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Touch-to-Talk: A GUI-Based, Cost-Effective Tactile Robot for ASL Gesture Generation from Text Images

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Abstract: The Tactile Robot Interpreter (TRI) is an innovative assistive device developed to bridge communication barriers for individuals with multi-sensory impairments. By combining computer vision with robotics, TRI captures text from images or documents and translates it into American Sign Language (ASL) gestures through a robotic hand, facilitating inclusive and accessible communication. However, to ensure broader adoption and real-world applicability, there is a pressing need for a cost-effective yet fully automated solution that maintains the system's functional integrity while remaining affordable for diverse communities. The robotic hand is controlled by an Arduino Uno and actuated by servo motors, which accurately replicate ASL signs based on the corresponding text input acquired through visual methods. A distinctive feature of TRI is its ability to convey ASL through touch, enabling blind and deaf users to perceive sign language by feeling the robotic hand's movements. This innovation opens new avenues for communication, education, and digital accessibility, significantly enhancing the independence and social participation of the visually and hearing impaired.. By transforming text into a tangible, interactive ASL experience, the TRI project paves the way for a more inclusive and connected world.

Keywords: ASL Signs, Tactile Robot, Arduino, Text Images

I. INTRODUCTION

This Communication is a fundamental human right, yet individuals with multi-sensory impairments, particularly those who are both blind and deaf, face significant challenges in accessing information and engaging in conversations. Traditional methods of communication, such as Braille and tactile sign language, often require specialized training and are not always widely accessible. In an era where technology bridges gaps and enhances accessibility, there is an urgent need for an innovative solution that enables seamless interaction for the multi-sensory impaired community. The Tactile Robot Interpreter (TRI) is a groundbreaking initiative that leverages computer vision and robotics to convert textual content from images or documents into American Sign Language (ASL) gestures. Unlike conventional assistive technologies, TRI introduces a tactile communication mechanism, allowing users to physically perceive the robotic hand's movements to interpret ASL. This innovative approach empowers individuals who are both blind and deaf to engage with written content, participate in conversations, and navigate digital information independently. Recognizing the need for widespread accessibility, the system incorporates a cost-effective robotic hand powered by an Arduino Uno and servo motors, making TRI a more affordable and practical solution for inclusive communication across diverse communities. The potential impact of TRI extends beyond individual users, offering valuable support for educators, caregivers, and interpreters working with multi-sensory impaired individuals. Its intuitive and user-friendly design makes it a practical tool for various educational and professional settings, fostering a more inclusive society. By transforming static text into a dynamic, tactile ASL experience, TRI paves the way for enhanced independence, accessibility, and social integration for individuals with complex communication needs.

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II. LITERATURE REVIEW

Figure 1 illustrates the standard American Sign Language (ASL) hand signs for each alphabet, which form the basis for mapping text input to corresponding robotic gestures in the system.

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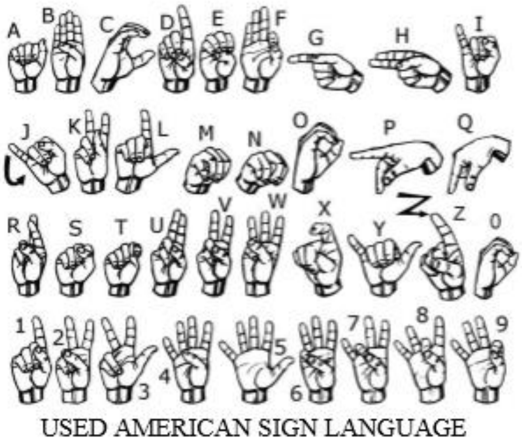

Fig 1 Images of ASL language

The reliance on interpreters in existing communication methods limits the autonomy of deaf-blind individuals, emphasizing the need for an affordable, open-source robotic hand [1]that can sign tactile ASL and integrate with mainstream communication devices without requiring an interpreter.GlovePi is a wearable device [2] that helps deaf-blind individuals communicate with others, using an Android app to convert Malossi alphabet messages into text, with future plans to add touch-based text output and phoneme mapping for wider communication. Blind individuals cannot access documents or electronic media that are not in Braille[3], so we are developing an enhanced Braille system that scans images, converts them to text using OCR, and translates the text into Braille using a Raspberry Pi and solenoids for display.Sign language recognition is challenging due to the lack of sign language-specific data, but incorporating hand shape information can improve accuracy. Further research is needed to model hand movements in a language-independent way and enhance recognition systems using multilingual sign language resources.Research in [4] shows that modeling handshape information in a language-independent way can improve sign language recognition accuracy. The study also highlights that multilingual sign language resources can be effectively used to develop recognition systems.Machine learning models like CNN, Inception[5], and LSTM enhance sign language recognition accuracy, where gesture recognition and precise skin spot segmentation play key roles, and studying text comprehension tasks can further improve communication for individuals with hearing impairments.

III. EXPLANATION OF THE PROPOSED SYSTEM

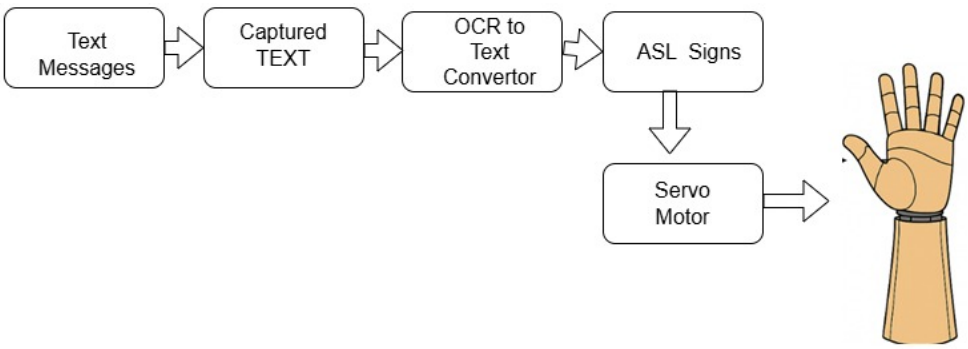

Fig 2 Block diagram of the Tactile Robot

The Tactile Robot Interpreter (TRI) is an American Sign Language (ASL) based system that converts text from an image into physical signs that can be interpreted through touch. Figure 2 presents the block diagram of the Tactile Robot Interpreter (TRI), outlining the sequential process from input acquisition to ASL gesture generation through the robotic hand. The process starts with input selection via a Graphical User Interface (GUI) created using Python and Tkinter, where users can choose the input through left and right mouse clicks. For image input, a camera captures the text, and Python libraries such as PyTesseract and OpenCV are used to extract the text. Alternatively, input can be

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retrieved from a specified email address. The extracted text is converted into a sequence of six ternary digits (0, 1, 2), where 0 represents 0 degrees, 1 represents 180 degrees, and 2 represents 90 degrees. These six digits correspond to the positioning of the hand's five fingers (pinky, ring, middle, index, thumb) and the rotation of the arm (represented by the sixth digit). These converted digits are then transmitted to an Arduino board, which controls five servos and a vibration motor. The Arduino program assigns the correct movements to the servos and motor based on the received digits, generating physical hand gestures. The output is a tactile representation of the sign language, enabling individuals with visual and auditory impairments to interpret the signs through touch, thereby improving communication for those with multi-sensory impairments. Figure 3 shows the circuit diagram of the servo motor connections to the Arduino, illustrating how the control signals are routed for accurate hand gesture replication.

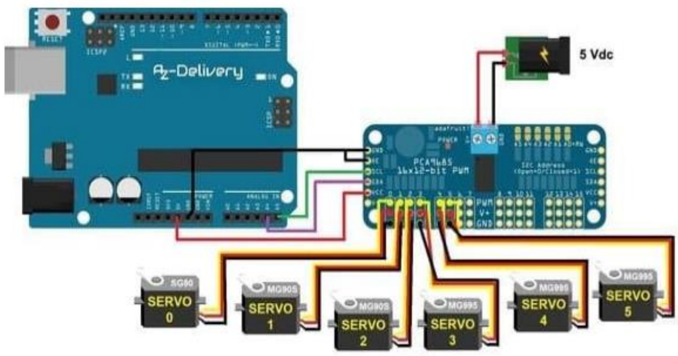

Fig 3 Circuit diagram of the servo motor connections to the Arduino.

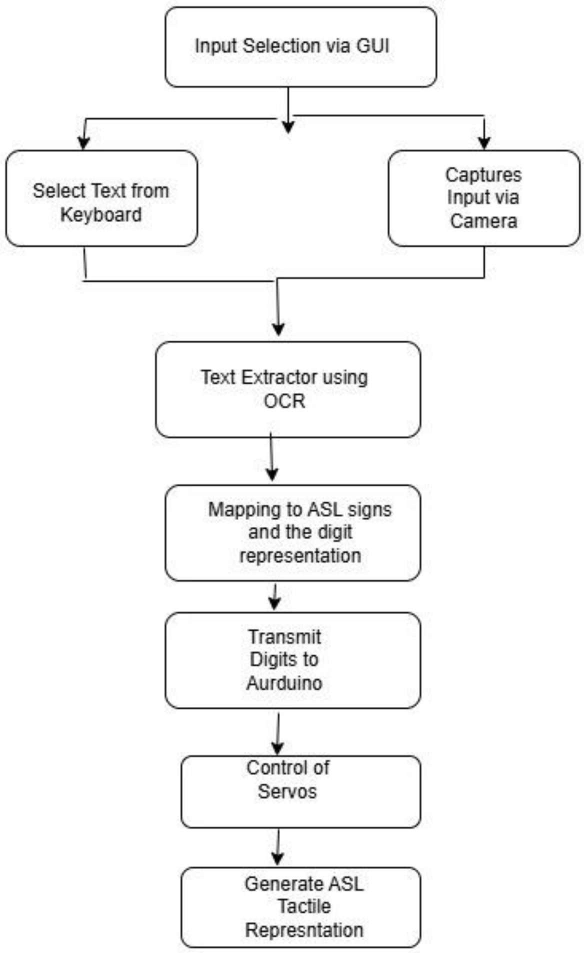

Fig 4 Flowchart of the proposed system.

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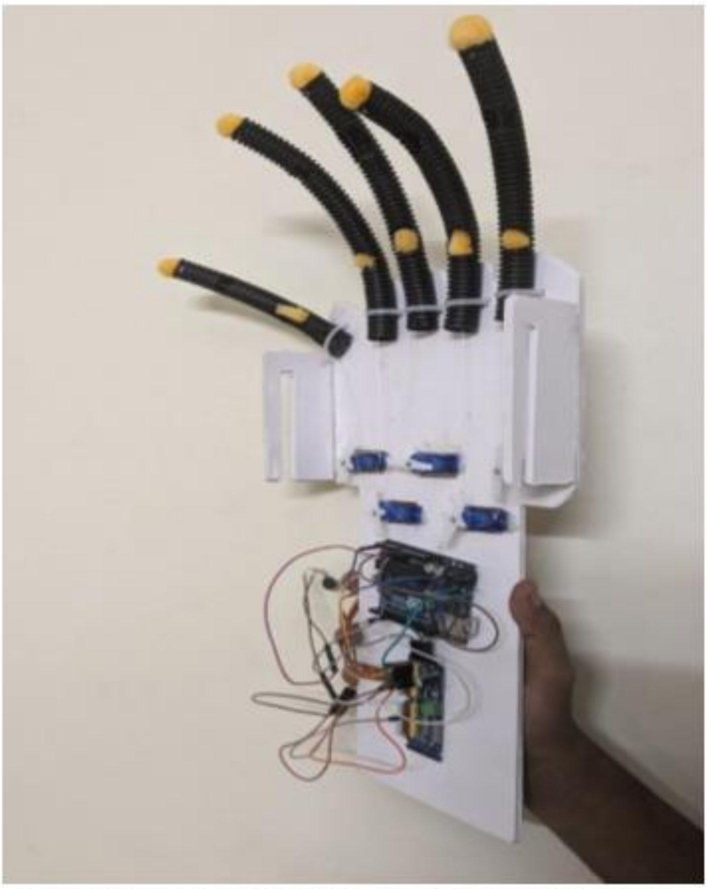
IV. EXPLANATION OF THE PROPOSED SYSTEM

Figure 4 illustrates the flowchart outlining the sequence of operations in the proposed system. The hardware setup for the Arduino circuit includes six servos and a PCA9685 PWM driver to ensure precise and independent control of each servo. The Arduino serves as the main controller, executing programmed instructions and sending commands to the PCA9685 via the I2C communication protocol. The PCA9685 acts as an interface, generating 16-channel PWM signals that control the position and movement of the servos based on the pulse width received from the Arduino.

Each servo is connected to the output channels of the PCA9685 through their signal wires and requires a separate power source to provide sufficient current for smooth operation. The programmed instructions in the Arduino specify the desired angles for each servo, enabling precise and synchronized movements. By adjusting the pulse width for each servo, the setup allows for intricate and coordinated motion, making it suitable for applications such as robotic arms, animatronics, and other projects involving multiple servo-driven movements.



Tactile robot interpreter with servos and control

Fig 5 Assembled model of the Tactile Robot Interpreter

Figure 5 illustrates the assembled model of the Tactile Robot Interpreter, highlighting the integration of servo motors and control circuitry. This robot can extract text from images and input from a computer, converting it into tactile sign language that can be interpreted by deaf and blind individuals. A user-friendly Graphical User Interface (GUI) has been developed, allowing users to either input text directly or capture a text image using a camera. The figure 7 and Figure 8 illustrates the GUI layout and its visual display. Using Optical Character Recognition (OCR), the captured image is processed and converted into English alphabets, as shown in the figure.

For example, if the word "Helen Keller" is captured through the camera, the OCR module extracts and recognizes the individual characters from the image. Each alphabet is then mapped to its corresponding American Sign Language (ASL) sign. Figure 9 shows the output of the OCR, and Figure 10 shows the output generated for the servo motor in the Arduino IDE. Based on this mapping, specific servo motor positions are generated.

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These positions guide the robotic hand in adjusting its movements to accurately display the respective ASL signs, enabling tactile communication for users with visual and auditory impairments. This system aims to enhance communication for visually impaired individuals and can also serve as a tool for teaching sign language to both disabled and able-bodied people. Using computer vision algorithms, the system recognizes and extracts text from images or documents, then employs machine learning models to translate the text into ASL gestures.

Opening GUI Interface

Fig 7 Graphical user interface (GUI) interface.

Fig 8 Input given through the mobile phone display.

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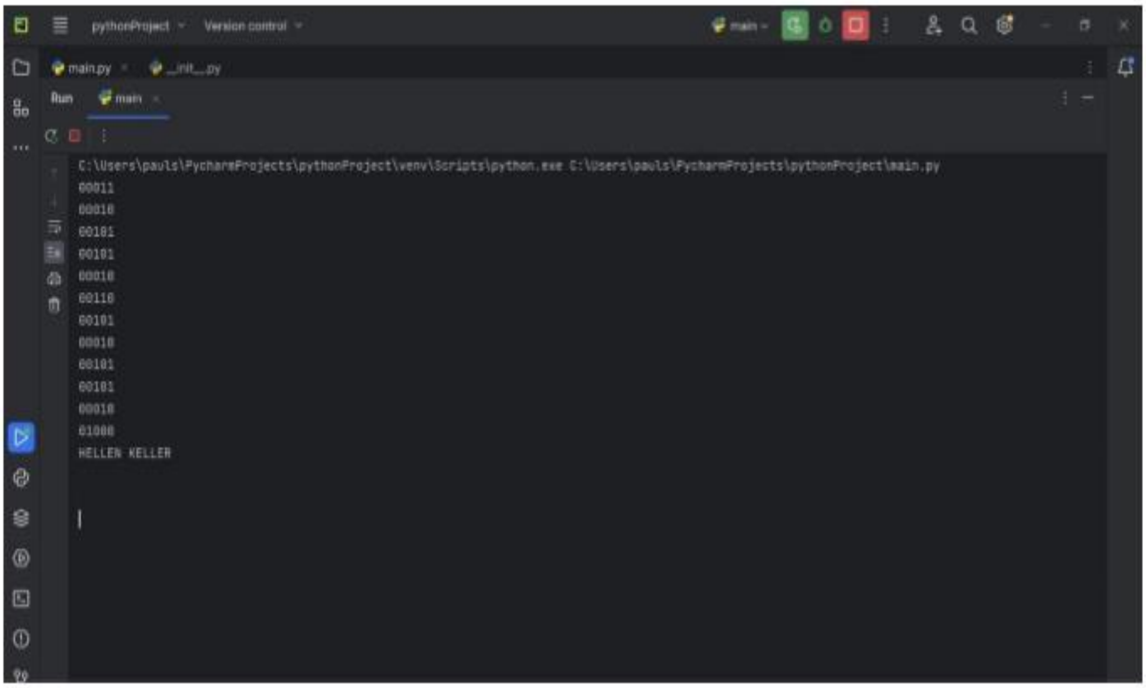

Fig 9 Output of the OCR

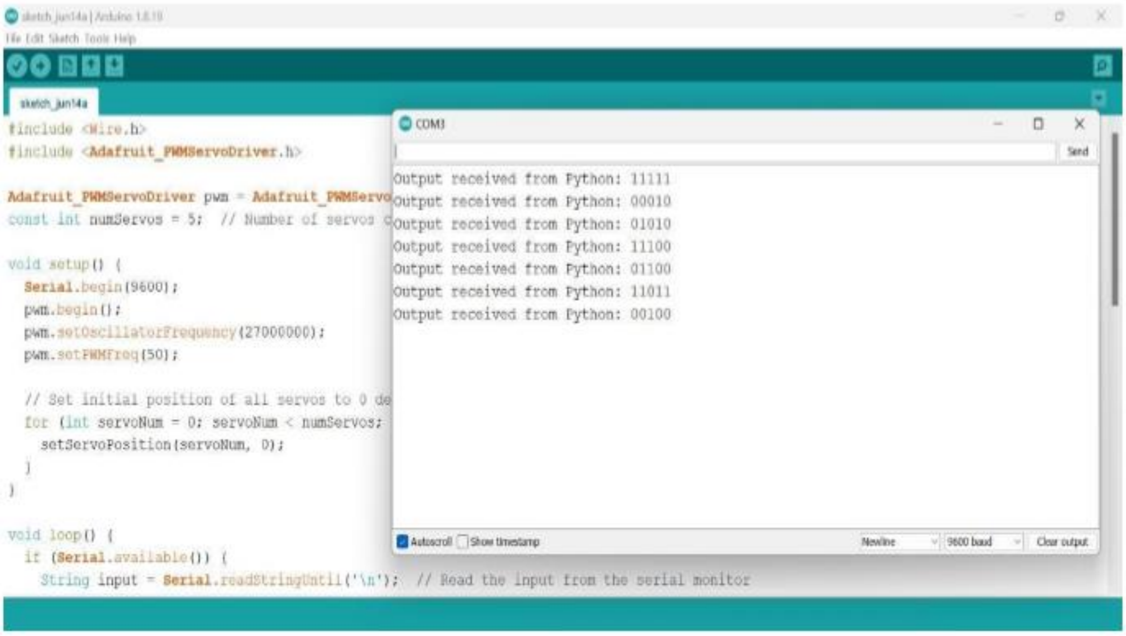

Fig 10 Output generated for the servo motor in the Arduino IDE.

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V. CONCLUSION

In conclusion, this robot represents a significant advancement in bridging communication gaps for deaf and blind individuals. By extracting text from images and computer inputs and converting it into tactile sign language, it provides an accessible and effective solution for improving communication. We used an Arduino board with servos to make this system cost-effective, while its open-source, user-friendly design makes it ideal for use in special schools. Its ergonomic features ensure comfort and ease of use. Beyond aiding visually impaired individuals, this project also serves as a valuable educational tool for teaching sign language, fostering greater inclusivity and understanding across diverse communities. With its integration of computer vision and machine learning, this system showcases the potential of technology to revolutionize communication for individuals with sensory impairments.

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