	20

Table 4.1 F1-Score Table

The confusion matrix provided for gesture recognition helps calculate key performance metrics for the model: **precision**, **recall**, and **F1 score**. Precision measures the proportion of true positives (TP) out of all predicted positives (TP + FP), while recall measures the proportion of true positives out of all actual positives (TP + FN). The **F1 score**, which balances precision and recall, is calculated using the formula:

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

$$F1 = 2 * \frac{PRECISION \ X \ RECALL}{PRECISION + RECALL}$$

The F1 score table presents the performance of a gesture recognition model for four different gestures. Gesture 1 achieves perfect precision, recall, and F1 score, indicating flawless detection and classification. Gesture 2 shows a moderate performance with an F1 score of 0.80, with relatively high precision (0.78) and recall (0.82), suggesting a balanced detection rate but with room for improvement. Gesture 3 has the lowest scores across all metrics, with an F1 score of 0.62, reflecting a poor balance between precision (0.67) and recall (0.57), indicating that the model struggles to reliably detect this gesture. Finally, Gesture 0 exhibits an F1 score of 0.75, driven by a good recall rate (0.83) but lower precision (0.69), implying that while the gesture is frequently detected, there is a higher rate of false positives.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

4.2.4 Results and Discussion

The performance discussion of the obtained results for the gesture-controlled home automation system utilizing a webcam and MediaPipe is essential for understanding the system's effectiveness. Below are the key points:

➢ Accuracy and Reliability:

- Examining how well the system detects and identifies hand gestures accurately using the webcam and MediaPipe framework is crucial for evaluating its overall reliability. This includes ensuring that the system correctly maps gestures to the intended actions for controlling devices such as lights, fans, and buzzers.

➢ False Positive and False Negative Rates:

- Analyzing instances where gestures are misinterpreted (false positives) or missed entirely (false negatives) helps measure the precision and sensitivity of the gesture recognition model. Balancing these rates ensures the system minimizes errors while maintaining a smooth and responsive user experience.

➢ Response Time and Timely Action:

- Assessing how quickly the system responds to gestures after detection ensures prompt actions such as turning on/off devices. A fast response time enhances user satisfaction and ensures seamless control of home appliances.

➢ Integration with LCD Feedback:

- Evaluating how effectively the system integrates with the LCD display for real-time status updates is essential. The LCD's accurate and clear feedback for each gesture ensures users can easily monitor and confirm their commands.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

➢ Environmental Adaptability:

- Discussing the system's ability to function under varying lighting conditions and user positions demonstrates its robustness. This includes ensuring that the system consistently detects gestures without being affected by background noise or environmental distractions.

➢ Safety and Practicality:

- Addressing the safety implications ensures that the system operates reliably without causing unintended actions or failures. This is crucial for maintaining user trust and ensuring the system can be safely used in a home environment.

A comprehensive assessment covering accuracy, response time, robustness, user feedback, environmental adaptability, real-world testing, limitations, and safety considerations provides a well-rounded understanding of the project performance and highlights its effectiveness in creating a gesture-controlled home automation system

4.3 Summary

The purpose of this chapter is to demonstrate how the gesture-controlled home automation system performs efficiently using a webcam and MediaPipe for detecting and analyzing hand gestures. By continuously capturing and assessing real-time data, the system identifies specific gestures and translates them into actions such as turning lights or fans on and off, or activating a buzzer. The integration of a webcam in this project is justified by its ability to perform non-intrusive monitoring, enabling seamless and continuous hand gesture recognition without requiring physical contact or additional wearable devices.

The efficiency of the system is further highlighted by the lightweight and adaptable design of the MediaPipe framework, which ensures smooth operation even on low-power devices like the Raspberry Pi. MediaPipe's capability to adapt to various environmental conditions enhances the versatility and reliability of the system. Additionally, the cost-effectiveness of the webcam and the open-source nature of the MediaPipe library make this approach a practical and accessible choice for integration into smart home systems.

The ability of the system to provide real-time feedback through an LCD display ensures clear communication of device status to users, improving usability. Furthermore, the system's design allows for seamless integration with other smart home components, creating a comprehensive and user-friendly automation solution. Importantly, the non-intrusive nature of the webcam and gesture-based control is likely to enhance user acceptance, as it eliminates the need for physical switches or voice commands. Ultimately, this system contributes to a more convenient and efficient home automation experience.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Throughout the course of this project, the objectives outlined have been meticulously pursued, resulting in the successful development of an efficient gesture-controlled home automation system tailored specifically for seamless user interaction. The core focus was on creating a robust system capable of accurately recognizing hand gestures, which serve as the primary means of controlling various appliances. The system was designed not only to identify specific gestures but also to promptly send relevant commands for real-time execution of tasks such as turning devices on or off. This objective was achieved through the integration of MediaPipe and a webcam, ensuring a seamless and responsive system. The use of cost-effective components, including a Raspberry Pi, further solidified the accessibility and practicality of the home automation solution, making it a viable system for a wide range of users.

The system's performance was systematically evaluated, surpassing expectations in terms of accuracy and reliability in recognizing hand gestures under various conditions. By successfully achieving these objectives, the project has demonstrated the feasibility of creating an advanced gesture-controlled solution while justifying its significance in enhancing convenience and energy efficiency within smart homes. The developed system stands as a testament to the successful fusion of innovative technology, affordability, and effective performance, marking a substantial contribution to advancing gesture-based home automation solutions.

5.2 Potential for Commercialization

The gesture-controlled home automation system utilizing MediaPipe and a webcam presents a compelling opportunity for commercialization, offering a precise and effective solution for enhancing convenience, energy efficiency, and accessibility in various industries. The unique capabilities of gesture recognition technology make this innovation particularly appealing for widespread adoption in the following sectors:

1 **Smart Home Industry**: In the smart home sector, integrating a gesture-controlled automation system can revolutionize the way users interact with appliances. Manufacturers of smart home devices and systems could incorporate this technology to provide a seamless and hands-free user experience, appealing to a wide range of consumers, including individuals with mobility challenges.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2 **Healthcare and Assisted Living**: Gesture-controlled systems can be highly beneficial in healthcare and assisted living facilities, where hands-free control of devices is critical. This technology could empower patients and the elderly to operate essential appliances with ease, improving their quality of life and independence.

3 **Hospitality Industry**: Hotels, resorts, and luxury accommodations could adopt gesture-controlled systems to enhance the guest experience. From adjusting room lighting to controlling entertainment systems, the integration of this technology could create a more personalized and sophisticated environment for visitors.

4 **Industrial and Commercial Applications**: Beyond residential applications, gesture recognition technology can be utilized in industrial and commercial settings to control machinery or automate processes in environments where physical contact with controls may be impractical or unsafe.

5 **Integration with IoT Ecosystems**: As IoT (Internet of Things) ecosystems expand, gesture-controlled home automation systems could seamlessly integrate with existing smart devices and infrastructure, contributing to comprehensive and interconnected smart environments.

The successful commercialization of gesture-controlled home automation systems will depend on ensuring the accuracy and robustness of the gesture recognition models, addressing compatibility with a wide range of devices, and fostering partnerships with key stakeholders across industries. Given the growing emphasis on hands-free solutions and the rapid adoption of smart technologies, this innovative system holds significant potential to find widespread adoption and contribute to a more convenient and efficient future.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

5.3 Future Works

The future development of gesture-controlled home automation systems utilizing MediaPipe and webcams holds exciting possibilities for further improvement and refinement. Several areas of focus can enhance the effectiveness and applicability of these systems:

1. **Advancements in Gesture Recognition Models**: Continuous improvements in machine learning models and algorithms can lead to higher accuracy and sensitivity in detecting subtle and complex gestures. Research efforts should aim to optimize models for better

performance while maintaining efficiency, especially on low-power devices like Raspberry Pi.

2. **Integration of Multi-Modal Sensors**: Combining gesture recognition with other sensing technologies, such as voice commands or proximity sensors, can create a more versatile and comprehensive smart home system. Multi-modal inputs can reduce false positives and enhance the system's usability in diverse scenarios.
3. **Personalized Gesture Libraries**: Future systems could allow users to customize and train their own gesture sets, tailoring the system to their specific needs and preferences. This flexibility could increase user engagement and broaden the range of possible applications.
4. **Real-time Processing Enhancements**: Optimizing real-time processing capabilities is crucial for minimizing latency and improving responsiveness. Employing advanced hardware accelerators or lightweight algorithms can enable faster analysis, ensuring seamless user interaction.
5. **Integration with IoT Ecosystems**: Expanding compatibility with existing IoT devices and ecosystems can enhance the system's utility. This includes seamless communication with smart appliances, home hubs, and cloud-based platforms for broader functionality and remote control capabilities.
6. **Improved User Interface and Feedback Mechanisms**: Enhancing the user interface, such as creating intuitive mobile or desktop applications for configuration and monitoring, can improve accessibility. Customizable feedback mechanisms, like visual indicators on LCDs or audible cues, can also make the system more user-friendly.
7. **Energy Efficiency and Hardware Optimization**: Future systems should focus on reducing power consumption and optimizing hardware requirements to ensure efficient

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

operation, especially in resource-constrained environments. This can make the system more sustainable and practical for widespread adoption.

8. **Advanced Safety and Security Features**: Incorporating safety measures like detecting unauthorized gestures or ensuring secure communication between devices can address privacy concerns and enhance the system's reliability in critical applications.
9. **Long-term Performance Analysis**: Implementing tools for long-term monitoring and analytics can provide insights into user behavior and system performance. This data can help refine algorithms, improve functionality, and adapt the system to changing user requirements.
10. **Collaboration and Open-source Development**: Encouraging collaboration between developers, researchers, and industry stakeholders can foster innovation. Open-source contributions can accelerate progress, promote standardization, and ensure accessibility for a broader audience.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

By focusing on these future works, gesture-controlled home automation systems can advance significantly, making them more efficient, versatile, and accessible. These developments hold the potential to transform smart living spaces, improve user convenience, and contribute to a more connected and intelligent future.

APPENDICES

Appendix A Gantt Chart for BDP 1

PSM 1 PLANNING GANTT CHART 2024														
ACTIVITES	**DURATION (WEEK)**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Find Supervisor	■													
BDP 1 Briefing		■												
Decide Project Title		■	■											
Chapter 1 (Introduction)			■	■	■									
Research journals (Literature Review)					■	■	■	■						
Component research							■	■	■	■				
Chapter 3 (Methodology)										■	■			
Finalize the component use in the project										■	■	■		
Draft Submission											■	■		
Slide preparation											■	■		
Final report submission													■	
Presentation BDP 1														■

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Appendix B Gantt Chart for BDP 2

PSM 2 PLANNING GANTT CHART 2024/2025													
ACTIVITES	**DURATION (WEEK)**												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
BDP 2 Briefing	■												
Research about Home Automation System		■	■	■	■								
Hand Gesture Coding						■	■						
Hardware Design							■	■	■				
Edit Report								■	■	■	■		
Finalize Prototype										■	■	■	
Update Project Report											■	■	
Testing Prototype											■	■	
Poster Preparation												■	
Final report submission												■	
Presentation BDP 2													■

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Appendix C Full Coding

```python
import cv2
import mediapipe as mp
import RPi.GPIO as GPIO
import time
from RPLCD.i2c import CharLCD
import os
import logging

# Configure logging
logging.basicConfig(filename='/home/ACE/test7_log.txt', level=logging.DEBUG)

# GPIO setup
GPIO.setwarnings(False)
GPIO.setmode(GPIO.BCM)

# Relay pin definitions
RELAY_1_PIN = 14  # Light
RELAY_2_PIN = 15  # Fan
RELAY_3_PIN = 18  # Buzzer

# Set relay pins as output and initialize to OFF
RELAY_PINS = [RELAY_1_PIN, RELAY_2_PIN, RELAY_3_PIN]
for pin in RELAY_PINS:
    GPIO.setup(pin, GPIO.OUT)
    GPIO.output(pin, GPIO.HIGH)  # Relays OFF initially

# Timer and gesture threshold
GESTURE_THRESHOLD = 2  # Time in seconds to confirm gesture
BODY_PRESENCE_THRESHOLD = 5  # Time in seconds to turn off outputs if no body is detected
last_body_detection_time = time.time()

# Active outputs tracker
active_relays = set()  # Track active relays

# Initialize MediaPipe modules
mp_hands = mp.solutions.hands
mp_pose = mp.solutions.pose
hands = mp_hands.Hands()
pose = mp_pose.Pose()
mp_drawing = mp.solutions.drawing_utils

# Open webcam
cap = cv2.VideoCapture(0)
```

```python
# Initialize LCD (16x2)
lcd = CharLCD(i2c_expander='PCF8574', address=0x27, port=1, cols=16, rows=2)

def update_lcd():
    """Update the LCD display to show all active relays."""
    lcd.clear()
    statuses = []
    if GPIO.input(RELAY_1_PIN) == GPIO.LOW:
        statuses.append("Light On")
    if GPIO.input(RELAY_2_PIN) == GPIO.LOW:
        statuses.append("Fan On")
    if GPIO.input(RELAY_3_PIN) == GPIO.LOW:
        statuses.append("Buzzer On")

    # Combine statuses into one or two lines for the LCD
    if statuses:
        line1 = ", ".join(statuses[:2])  # First two statuses
        line2 = ", ".join(statuses[2:]) if len(statuses) > 2 else ""  # Remaining statuses
        lcd.write_string(line1)
        if line2:
            lcd.crlf()
            lcd.write_string(line2)
    else:
        lcd.write_string("All Off")

def detect_gesture(landmarks):
    """
    Detect the hand gesture based on finger landmarks and return:
    0 for all fingers closed,
    1 for index finger only,
    2 for index and middle fingers,
    3 for index, middle, and ring fingers.
    """
    index_extended = landmarks[8].y < landmarks[7].y and landmarks[7].y < landmarks[6].y
    middle_extended = landmarks[12].y < landmarks[11].y and landmarks[11].y < landmarks[10].y
    ring_extended = landmarks[16].y < landmarks[15].y and landmarks[15].y < landmarks[14].y

    if not index_extended and not middle_extended and not ring_extended:
        return 0  # All fingers closed
    elif index_extended and not middle_extended and not ring_extended:
        return 1  # Only index finger
    elif index_extended and middle_extended and not ring_extended:
```

```python
        return 2  # Index and middle fingers
    elif index_extended and middle_extended and ring_extended:
        return 3  # Index, middle, and ring fingers
    return -1  # Undefined gesture

while cap.isOpened():
    ret, frame = cap.read()
    if not ret:
        logging.error("Failed to grab frame from webcam.")
        break

    # Flip the frame horizontally for a selfie-view display
    frame = cv2.flip(frame, 1)

    # Convert the image to RGB
    rgb_frame = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)

    # Process the frame for hand and body detection
    results_hands = hands.process(rgb_frame)
    results_pose = pose.process(rgb_frame)

    body_detected = False

    # Check for body presence
    if results_pose.pose_landmarks:
        body_detected = True
        last_body_detection_time = time.time()  # Reset the timer
    else:
        # Turn off all outputs if body is absent for the threshold duration
        if time.time() - last_body_detection_time > BODY_PRESENCE_THRESHOLD:
            for pin in RELAY_PINS:
                GPIO.output(pin, GPIO.HIGH)
            active_relays.clear()
            update_lcd()

    # If hands are detected, process gestures
    if results_hands.multi_hand_landmarks:
        for landmarks in results_hands.multi_hand_landmarks:
            detected_gesture = detect_gesture(landmarks.landmark)

            if detected_gesture == 1 and RELAY_1_PIN not in active_relays:
                GPIO.output(RELAY_1_PIN, GPIO.LOW)  # Turn on light
```

```
                active_relays.add(RELAY_1_PIN)
            elif detected_gesture == 2 and RELAY_2_PIN not in active_relays:
                GPIO.output(RELAY_2_PIN, GPIO.LOW)  # Turn on fan
                active_relays.add(RELAY_2_PIN)
            elif detected_gesture == 3 and RELAY_3_PIN not in active_relays:
                GPIO.output(RELAY_3_PIN, GPIO.LOW)  # Turn on buzzer
                active_relays.add(RELAY_3_PIN)
            elif detected_gesture == 0:
                for pin in RELAY_PINS:
                    GPIO.output(pin, GPIO.HIGH)
                active_relays.clear()

            # Draw landmarks
            mp_drawing.draw_landmarks(frame, landmarks, mp_hands.HAND_CONNECTIONS)

    # Draw body landmarks for debugging
    if results_pose.pose_landmarks:
        mp_drawing.draw_landmarks(frame, results_pose.pose_landmarks, mp_pose.POSE_CONNECTIONS)

    # Update the LCD display
    update_lcd()

    # Show the frame
    cv2.imshow("Gesture and Body Detection", frame)

    # Break the loop on pressing 'q'
    if cv2.waitKey(1) & 0xFF == ord('q'):
        break

# Cleanup
cap.release()
cv2.destroyAllWindows()
GPIO.cleanup()
```

REFERENCES

[1] Dinh, D.-L., Kim, J. T., & Kim, T.-S. (2014). Hand Gesture Recognition and Interface via a Depth Imaging Sensor for Smart Home Appliances. Energy Procedia, 62, 576–582. https://doi.org/10.1016/j.egypro.2014.12.419

[2] H. A, H. P and P. Asha, "Gesture based Home appliance control system for Disabled People," 2021 Second International Conference on Electronics and Sustainable Communication Systems (ICESC), Coimbatore, India, 2021, pp. 1501-1505.

[3] Malatesta, T., Eon, C., Breadsell, J. K., Law, A., Byrne, J., & Morrison, G. M. (2022). Systems of social practice and automation in an energy efficient home. Building and Environment, 224, 109543. https://doi.org/10.1016/j.buildenv.2022.109543

[4] Chen, R. C., Chao, W. K., & Manongga, W. E. (2023). Using Finger for Smart Home Applications. https://doi.org/10.1109/icce-taiwan58799.2023.10227019.

[5] Z. Zou, Y. Wang, L. Wang, X. Wu, C. Xu and M. Zhou, "Design of smart home controller based on raspberry PI," 2020 IEEE 5th Information Technology and Mechatronics Engineering Conference (ITOEC), Chongqing, China, 2020, pp. 1548- 1551.

[6] T. Q. Vinh and N. T. Tri, "Hand gesture recognition based on depth image using kinect sensor," 2015 2nd National Foundation for Science and Technology Development Conference on Information and Computer Science (NICS), Ho Chi Minh City, Vietnam,2015, pp. 34-39.

[7] A. P. Dhote, V. R. Parihar, R. P. Sonar and R. S. Nage, "A novel system of real time hand tracking and gesture recognition," 2017 International Conference on Inventive Computing and Informatics (ICICI), Coimbatore, India, 2017, pp. 512-516.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

[8] Zhang, F., Bazarevsky, V., Vakunov, A., Tkachenka, A., Sung, G., Chang, C., & Grundmann, M. (2020, June 18). MediaPipe Hands: On-device real-time hand tracking. arXiv.org. https://arxiv.org/abs/2006.10214.

[9] N. Valov and I. Valova, "Home Automation System with Raspberry Pi," 2020 7th International Conference on Energy Efficiency and Agricultural Engineering (EE&AE), Ruse, Bulgaria, 2020, pp. 1-5

[10] M. U. H. A. Rasyid, F. A. Saputra and A. Prasetiyo, "I-ON Smart Controller: Portable Smart Home Solution Based on Arduino And Raspberry Pi," 2018 International Conference on Applied Science and Technology (iCAST), Manado, Indonesia, 2018, pp.161-164

[11] Wicaksono, H., Aleksandrov, K., & Rogalski, S. (2012). An intelligent system for improving energy efficiency in building using ontology and building automation systems. In InTech eBooks. https://doi.org/10.5772/48006

[12] C. C. Martin et al., "A real-time ergonomic monitoring system using the Microsoft Kinect," 2012 IEEE Systems and Information Engineering Design Symposium, Charlottesville, VA, USA, 2012, pp. 50-55

[13] L. Raju, G. Sowmya, S. Srividhya, S. Surabhi, M. K. Retika and M. Reshmika Janani, "Advanced Home Automation Using Raspberry Pi and Machine Learning," 2021 7th International Conference on Electrical Energy Systems (ICEES), Chennai, India, 2021, pp. 600-605

[14] Statista. (2023, September 26). CO2 emissions from energy use in Malaysia 2013-2022. https://www.statista.com/statistics/1394260/malaysia-co2-emissions-from-energy use/#:~:text=In%202022%2C%20the%20amount%20of,highest%20in%20that%20same%20year.

[15] B. Kaur, P. K. Pateriya and M. K. Rai, "An Illustration of Making a Home AutomationSystem Using Raspberry Pi and PIR Sensor," 2018 International Conference on Intelligent Circuits and Systems (ICICS), Phagwara, India, 2018, pp. 439-444.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

[16] Sai, V., Saxena, I., D. Saisanthiya, & Retnadhas, M. (2023). *Robust Intelligent Posture Estimation for an AI Gym Trainer using Mediapipe and OpenCV*. https://doi.org/10.1109/icnwc57852.2023.10127264

[17] Madrid, G. K. R., Villanueva, R. G. R., & Caya, M. V. C. (2022, October 1). *Recognition of Dynamic Filipino Sign Language using MediaPipe and Long Short-Term Memory*. IEEE Xplore. https://doi.org/10.1109/ICCCNT54827.2022.9984599

[18] P Sharmila, Devi, V. B., R Jegatha, Anu Rekha S, & Hartika NK. (2023). IoT-Oriented Gesture Automation with Mesh Detection Through OpenCV and Pyfirmata Protocol Using ResNet-Mediapipe. *2019 Innovations in Power and Advanced Computing Technologies (I-PACT)*, 1–5. https://doi.org/10.1109/i-pact58649.2023.10434872

[19] Gulati, S., Rastogi, A. K., Virmani, M., Jana, R., Pradhan, R., & Gupta, C. (2022). Paint / Writing Application through WebCam using MediaPipe and OpenCV. *2022 2nd International Conference on Innovative Practices in Technology and Management (ICIPTM)*, 287–291. https://doi.org/10.1109/iciptm54933.2022.9753939

[20] Siju, I., & Selvam, P. (2024). A Novel Approach for Lightweight Sign Language Recognition Leveraging Google Mediapipe and Deep Neural Net. *2024 First International Conference on Software, Systems and Information Technology (SSITCON)*, 1–6. https://doi.org/10.1109/ssitcon62437.2024.10796746

[21] Sakthimohan M, Sakthi S, Pugalmani R, Harish Kumar R, & G, E. R. (2024). Automated Smart Home Assistive System Implementation for Physically Impaired Community Using Eye Gestures. *2022 8th International Conference on Advanced Computing and Communication Systems (ICACCS)*, 81–85. https://doi.org/10.1109/icaccs60874.2024.10717287

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA