"DIABLO: Deep Interactive Artificial Bionic Linguistic Operator"

A Report on Mini Project submitted in partial fulfillment of the requirements for the degree of Bachelor of Technology

by

Soumodeep Biswash	**(212010014028)**
Raihan Ahmed Sadiyal	**(212010014021)**
Deep Acharjee	**(202010026007)**
Kamalika Roy	**(212010014010)**

Under the Supervision of

Mr. Ruhul Amin Laskar

Assistant Professor,

Department of Electronics and Telecommunication Engineering

BARAK VALLEY ENGINEERING COLLEGE

(Affiliated to ASTU, Approved by AICTE)

Nirala, Karimganj, Assam-788701

January-May, 2024

ACKNOWLEDGEMENT

We would like to express our sincere gratitude to several individuals whose support and guidance have been invaluable in the completion of our internship.

First and foremost, we extend our deepest appreciation to Dr. Diganta Goswami, Principal, Barak Valley Engineering College, Karimganj for his unwavering support and for providing an academic environment that encourages excellence and innovation. His leadership has been instrumental in shaping our educational journey.

We are also profoundly grateful to the Head of the Department, Department of Electronics and Telecommunication Engineering, Dr. Saharul Alom Barlaskar for his continuous encouragement and for fostering a learning atmosphere that has greatly contributed to our professional development. His insights and advice have been crucial in navigating the challenges of our Mini Project.

Our heartfelt thanks go to the Project Coordinator Mr. Ruhul Amin Laskar for his dedicated efforts in organizing and managing the Mini Project. His constant support, valuable feedback, and guidance throughout the mini project have been indispensable in achieving our objectives.

Additionally, we would like to extend my appreciation to our parents for their unconditional support, understanding, and encouragement. Their belief in us has been a source of immense strength.

Thank you all for your support and encouragement.

ABSTRACT

Robotics has emerged as a field of immense innovation, offering solutions across various domains. In this project, we present the design and implementation of a versatile robotic system using Raspberry Pi, integrated with gesture recognition and computer vision capabilities. The system leverages the Mediapipe library for gesture detection and face recognition, enabling intuitive human-robot interaction. For human tracking, the robot utilizes VL53L0X lidar and HC-SR04 ultrasonic sensors, providing accurate and reliable distance measurements. The robot offers multiple modes of operation, including Active Mode for general functionalities, Follow Mode for human tracking, Manual Control Mode for direct user input, and an ASL Interpreter Mode for American Sign Language recognition. These modes are facilitated by an LCD display for visual feedback and L298N motor drivers for motion control. The integration of these components enables a seamless user experience, allowing users to interact with the robot through intuitive gestures and receive real-time feedback on the LCD display. Through this project, we demonstrate the potential of Raspberry Pi-based robotics systems in enhancing human-robot interaction and expanding the capabilities of autonomous systems.

Keywords: Mediapipe, ASL Gestures, Robotics, Machine Learning

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

1) **CNN –** Convolutional Neural Network
2) **LCD**- Liquid Crystal Display
3) **DC-** Direct Current
4) **LIDAR-** Light Detection & Ranging

Chapter 1
INTRODUCTION

As the global population continues to age and the prevalence of disabilities increases, addressing the unique and complex challenges faced by elderly and disabled individuals has become an urgent concern for societies worldwide. Many people in these demographics encounter a myriad of daily obstacles that significantly impact their quality of life and ability to live independently. Mobility issues, such as difficulty in navigating around the house or reaching for objects, present formidable challenges for those with limited physical abilities. Additionally, remembering to take medication on time and in the correct dosage is a significant challenge for individuals with cognitive impairments or memory issues, further complicating their daily routines and health management.

Beyond physical limitations, individuals with speech and hearing impairments often struggle with effective communication, leading to feelings of isolation, frustration, and even depression. Safety concerns are also highly prevalent among elderly and disabled individuals, who may face increased risks of accidents, falls, or other emergencies due to limited mobility or sensory impairments. These safety issues not only threaten their physical well-being but also contribute to anxiety and a decreased sense of security.

Moreover, the digital divide exacerbates the challenges faced by these populations. Difficulty in using technology or accessing information can hinder communication, limit access to essential resources and services, and create barriers to healthcare, social engagement, and participation in everyday activities. This technological gap further isolates elderly and disabled individuals from the modern digital world, reducing their opportunities for social interaction and access to vital support systems.

In response to these multifaceted challenges, innovative solutions leveraging advanced technology and robotics hold immense potential to significantly enhance the quality of life for elderly and disabled individuals. By designing and implementing robotic systems that address specific needs such as mobility assistance, medication management, communication support, and safety monitoring, we can empower these populations to lead more independent, fulfilling, and dignified lives.

In this comprehensive report, we present the design and implementation of a versatile robotic system specifically aimed at addressing the diverse and complex challenges faced by elderly and disabled individuals. By harnessing the capabilities of Raspberry Pi-based robotics, integrated with gesture recognition, computer vision, and other advanced technologies, our system aims to provide practical and effective solutions to enhance mobility, communication, safety, and access to essential resources for these vulnerable populations. This innovative approach promises not only to improve their daily lives but also to offer them greater autonomy and a better quality of life.

Chapter 2
LITERATURE REVIEW

Many scholars have looked into different strategies and approaches for dealing with issues including multifaceted challenges faced by elderly and disabled individuals, focusing on mobility limitations, medication management, communication barriers, safety concerns, and the digital divide. We categorize these solutions into three classes according to the taxonomy provided, and we also present a thorough assessment of the pertinent literature.

The initial research on this field [1] introduces a wheelchair system utilizing hand gestures and vision-based controls, focusing on improving mobility for individuals with physical disabilities. Following that, another study [2] explores the use of monocular and RGB-D cameras for hand gesture recognition in human-robot interaction, aiming to enhance the naturalness and intuitiveness of interaction with robots. The following study [3] discusses the increasing prevalence of service robots in industries like food service, highlighting their ability to understand social cues and improve service quality. The following study [4] concentrates on the accuracy of hand gesture communication using computer vision, particularly MediaPipe, for real-time control of robots, emphasizing its superiority over traditional methods like CNNs.

The initial research on this field [4] introduces a sophisticated system for robots to autonomously follow humans, emphasizing a dynamic tracking algorithm and improved control for real-life applications. Following that, another study [5] presents a framework for robots to track humans using state-machine control and deep learning algorithms, focusing on safe navigation in challenging environments. The following study [6] discusses Human Following robots, highlighting their design, sensing mechanisms, and focus on maintaining a constant distance from users, particularly in crowded areas.

The research on this field [7] discusses advancements in robots that autonomously follow humans, focusing on a smart tracking algorithm and control system to navigate challenging environments and maintain a constant distance from the user.

Chapter 3
METHODOLOGY

3.1 Hardware Components

Raspberry Pi 3B:

A credit card-sized single-board computer capable of running Linux-based operating systems. It serves as the main controller for the robotic system, facilitating program execution, sensor interfacing, and motor control.

Fig. 3.1: Raspberry Pi 3B

16x2 LCD Display:

A liquid crystal display module consisting of two lines with 16 characters each. It provides visual feedback and status information to the user regarding the robot's operation, mode, and detected gestures.

Fig. 3.2: 16x2 LCD Display

L298N Motor Driver:

A dual H-bridge motor driver module capable of controlling two DC motors independently. It allows the Raspberry Pi to drive the wheels of the robot in both forward and reverse directions with speed control.

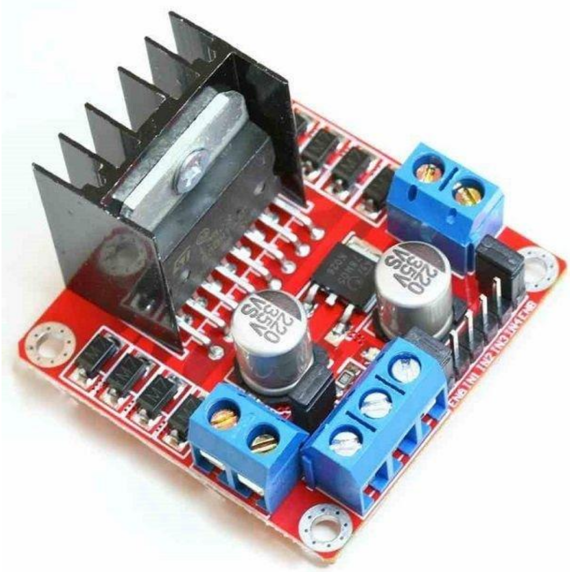

Fig. 3.3: L298N Motor Driver

Dual DC Motor Wheels:

Two DC motor wheels equipped with rubber tires and encoders for precise movement control. These wheels enable the robot to navigate its environment and execute various maneuvers.

Fig. 3.4: Dual DC Motor Wheels

Power System with 20A 3S BMS and 6 Li-ion Cells:

A custom power system comprising six lithium-ion cells connected in series, managed by a 20A 3S (3-series) Battery Management System (BMS). This power system supplies the necessary voltage and current to the Raspberry Pi, motors, and other components of the robotic system.

VL53L0X TOF based Lidar:

The VL53L0X uses time-of-flight technology to measure the distance to a target by emitting a short infrared pulse and measuring the time it takes for the pulse to reflect back to the sensor. Designed for low power consumption, it is suitable for battery-powered devices and includes various power-saving modes to extend battery life. The sensor supports high-speed distance measurements and can detect multiple objects in its field of view, making it ideal for applications like robotic navigation and obstacle avoidance.

Fig. 3.5: VL53L0X TOF based LIDAR

HC-SR04:

The HC-SR04 measures distance by emitting an ultrasonic pulse and timing how long it takes for the echo to return. It can measure distances from 2 cm to 400 cm with an accuracy of about 3 mm. The sensor is widely used due to its simplicity and affordability. It is easy to interface with microcontrollers and other digital systems using a straightforward 4-pin configuration (VCC, Trig, Echo, GND). The HC-SR04 is commonly used in robotics, obstacle avoidance, presence detection, and various DIY electronics projects due to its reliable performance and ease of use.

Fig. 3.6: HC-SR04

3.2 Hardware Interfacing

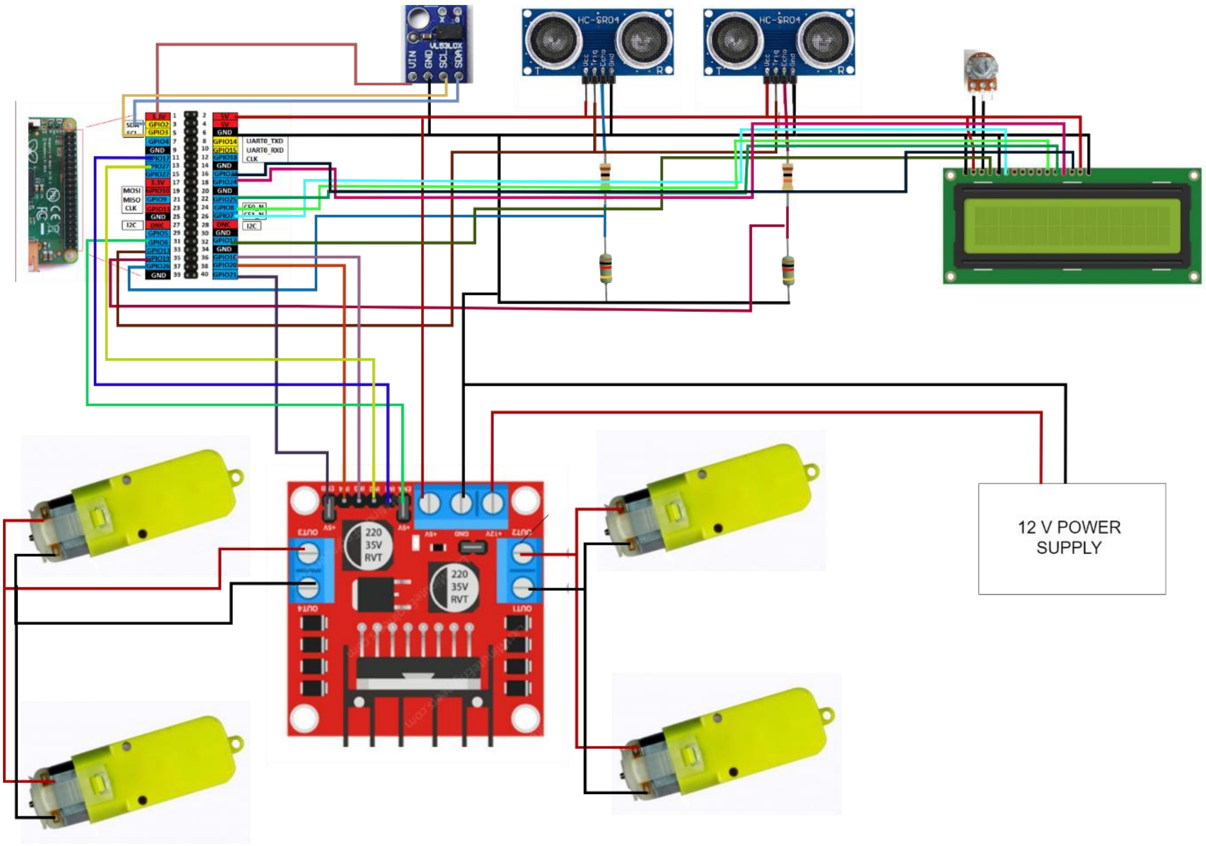

Fig. 3.7: Hardware Interfacing

The hardware interfacing setup for the robot involves connecting the output of the Battery Management System (BMS) to the 12V input and ground pins of the L298N motor driver, which in turn is linked to the wheels for motor control. Raspberry Pi GPIO pins are utilized to control the motor driver's ENA, IN1, IN2, IN3, and IN4 pins, enabling precise movement. Additionally, connections are made between the Raspberry Pi GPIO pins and the LCD display, with the 5V pin powering the LCD and the variable end of a 10k potentiometer adjusting display contrast. Data pins D4-D7 of the LCD are linked to specific GPIO pins, allowing for 4-bit mode operation. Ground connections ensure a common reference point for all circuits. This setup facilitates robust motor control and clear display output for the robot's operation. The SCL and SDA pins of VL53L0X are connected to SCL and SDA pins of raspberry pi with its Vin pin being connected to 3.3V pin of raspberrypi and GND connected to GND. The triggers of both the HC-SR04 along with their Vin and GND connected to GPIO 13, 5V and GND pins respectively. The echo pin of left HC-SR04 is connected to GPIO 19 through a voltage divider made up of 670 ohm and 1k ohm resistors. Similar setting is done for the right HC-SR04 with GPIO 26.

3.3 Pre-trained Models Used

Mediapipe Library:

An open-source library developed by Google for building real-time multi-modal machine learning pipelines. It provides pre-trained models and algorithms for tasks such as gesture recognition, face detection, and hand tracking, enabling advanced functionalities in the robotic system.

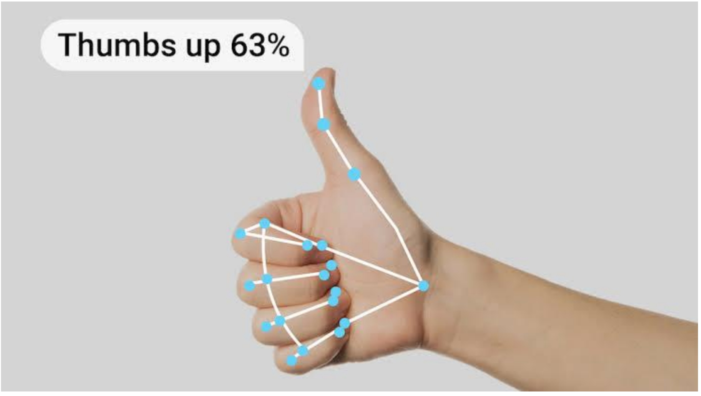

Fig. 3.8: Hand Tracking Pipeline of Mediapipe

3.4 Software Methodology

Utilizing the Mediapipe framework, we developed a gesture detection model by collecting a dataset of American Sign Language (ASL) gestures and command gestures, comprising 1000 images for each alphabet, number, and command. The Mediapipe hand tracking pipeline was employed to extract hand coordinates from each image, creating a labeled dataset pairing hand coordinates with corresponding gesture labels. This dataset was split into training and testing sets, and a random forest classifier was trained on the training set, achieving an impressive accuracy of 99%.

Chapter 4

RESULTS

Table 4.1: Performance Table of Various Gestures Models Used

Model Name	Accuracy	Precision	Recall	F1-Score
ASL Alphabet Model	98.93%	98.94%	98.93%	98.93%
ASL Number Model	98.74%	98.76%	98.74%	98.74%
Control Gestures Model	99.55%	99.56%	99.56%	99.56%

ROBOT FUNCTIONALITIES:

- ACTIVE MODE: After powering on, a particular gesture takes the robot to Active mode and another gesture deactivates this mode. All the functionalities of the robot are available only when in this mode.
- FOLLOW MODE: A particular gesture takes the robot to human following mode and another gesture deactivates it.
- MANUAL CONTROL MODE: Two particular gestures are assigned to activate and deactivate this mode. In this mode, two gestures are used to move the robot forward and backward.
- ASL INTERPRETER MODE: Two particular gestures are used to move in and out of this mode. This mode has 2 modes within it for alphabet detection and number detection which has a particular gesture assigned to it to switch between modes. Also except alphabets and numbers this mode can also detect gesture for space ‘ ’, period ‘.’ and for deleting in case of any mistakes.

Chapter 5
CONCLUSION

In summary, our exploration into the challenges faced by elderly and disabled individuals highlights the pressing need for innovative solutions that cater to their unique requirements. Through the development of our Smart Assistant Robot, we've taken a significant step towards addressing these challenges by offering comprehensive support in mobility, communication, safety, and access to resources. However, this is just the beginning of our journey.

Moving forward, we envision enhancing our robotic system by integrating cutting-edge technologies such as AI-driven predictive capabilities for medication management, advanced sensors for real-time environment analysis, and seamless integration with wearable devices for continuous health monitoring. We also want to incorporate a GPS based human tracking feature for better human following capabilities

REFERENCES

1) Garg, R., Shriram, N., Gupta, V., & Agrawal, V. (2009, November). A smart mobility solution for physically challenged. In 2009 IEEE International Conference on Vehicular Electronics and Safety (ICVES) (pp. 168-173). IEEE.

2) Qi, J., Ma, L., Cui, Z., & Yu, Y. (2024). Computer vision-based hand gesture recognition for human-robot interaction: a review. Complex & Intelligent Systems, 10(1), 1581-1606.

3) Jessintha, D., Jaisiva, S., & Ananth, C. (2023, March). Social Service Robot using Gesture recognition technique. In Journal of Physics: Conference Series (Vol. 2466, No. 1, p. 012020). IOP Publishing.

4) Wameed, M., ALKAMACHI, A. M., & Erçelebi, E. (2023). Tracked robot control with hand gesture based on mediapipe. Al-Khwarizmi Engineering Journal, 19(3), 56-71.

5) Gupta, M., Kumar, S., Behera, L., & Subramanian, V. K. (2016). A novel vision-based tracking algorithm for a human-following mobile robot. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 47(7), 1415-1427.

6) Algabri, R., & Choi, M. T. (2020). Deep-learning-based indoor human following of mobile robot using color feature. Sensors, 20(9), 2699.

7) Nivethika, S. D., SenthilPandian, M., Srinivasan, D., Naresh, M., Danush, N., & Kumar, A. (2022, December). Intelligent Movement Tracking Robot. In 2022 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS) (pp. 1-4). IEEE.

8) Hussain, M. J., Shaoor, A., Alsuhibany, S. A., Ghadi, Y. Y., al Shloul, T., Jalal, A., & Park, J. (2022). Intelligent sign language recognition system for e-learning context