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Smart Communication Haptic Glove for Deaf and Dumb People

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Abstract: *Most of us are blessed with natural ability to see, listen and interact. However, few people do not have this ability. Due to various reasons like birth defects, accidents, oral diseases, and environmental impacts the number of such people is rapidly increasing in the recent years. Most of the deaf and dumb use gesture and sign symbol for the communication. Sign language is the form of communication where shapes, arms or body, orientation and movement of hands, and facial expressions are systematically combined. But, sign language is ineffective in many cases. It may not be sufficient when such people are involved in the educational, social and professional environments where they want to interact with others. Therefore, there is an immediate need to have an advanced sign language detection and gesture recognition system. The need, design methodology and implementation strategies of a smart glove are discussed in this paper. The main objective of the work is to bring the technology for the help of differently abled people to communication effectively and in most meaningful form. The hand glove converts the hand/finger gestures in to meaningful voice messages over an Android phone.*

Keywords: Sign Language Recognition, Wearable Technology, Flex Sensors, Motion Sensors, Assistive Device

I. INTRODUCTION

The Smart Communication Haptic Glove is an innovative assistive device designed to enhance communication for individuals who are deaf and mute. This wearable technology translates hand gestures into text or speech, allowing users to interact seamlessly with those who do not understand sign language. Equipped with flex sensors, motion sensors, microcontrollers, and haptic feedback systems, the glove detects finger movements and converts them into a digital format. The integrated text-to-speech module then generates audio output, enabling real-time conversation. Additionally, haptic feedback provides a means for the user to receive responses through vibrations. Communication is the fundamental pillar of human civilization, enabling the exchange of thoughts, emotions, and information that drives social cohesion, personal development, and societal progress. For the majority, this exchange occurs effortlessly through spoken language. However, a significant portion of the global population, specifically individuals who are deaf and mute, faces profound and persistent barriers to conventional verbal communication. While sign languages, such as American Sign Language (ASL) or Indian Sign Language (ISL) common in places like Nagpur, serve as incredibly rich, nuanced, and visually dynamic forms of expression within their community, their comprehension is unfortunately not universal. The vast majority of the hearing population remains unfamiliar with these languages, creating a substantial and often isolating communication chasm.

This profound communication disparity frequently leads to tangible consequences for deaf and mute individuals, including social marginalization, reduced access to educational and professional opportunities, and significant hurdles in navigating everyday situations like medical appointments, legal proceedings, or simply interacting in public spaces. The reliance on human interpreters, while crucial, often introduces delays, costs, and is not always a readily available solution, further exacerbating feelings of exclusion and dependence. The rapidly advancing digital landscape, paradoxically, often amplifies this challenge, as most prevalent communication technologies are primarily designed for auditory or textual interaction, overlooking the unique needs of visual-spatial sign language. Consequently, there is an imperative and pressing demand for innovative technological solutions that can effectively transcend these existing communication barriers, fostering true inclusivity and enabling seamless, real-time interaction.

II. LITERATURE REVIEW

A sign language recognition system was discussed by P. S. Rajam et al. . In this method, binary signals are generated for 32 signs which represent different positions of the fingers. The positions of the fingers were detected and converted into text using image processing techniques. The result of this technique was able to recognize images with 98.125% accuracy. Height of fingers is measured with the bottom of palm close to wrist as reference point. Finger patterns were recognized by features and data acquisition system is used for palm image extraction and sign detection. It is then converted to text. Authors have showed that image processing as one of the methods to recognize sign language [4]. A glove which is coupled to an AVR microcontroller is presented by Ahmed et al. It is an electronic glove having multiple flex sensors and the signals are interfaced to a microcontroller.

To develop glove sensor-based Sign Language Recognition (SLR), studies should be appropriate and should have full-text versions that are accessible online. Besides, only articles written completely in English were considered This research helped in selecting flex sensors and IMU sensors to improve gesture recognition accuracy in the haptic glove.flex sensors and IMU sensors to improve gesture recognition accuracy in the haptic glove. ESP32 for wireless connectivity and cloud integration for future expansion. In the past years, sign language recognition based on sensory gloves has gained increasing attention, especially due to the many affordable sensors that have been released commercially. Researchers have created datasets or have taken data from publicly available databases such as (American, Chinese) databases. However, the number of studies that use an available database is significantly lower than the number of studies that use their own database. The majority of the papers reviewed were focused on each selected author's data set. The development of sensory gloves holds great importance, and it plays a key role in the successful translation device for speech/hearing impaired. By taking into consideration some of the most important key factors in this regard from the literature, the researchers of this research forward several recommendations related to developers. Recommendations that are related to developers can be categorized into four sectors, which are: new technology, interface & output, device, and recognition

III. WORKING

The Smart Communication Haptic Glove is an innovative assistive device meticulously designed to empower deaf and mute individuals by translating hand gestures into understandable text or speech. This wearable technology facilitates seamless interaction with those unfamiliar with sign language, directly addressing critical communication barriers. At its core, the project functions through a sophisticated integration of hardware components and intelligent software. The hardware input begins with Flex Sensors embedded in the glove, which detect finger bends by changes in electrical resistance. An MPU6050 Gyro/Accelerometer simultaneously captures the hand's orientation and motion in 3D space. These analog signals are then converted into clear digital states, feeding into the Arduino Uno microcontroller, the system's central processing unit. The Arduino, programmed with specific instructions, interprets these digital inputs from both the flex and motion sensors.

The software component, developed using the Arduino IDE and potentially Python for higher-level applications, dictates the system's workflow. The process initiates with the calibration and initialization of the sensors. Subsequently, the system continuously reads raw hand movement data. This data undergoes analysis to extract meaningful features and identify specific gesture patterns. These identified patterns are then rigorously compared against a predefined gesture database.

Upon a successful match, the recognized gesture is translated into a corresponding text string or message. This output can then be displayed on an LCD/OLED screen or converted into audible speech via a voice module. For external connectivity, a CP210x USB to UART Bridge Controller enables the Arduino to communicate with a computer via USB, allowing for further data processing or display. Crucially, the system provides haptic feedback (vibrations) to the user, offering immediate tactile confirmation that their gesture has been recognized.

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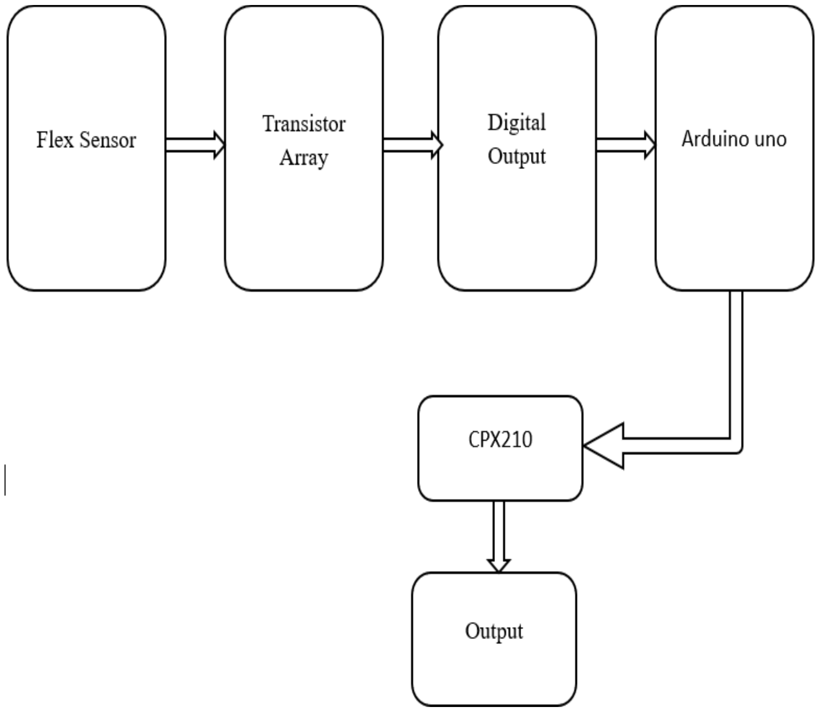

Fig 1. Block Diagram Smart Communication Haptic Glove

The block diagram of the Smart Communication Haptic Glove system illustrates the sequential data flow from physical input to meaningful output. The process initiates with the Flex Sensor, which serves as the primary input by converting finger bends into varying electrical resistance signals. These signals then proceed to a Transistor Array, likely responsible for amplifying or digitizing the weak analog inputs into more distinct signals. Following this, a Digital Output stage ensures that these processed signals are transformed into clear, discrete digital states, making them readily interpretable. These digital signals are then fed into the Arduino Uno, which acts as the system's central processing unit, interpreting the digital states to understand the user's hand postures and gestures based on its programmed logic. The Arduino's output is subsequently directed to a CPX210, a USB to UART Bridge Controller, which is crucial for converting the Arduino's serial communication signals into a Universal Serial Bus (USB) format. Finally, this USB data is transmitted to the Output block, signifying a connection to a computer where the processed gesture information can be displayed, converted to text or speech via software, or utilized for further applications, thereby enabling effective communicatin.

The provided image displays a detailed circuit diagram for the Smart Communication Haptic Glove, showcasing the interconnection of its various components to enable gesture-based communication.

At its core, the system's power management begins with a Power Supply (220V), which feeds into a Transformer to step down the voltage, likely to 12V. This is then rectified from AC to DC and smoothed by a Rectifier and a Transistor array (acting as a voltage regulator or filter) to provide regulated 5V and GND power rails1.

The primary inputs come from five Flex Sensors (Flex 1 to Flex 5), each connected to the Arduino board. A typical flex sensor setup involves one end connected to 5V and the other to a 3.3kΩ resistor that goes to GND, forming a voltage divider2. The voltage at the junction of the flex sensor and the resistor is sent to an Analog Input pin on the Arduino ATmega 2560 (Mega, not Uno as previously discussed, which offers more pins)3. As the sensor bends, its resistance changes, altering the voltage read by the Arduino. The diagram also shows multiple BC557 PNP transistors and 3.3kΩ resistors used to connect various inputs (likely other flex sensors or digital switches) to digital pins (D2, D3, D4, D6) on the Arduino, effectively converting analog states to digital HIGH/LOW signals4444.

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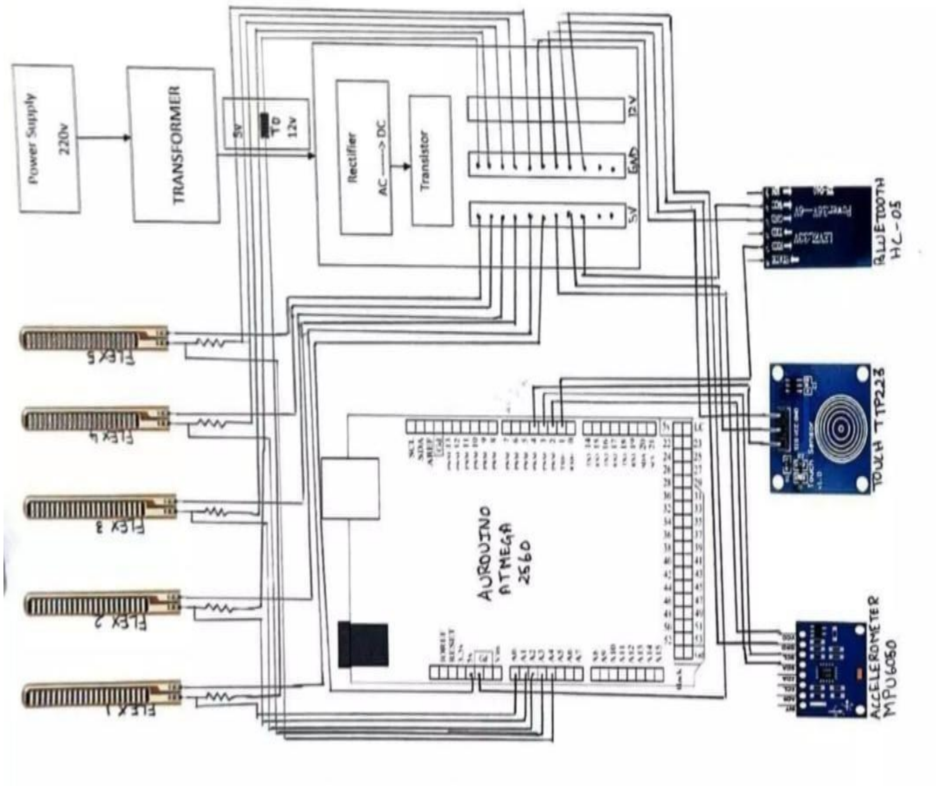

Fig 2. Circuit Diagram Smart Communication Haptic Glove

The glove incorporates additional sensors. An Accelerometer MPU6050 (Gyro/Accelerometer) is connected to the Arduino ATmega 2560 via its I2C communication lines: SDA (Serial Data Line) to Arduino's A4 pin, and SCL (Serial Clock Line) to Arduino's A5 pin5. An interrupt pin (INT) from the MPU6050 is connected to digital pin D2 on the Arduino, allowing for efficient data handling6. A Touch TTP223 sensor is also depicted, connecting its output to digital pin D7 on the Arduino. A Bluetooth HC-05 module, crucial for wireless communication, is connected to the Arduino's hardware serial pins, with its TX (transmit) connected to the Arduino's RX (receive) and its RX connected to the Arduino's TX7.

The Arduino ATmega 2560 acts as the central microcontroller, receiving and processing data from all the connected sensors (flex, accelerometer, touch). Based on its programmed logic, it interprets these inputs to recognize hand gestures8. The processed data can then be transmitted wirelessly via the Bluetooth module, or potentially to other output devices (not explicitly shown in detail for visual/audio output in this circuit, but mentioned in the document's flowcharts like LCD/OLED Display or Voice Module). This comprehensive circuit design allows the glove to accurately capture and process hand movements for communication purposes.

III. HARDWARE REQUIREMENT

The Smart Communication Haptic Glove project necessitates a robust set of hardware components and a well-defined software architecture to achieve its goal of bridging communication gaps for deaf and mute individuals. From a hardware perspective, the system's foundation is built upon an Arduino Uno microcontroller, serving as the central processing unit responsible for orchestrating data flow and logic. Input acquisition relies on multiple Flex Sensors that detect finger bending by measuring changes in electrical resistance, alongside a Gyro/Accelerometer module, such as the MPU6050, which captures the nuances of hand motion, orientation, and rotational velocity. An additional Touch Sensor, like the TTP223, contributes to the input array. For seamless external communication, the glove incorporates a

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Bluetooth HC- 05 module, enabling wireless connectivity with devices such as Android smartphones. Communication with a computer is facilitated by a USB-to-UART Bridge Controller (e.g., CPX210 or FTDI FT232R), converting serial data from the Arduino into a USB-compatible format. Powering these components requires a stable 220V power supply, which is stepped down and regulated by a Transformer, Rectifier, and supporting Transistor Array to deliver the necessary 5V. Output and user feedback are crucial, necessitating Haptic Feedback Systems, typically vibration motors, for tactile responses, and either an LCD/OLED Display for visual text or a Voice Module for audible speech output. The intricate wiring also involves various standard electronic components like transistors (e.g., BC557 PNP), resistors (e.g., 3.3kΩ), MOSFETs, and push-button switches, all integrated within an ergonomic and durable glove structure.

TABLE 1

Sr.No.	Component Name
1.	Arduino Uno
2.	Flex Sensor
3.	Gyaroscope
4.	MOSFET
5.	Register
6.	Gloves

SOFTWARE REQUIREMENT

On the software side, the project primarily utilizes the Arduino IDE for programming the microcontroller, providing the environment for writing, compiling, and uploading the C/C++ code that defines the glove's behavior. Python serves as a versatile high-level programming language, essential for tasks such as managing gesture databases, developing user interfaces on connected devices, or handling server-side data processing. The system's intelligence is driven by robust algorithms required for real-time sensor data processing, enabling highly accurate recognition of diverse sign language gestures by mapping sensor readings to patterns stored within a predefined gesture database. Key functional software modules include a text-to-speech module for converting recognized gestures into audible language, and a speech-to-text-to-haptics translation module to convert incoming auditory or text information into tactile vibrations for the user. Additionally, the software must support the necessary communication protocols for wireless connectivity, enabling the exchange of text messages and even Braille messages with an Android application, thus fostering comprehensive two-way communication.

This flowchart outlines the operational process of the Smart Communication Haptic Glove. It begins with initializing the Arduino and calibrating sensors like Gyro, Flex, and potentially a camera. The system then continuously reads and analyzes hand movement data. This analyzed data is compared against a predefined gesture database.If a match is found, the gesture is converted to text or a message which is then sent to an output device like an LCD/OLED display or a voice module, simultaneously providing haptic feedback via a vibration motor If no match is found, the system continues reading .

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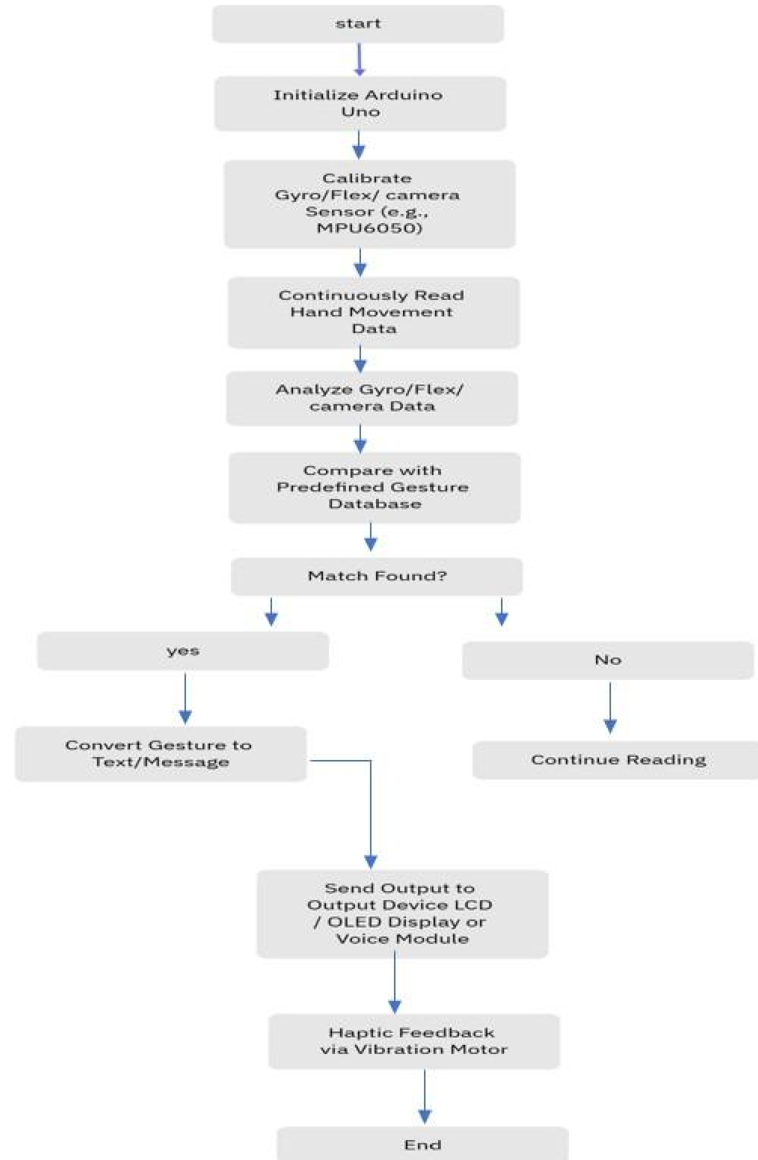

Fig 3. Flowchart

IV. CONCLUSION

The Smart Communication Haptic Glove project successfully developed a device aimed at assisting deaf-blind individuals in communicating with people unfamiliar with Braille. The Smart-Glove can connect to an Android mobile, enabling the exchange of text messages to and from the glove and facilitating the sending and receiving of Braille messages. This glove is designed to be light, inexpensive, user-friendly, and safe. The project's creators believe it offers an effective and highly beneficial tool for deaf-blind individuals, particularly if they learn Braille, thus empowering them to communicate with their families and the broader community. Future developments may include support for additional languages and alternative communication methods such as Wi-Fi or GSM modules for enhanced connectivity and range.

V. ACKNOWLEDGMENT

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