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Advancements in Sign Language Interpretation Using Glove Technology

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Annotation: Every human deserves a way to communicate with and express themselves to the people around them. A person can express their feelings with speaking or writing, but in the case of deaf and mute people, expressing themselves is very complex. Sign languages are the primary modes of communication among deaf and mute people. Sign languages are visual languages that use signs made by moving the hands, arms, body, and facial expressions. Sign languages are genuine languages, independent of the spoken languages, and form the basis of language development in a sign language child . The knowledge of sign language is very inadequate among the speaking and hearing people. This creates a communication gap between the two groups. This communication gap leads to the extremities of psychological and societal impacts on the deaf and mute communities. This demonstrates a definite need for a method to bridge the communication gap. Finger Glove is developed to facilitate the communication between speaking and hearing people with deaf and mute people using a pair of gloves. A glove for the deaf and mute person with sensors such as flex, accelerometer, and gyroscope is designed to detect sign language gestures and translate them into textual format. An Android application for the speaking and hearing person is developed which takes a string input of text and converts it into speech text output [1]. The complete system is tested and results are recorded and presented. The knowledge of sign language is scarce among the speaking and hearing people. The gap of knowledge of sign language creates faulty assumptions regarding the deaf and mute community, which in turn leads to bullying. This disadvantage creates a definite need for a device to translate sign languages to speech. The proposed device creates a pair of gloves, where the user wears one glove and makes sign language gestures. The glove translates the sign language gestures into speech. The glove consists of different sensors (flex, accelerometer, and gyroscope) for detecting gestures and translating them to speech format. The main aim of this research is to develop a cost-efficient, portable glove that aims to translate sign language to speech.

1. Introduction

Many hearing- and speech-impaired individuals deserve to live life to the fullest. Still, due to communication problems, these people suffer psychological and social impacts. The deaf–mute population constitutes a substantial global minority, about 70 million persons worldwide. Speech- and hearing-impaired individuals develop psychic diseases like impaired personal reflection. The problem with sign languages is that it tends to be spatially and biologically oriented. This makes recognition/decomposition difficult, error-prone, and demands prior knowledge of the language. Most of the population cannot recognize sign language (SL) and generally use spoken language to communicate. The most common languages worldwide are English, Hindi, Chinese, and Arabic. Thus, communication often breaks down. The words used by the deaf and dumb as Sign Language (SL) are absent from these general plain languages. Thus, there is a need for deaf-mute communication devices to translate SL into spoken language and vice versa [1].

Speech gesture is the foundation of linguistics for hearing- and speech-impaired peoples. This work addresses communication problems encountered by hearing- and speech-impaired peoples that have not previously been accounted for. The hand is used to produce a gesture along with other facial effects for sign language. This work focuses on wearable gloves that can recognize sign language with reasonably high degrees of accuracy. Five cases of sign language deformation are considered, and it asserts that these situations have not been accounted for in other work. Recognizing sign language deformation requires studying the underlying human cognition and monitoring. They have continued to work on better methods of recognition - especially those that recognize deformation - but at increasing complexities involving higher-level modeling of human cognition. Such modeling has remained an open problem in the field [2].

This work describes a glove that recognizes sign language with reasonable accuracy according to specification for its intended application involving deaf-mute communication. Thus, this work outlines the design of the glove in detail. It provides feedback on a so-called 'Intelligent Glove' that was designed to assist in recognizing actual sign language gestures. The knowledge base that accompanies the glove allows simple-to-complex signs with considerable degrees of accuracy to be defined and recognized.

2. Background on Sign Language

Sign Language (SL) is a language made up of hands, arms, facial expressions, and body postures to express thoughts and feelings. However, sign languages are not universal; each country tends to have its own sign language. For instance, British Sign Language differs from American Sign Language. People who can hear but cannot speak use sign language to communicate. The sign language consists of hand gestures that indicate specific words. Most of the general population cannot understand sign language, and the people who can understand it are very few and far between. Some people interpret sign language for hearing-impaired people, but that also becomes a bottleneck on many occasions. To overcome these limitations, a system is designed to convert the finger movements and wrist motion of sign language into speech using different sensors attached to a glove. As the person wearing the glove performs a sign gesture, this motion is captured by various sensors, which are then preprocessed and transmitted to a PC. At the PC, the sound corresponding to this sign is produced [1]. The glove-based sign language implementation is done as a product of signals from various sensors and components is set up. The experiment is conducted to calculate the data collected for both 6-Axis Accelerometer and 3D Gyroscope. The comparison of analysis and implementation methods is presented between 2-axis and 3-axis sensors, and important observations are noted and depicted. A mechanism for processing inputs for digitization into binary integers is implemented. The actual implementation of the parts decided for input capture is illustrated. The data storage and training phases of the ANN are shown. Proper testing of the system is done using various real-life scenarios, and appropriate measurements of performance are calculated and discussed with proper examples [2].

2.1. History of Sign Language

A sign language is a system of communication used by the deaf and speech impaired communities using gestures by hand movements and body postures. Each country has its own uniqueness and signatures for any idea, thought, or feeling. An interpreter must know about the grammar, syntax, and peculiarities of the corresponding oral languages [2]. Sign language is rich in gestural movement with a variety of hand gestures which are used for alphabets and phrases. Alphabets are used frequently for new words and unknown words. Only a few pronunciations have one-to-one gestures for words. On the other hand, word phrases or signs consist of more gestures which are a combination or concatenation of motion and non-motion gestures. The choice of the word phrase is from the vocabulary of that country. The equipment has a glove, camera, and a wireless communication unit along with a high-speed digital signal processor unit to infer from the glove or camera units and control the communication unit [1]. It describes vision-based recognition of gestures and invented a glove-based system for gesture recognition displayed on a mobile.

Sign language recognition is done through different mediums such as data gloves, sensor glove, vision recognition systems, multi-sensor glove, and real-time systems. The gesture data is acquired using various sensors, one of which is a glove as an input device. The output is a word or an ASL interpreter. Data gloves are used for sign language interpretation, which is a sense glove for sign language used to recognize individual gestures. A complex hand shape detection approach is provided for 3-D vision-based recognition of gestures using machine learning techniques which are relatively complex to carry. Data gloves use Flex sensors for hand signs and printed circuit board sensor units for finger motions. The sign language recognition of alphabets and word phrases is done in ASL using a data glove and also for gesture representation, linguistic matched with the model. More sensing units provide the detection of more degrees of a hand gesture. A linguistic model that maps a sequence of letters to a phrase is a combination of the ASL and recognition model.

2.2. Importance of Sign Language in Communication

Sign language is the main tool to communicate with the deaf and dumb. However, most of the people cannot use sign language to communicate, which leads to a lot of misunderstanding. Moreover, the employment rate of the hearing-impaired is very low. This may be due to the communication barriers between people with hearing disabilities and able-bodied people who do not understand sign language. Although there are some translators that can convert the sign to text at present, these systems are expensive and unfriendly to most people. The glove needs to be worn in-order to understand the sign language which is a-natural language by deaf persons. But it is becoming more and more popular among people who are in support of the deaf community [2]. Most of these devices are either too expensive or complex, making them inaccessible to the average person. This able-bodied person uses a hardware glove. The glove is a hardware tool designed to recognize each finger motion and output it over the com port.

Menva, a prototype, is built based on this hardware glove, an interactive software system designed to evaluate learning progress in sign language. It has two primary lengths which include teaching by showing the letters and dialogues random testing. During testing phases are displayed only name of a letter in-some letters and a text dialogue-pair to signing. The goal state is evaluated through searching for a shortest series of transformations [3]. Currently, most people who do not understand sign language are unable to communicate with the deaf, but efforts to help bridge this communications gap have blossomed. A soft wearable glove is designed to help make the deaf visible and convert gestures into audio. Using cheap flex sensors and an analog to digital converter, the device maps the fingers to the available orientation. Complementing the glove is a solitary mobile phone application that interfaces with the glove and produces the relevant audio output. Once the audio is transcoded, it can be used in common scenarios, such as conversion to a written form or use with known speech recognition systems.

This invention can help to break the communication barrier between the hearing impaired and the rest of the community. The primary goal is to design a low-cost, standalone glove device for accurate translation of sign language. The finger gestures employ resistive flex sensors to accurately detect the degrees of finger bending. Other types of sensors are also investigated to identify a suitable choice of technology for this use case. A Wi-Fi enabled development board uses a microcontroller to convert the data received from the sensors into a Bluetooth enabled surrounding that runs on a mobile phone application for augmented and virtual reality applications. Such an application allows presentation of information and stimuli to the user’s environment. The output signal is modulated frequencies of audio oscillators that generate spectrally pure tones. [4][5]

3. Technology Overview

The system consists of two transceivers, one located on a glove worn by the signer and the other located on a computer with a receiver. The system hopes to improve upon accuracy, speed, portability, affordability, and the practical aspect of sign languages interpreting technology. A wide range of solutions includes HMMs and neural networks. Each of these solutions has its advantages and drawbacks. To a very large extent, most of these previous works use the same approach with similar overall recognition systems. Each study, however, follows a different temporal representation. This offers insights into the diverse nature of approaches with respect to the temporal signals employed.

Surface electromyography (sEMG) is the electrical bio-potential acquired from the muscle activity. It is intrinsically more robust to variations in hand shapes and skin tone than RGB images. It can more directly be used to detect the neural triggers causing the gestures and tracks muscle activities beyond hand shape recognition. An accurate and reliable sensor glove would greatly improve the communication travel speed of the Deaf and Hard of Hearing community. The publicly available datasets based on multi-modal sensor gloves are limited, under subtle gestures. A few estimators are built with sEMG data utilizing the state-of-the-art Kinematics and image-based models but with limited transferability.

A Smart Glove based Finger Recognition and Sign Language Translator system is designed for hearing-impaired people which translate ASL in real-time. The smart glove worn by the user has three main components flex sensors, accelerometer, and microcontroller. The flex sensor measures the bending angles of fingers. The accelerometer is interfaced to measure hand gestures. The information is sent to the processing unit via Bluetooth. The processing unit consists of PC and environment Programmable interface. The world has an unsolved problem of communication for deaf and mute people. It results in social isolation which at various levels translates into social imbalance. Deaf and mute people often find it difficult to communicate with normal people. As such, there is a need to develop devices which will ease the communication of the deaf and mute population of the world. Sign language interpretation is the process of transforming sign language into a target language. Sign languages are primarily expressed by the hands and arms, but in addition they may use facial expressions and other usages of the body. Thus, the sign languages are complex and rich lexicon. [4][6][7]

3.1. Types of Wearable Technology

The Smart Glove is an aptly named hand-worn hardware device capable of translating American Sign Language gestures into English speech. Users wear this glove on their dominant hand, and the motion of the hand along with the orientation of each finger is sensed using a sensor array – Flex sensors (five), an Accelerometer (1D), and a gyroscope (1D). The values from these sensors are sent to an ARM Cortex-M4 microcontroller unit. The peripherals associated with the microcontroller are I2C based Flex sensors connected on I2C bus, and Headphone jack is used to connect it to the Android phone, which is powered by the USB remote control device. The sensors measure respective translations and rotations of each finger fitted to the palm. The firmware developed on Keil MDK ARM IDE handles ADC data acquisition, transfers it to Android phone. Using Markov and decision-tree algorithms, gestures are recognized on the phone and converted to speech using text-to-speech engines [1]. Hearing-impaired people use a sign language to communicate with each other, however it’s not known to the general public. Also, translation begins momentum now-a-days, but they are of large sizes and expensive. Sign language is primarily used by deaf and mute people, and over 70 million people use sign language around the world. Sign language primarily uses hand motion and finger orientation to express words and sentences.

The model presented aims at providing a glove consisting of flex-accelerometer and gyroscope sensors to give an inexpensive glove capable of real-time translation of sign words into text. System has 34 gestures for the words hello/goodnight, how are you, i love you, thank you, we’ll miss you, please forgive me, sorry, who are you. Home automation using hand gesture tracking using Arduino microcontroller, ultrasonic and IR sensors are used [2]. Thermal camera module detects the presence of fire smoke and gas leakage through the mobile app which sends messages to users via a GSM module. Existing fire alarm systems use either smoke or heat-based sensors. The proposed design combines both of the detectors to enhance the fire detecting capabilities and dependable systems such that the proposed model can be seen as a next-generation fire alarm system which uses IoT, the system consists of a thermal camera, gas, smoke, and PIR detectors, Arduino Wi-Fi module.

3.2. Overview of Glove Technology

Sensors are a measurement component, which can generate additional, informative, or complementary data about the physical world, groups, or features. Sensors convert directly measurable physical variables into analog or digital signals, which can be read by a circuit. Two major categories of sensors are transducers and non-destructive sensors. Since measuring precision is crucial for many applications, including distributed systems, and sensors are noisy, correlated, or affected by outliers, data fusion and other processing methods are required [1].

The transient and multiple aspects of a phenomenon can be sensed by using multiple sensors. In a distributed data-acquisition system, a great number of sensors can be used, but the excessive raw data overhead cannot be transmitted and stored. It is necessary to reduce the redundancy of data and to eliminate useless data. Basic definitions and characteristics of spatial, temporal, hyper-parameter, spectral, and relevance redundancies introduced at each acquisition process are presented as a general architecture of data-acquisition systems. Basic methods of data compression and transformation are surveyed. Data fusion methods are also surveyed. By using some test problems, two of the elementary and gradient and recent ultra-causal, modal, and compact data-fusion methods are compared.

Glove devices stand for one of the most important efforts aimed at acquiring data about hand movement. This paper analyzes the kind of devices, offers a road map of the technology development, and discusses precincts of the current technology. The technology field started about 30 years ago and continues to attract a growing number of researchers [8]. Among the currently used applications there are most popular devices like Nintendo Wii gaming console and many virtual reality-based glove devices.

4. Mechanisms of Sign Language Interpretation

A thumb is also used as it twitches during feelings. A combination of accelerometer and gyroscope is used to build a device with very small volume and weight. The device is attached with a good wrapping and a small battery can still make it portable. This auto sensor outputs real-time hand motion. It has a sufficient number of points of the sensor. Its output is more reliable with a support of matrix. When the sensor has no training data or it comes up with an unknown word, it has a strong signal output. It can also sense words in short time windows with some specific symbols as tags. The sign can also be recognized from the output of the whole sigmoid. Output of number of sensors is placed in a 30×3 matrix. A raw signal was transformed to stiffness and the angle is taken in degree. From just one training sample of sign, it can be successfully recognized again in diverse conditions. Combination of possibly two tasks is particularly suited for neural data processing. No one is currently working on this task and system design remains open. IMU signals were captured and analyzed in properly chosen functions. Some features derived from the functions were selected with a competitive machine learning technique. The output was switched and off in real sign process brings no additional effort to segmentation [1]. Three levels of a case gesture are proposed: gesture sequence, gesture type, and finger state measurement. The orientation of a hand against a body is transmitted by eye to hand laser beams' alignment. Effects of beam blurring on hand position detection and beam edge smoothing are considered. Adaptable thresholds are employed for detecting hand openness with global fuzzy segmentation of already established bezier curves drawn on the current screen. Visor monocle shape and an interactive computer—visor improvement are also presented. Adaptive local thresholding is implemented in the preprocessing stage. Illumination invariant edge information is used in gesture hand border detection and integration with structural analysis to recognize a signed number. It is modeled by a wavelet representation that is similar to those of American Digits in video software. For each wavelet curve, subcurves are dynamically allocated to properties and are integrated by the structural features of fingers even under damages of illumination.

4.1. Sensors and Data Collection

This chapter proves the adaptability of the sensor glove device in translating Pakistani Sign Language to Urdu words and sentences in real-time. A glove was designed that incorporates off-the-shelf IMUs and flex sensors, and was further improved with a custom-built glove design for better usability. A simultaneous reprogramming method was presented to minimize latency [8]. Experimental results demonstrate the glove's potential as a general-use, low-cost device for gesture recognition in signing languages, as well as its importance in increasing independence and dignity for the hearing-impaired community. This chapter contains details on the various components used in the glove and algorithms for recognizing gestures using sensors, as well as the project's complete workflow. In recent years, researchers have developed a variety of gloves designed to work with a passive-camera and active-camera setups, featuring wired, wireless, and dongle form factors, as well as litter or oversized, foam, or handmade designs. This section examines a comprehensive variety of glove designs available in the literature to compile a new database for future studies [3]. Below is a list of glove-mounted sensors available in the literature.

The above sensors have been used to gather different types of movements, such as 2D and 3D gestures, hand posture, finger and wrist movements, and glove tilt sensing. Various mixtures of sensors have resulted in successful designs. As the focus of this study is on wearable data gloves and the creation of a sensor glove prototype, the last two sensors—flex and gyroscope—will be examined in depth below. These sensors are desirable for research because they are able to detect almost any signer's gestures smoothly and incorruptibly. Apart from these sensors, several other cheap gyroscopes and accelerometers are available in China and other countries, which make this sensor desirable. Some might argue that another optical tool that uses dual cameras is better, but it would require the setup of fencing or tracking spots in the environment in order to get accurate data; any motion or obstruction in the range can disrupt the tracking and therefore the system.

Flex sensors are often pieces of a flexible material, usually a plastic, that change resistance based on how much they're bent. As they undergo flexing, they change from a low-resistance state when straight to a high-resistance state when bent. This exercise measures the angle on the hand as well. As they are analog sensors, they output values from zero to five volts in relation to how they are flexed. In this research, they are applied to gather the flexion of the thumb, index, middle, ring, and little fingers. From years of thoughts about designs and tests, the best flex locations were found to be the midway position between the first crease and the tip. They were glued to hard padded velcro tape for the best usage, as the nylon velcro tends to loosen in the long run and when bent. At the FDA, the device was approved earlier in 2009. [9][10][11]

4.2. Signal Processing Techniques

For sign language recognition, conventional glove recognition systems utilize many sensors to detect bending angles of fingers based on Inertial Measurement Unit. Also, several studies have built glove recognition systems to detect hand-gestures using 3D accelerometers, gyroscopes and magnetometers. In past decades, smart gloves have been widely used to recognize different hand gestures/sign languages. Commercial devices or platform devices usually have many sensors with high cost. A low-cost and simple glove design for sign language perception, which only have one TENG and one flex sensor to detect flexure information of thumb and forefinger.

Based on comprehensive feature extraction from the glove output signal and a supervised learning method, sign language recognition is conducted. The glove wearer only needs to wear the glove on thumb and forefinger and enact the sign language in a laboratory environment to extract and train the SLR algorithm. The glove output signal undergoes signal processing before transmitting to a host computer to realize the understanding of the sign language performed by a gloved user. Initially, an objective function is proposed to measure similarity between individually received S1 signal and group S2 signals from group S2 signals as a baseline. Efforts made to investigate the process of extracting the objective function and its successful application in SLR are presented. After identification, feature data of the identified gesture with a QRS complex is detected, and a SLR process based on the distance normalization of two signatures in correlation with the feature data is presented. A smart glove recognizing both letter gestures and isolated words of American Sign Language recognizing SLR system using a glove with 14 IMUs. A classification algorithm based on multi-order wavelets for feature extraction has been applied. Recognition rates over 85% demonstrated accurate hand gesture discrimination.

A hand motion estimation model that can represent 26 letters ASL across different subjects, indistinct image quality and illumination conditions is developed. A deep convolutional neural network approach is proposed to detect Leap Motion-based sign language in real time. Additionally, a sign-to-speech translation system and a heart rate monitoring system based on a steganographic principle have been proposed. Commercial glove-based actual systems usually have a high number of sensors, high complexity, high computation cost and non-real-time processing. The proposed glove-based system is a smart glove with singular sensor and simple structure at a low cost. [12][13][14]

5. Current Applications of Glove Technology

In interpreting sign language (SL), hearing-impaired people's sign gestures are detected and converted into audio text or audio speech by the recognition system, while the other way around is done in translation. A glove-based SL interpretation system aims to detect and recognize SL gestures easier and faster in real-time input. The latter is a complex process because, in addition to the hand shape, the hand position, palm orientation, transition time, and other features must be considered to improve the accuracy of recognizing gestures. As a result, the systems that use various types of 3D position sensors usually fail in real-time processing because they need further processing, and simultaneously, access phase or delay durations will slow down the detection. Moreover, automatic systems are only applicable to specific SL tasks [2]. A very limited number of systems track 3D hand motion using a glove representation in one region in the hand. Most previous SL recognition systems are computationally expensive and work off-line. A 3D SL recognition glove system with low-cost hardware is employed to capture SL gestures in real-time. All computations are performed on an embedded board, and the detector-glove can work in an environment that does not require any computers. The proposed combined Spherical Harmonic and graph-based methods for SL recognition are accurate where all fix PVC markers are attached on the glove.

Glove-based systems have been explored as another helpful technique to obtain hand movement data. With the development of computing, materials, sensors, and improvements in processing and classification methods, the new generation of glove systems has become powerful, highly accurate, comfortable, and cheap. With the recent dramatic decrease in the density and cost of key technologies, such as MEMS sensors, a glove can be a dead-reckoning, battery-operated, low-cost, and micro-scale sensor input technology by which the current position of a person can be estimated from the noise-free measurements of its previous position and the internal sensor data. Modern technologies now enable gloves to be made autonomous, overcoming the need to be connected to a computer. A glove-based assistive interpreter tool for hearing- and speech-impaired persons attempting to communicate with non-disabled individuals is proposed. It uses flex sensors, accelerometers, and a Bluetooth module. It takes input data as gestures or signs produced by the user's hands.

5.1. Real-Time Interpretation

Real-time Sign language interpretation has been implemented with a glove-based technology in many works. These advancements can be found in [15] where a glove-based sign language interpretation and communication system has been implemented with sensors. The gloves capture significant features, and AI has been implemented to classify actions in real-time. Specially designed virtual space has been created using software to realize gesture-based interaction. The glove performs intelligent sign language recognition that contains diversified and complicated gestures. A glove equipped with a triboelectric sensor is developed to recognize five letters of the sign language fingerspelling. Most current sign language translation solutions are limited to the recognition of only several discrete and simple words, numbers, or letters. The system includes the sensor-integrated glove, an AI processing block, and the interaction interface. This system successfully realizes the recognition of 50 words and even 20 sentences of sign language. [16][6][17]

The recognition results are projected into space with comprehensible voice and text to facilitate barrier-free communication between signers and nonsigners.

5.2. Educational Tools for the Hearing Impaired

The proposed system for gesture recognition by glove hardware is made on an innovative design for glove hardware. The design is a novel in terms of the glove's appearance being similar to the human hand and easy to put on since the spiral wire is connected to an opening ring for the thumb. The design is also innovated in terms of the finger fingerprints theme. These components are suitable and safe to be used by kids without any harm and provide safe safety mechanisms. Their layout, volume, and shapes needed to hold glove hardware for accurately momentarily recognizing and capturing gestures and minute hand movements for better fidelity in recognition results. Real-time adaptive gesture changes capability and a threshold for camera distance and fingernail colors were found to be limited conditions. A behavior skill assessment solution for educational tools and trainings for person-to-person communication is developed. Examination sheets with images of hand gestures on three levels of the learning sequence of 72 hand gestures are designed. The designed solution contains a sheet for examers to write down the hand gesture names according to a recognition result of the examination sheet, whereas a grasped glove is used. The positive outcomes of this solution can provide more understandable skills assessment tools for teachers and parents of instructed students of hand gestures (hand signs). Detecting deaf and mute people from the images gathered on the streets is a new type of normal behavior surveillance. The work proposes a new vein sequence of a hand as a new biometric trait to detect and verify user identity and authentication. In both verification and identification scenarios, the current evaluation results show the effectiveness of the approach to cross-different image acquisition conditions and different image preprocessing. An automatic evaluation benchmark including self-compiled datasets with realistic scenarios is built. The performance of various-hand shape and appearance-based algorithms is evaluated. Before the fine-tuned reshaping steps segmentation algorithms, convex-hull based representation was used. Gesture recognition uses a 3D glove and a video camera to interpret sign language like word formation with a sequence of 3D motion gestures. The design algorithm uses Kalman state prediction with spectrum analysis to extract residuals to check gesture completion and integration from raw signs. Off-line and on-line development and evaluation of the gesture recognition system was given [2].

6. Case Studies

The advancements in glove technology for sign language interpretation have produced various systems and techniques. One such technique is the ASL glove, an essential glove for the hearing impaired that is primarily used to translate American Sign Language into voice. Five sensors are mounted on the finger joints of the glove to recognize gestures and their positions, while a flex sensor is used to measure the angle of the fingers. This technique reduces dependence on others, as it is difficult for the hearing impaired to communicate verbally [2]. The proposed glove has three main parts: the flex defects, which conform to the hand of the person wearing it; the Arduino microcontroller, which acts as the brain of the device and is powered by a 9-volt battery; and a voice module, which converts the gestures of the American Sign Language into voice and audibly reads them. This project reduces the burden of having a translator present all the time, as computers can generate output through speakers. Thus, this invention is an alternative to costly hardware systems.

These smart gloves will need state-of-the-art sensors for hand position and orientation tracking. Furthermore, the architecture will need to combine and synchronize raw data dealing with different modes including approaches needing more data processing and more acceleration, minimum cost and fewer requirements processing. This invention may also comprise an OTG-compatible device that connects to the mobile phone for the deaf-mute person, which would be used for connecting laptops and various sensors as well. A separate application has been designed for the Android platform to interface the glove hardware by Bluetooth so that people connecting the glove across Bluetooth can view the converted text corresponding to the input sign irrespective of the existing text messaging apps.

The above case studies represent a selection of the most important approaches reported in the literature according to critical parameters that identify and characterize the system technologies and solutions proposed. As a disclaimer, this is not a comprehensive review of the topic but rather a tasting of the most representative and promising approaches to glove systems that provide effective and robust solutions to the sign language interpretation and recognition challenges. [18][19]

6.1. Successful Implementations

A wearable device called "Smart glove" that can recognize ASL (American Sign Language) gestures is created for translation of sign language to speech. People with hearing and speech impairments rely on sign language as their primary communication method. However, very few of those individuals know sign language, resulting in communication barriers between these individuals and the general population. There is a need for a technology to translate their sign language into voice in order to overcome this barrier [1]. The Smart glove is a hand-worn hardware device capable of translating gesture expressions made by the hand into speech with the help of hardware sensors and intelligent software working together. Accelerometers, Gyroscope, flex sensors, and pressure sensors are the hardware sensors. Based on the information captured by the sensors and interpreted by the on-board software, the speech is audibly expressed. The gesture tracking of the smart glove involves tracking of finger orientation, gesture recognition, and hand motion tracking. This paper explains the design and implementation of Smart glove in detail covering the design of both hardware and intelligent software. The translation of both Alphabet gestures (eg: A-Z) and Word gestures (eg: Hello, World) has been explained in detail here and the system that translates them is called Tactile-Sign to Speech Voice Systems. New approaches and algorithms have been proposed in the paper to solve the many hardware-dependent issues of the existing glove based design [2]. As the Smart glove is designed in such a way that it is modular in nature with distributed processing units, it encourages by allowing enhancement on few particular modules by modular enhancement only, which reduces complexity and interrelation between subsystems. An intermediate processing unit processes the gesture information and recognizes the gestures by checking the set of trained data with various classifiers. Decision Trees as a classifier are used for gesture recognition and error correction.

6.2. User Feedback and Experience

The current review paper specifically focuses on a novel Sign Language Interpretation System. It contains effective outlines for the software/hardware modules developed to enhance real-time performance of the system. It provides a smooth and understandable design approach detailing the computer vision, audio processing, and sign language interpretation activities supported by mathematical models and algorithms. A thorough analysis of the system’s performance is conducted by presenting the performance metrics and experimental results [2]. This architecture is very useful for both academic institutions and industries working in computer vision, audio/signal processing, and human-computer interaction. This review article specifically focuses on the identification of Sign Languages in terms of Sensory Gloves. Several systems, sensors, and methodologies are identified for recognizing various SL in sign languages based on the GUI of gloves used. The performance of the systems is evaluated based on the number of vocabulary words, types of gestures, the number of temporal frames, predictions techniques, environments, and countries of the origin using GUIs. The review infers significant research gaps and future directions in the Sign Language domain.

7. Challenges and Limitations

Due to the rapid advancement of technology today, most people use high-definition smart communication devices, digital media, and real-time video streaming for communication, socialization, and information exchange. However, this opportunity is not available to everyone. The challenge of deaf-mute people to communicate with a normal speech-hearing person is one of today's major concerns. The loss of the ability to speak or hear exerts psychological and social impacts due to the lack of proper communication. As a result, studies have recently focused on sign language interpretation, and specifically on systems based on sensory gloves that procure data on the shape or movement of the human hand.

Many researchers began examining glove systems systematically, but no attempts have been focused on summarizing the available software systems. The rigorous description of such systems is important for researchers to avoid unnecessary duplication of effort and to advance the state-of-the-art of hand gesture recognition. Since there is considerable diversity in glove systems, an effort has been taken here to create a coherent taxonomy to describe the latest research on glove systems for sign language recognition, as well as to analyze the system architectures and limitations of these glove systems. Sensor gloves have been continuously developed and have contributed to the evolution of many computer science fields, including virtual and augmented reality, ergonomics, computer vision, and medical applications. The aim of this paper is to review a range of glove systems that have been used for gesture or sign language recognition in order to gain insights into the design choices and limitations of these systems and the improvements that could enhance system performance.

Many systems have been proposed for the automatic recognition of sign language in its two-dimensional form using vision sensors. However, the lack of the large relevant annotated data has inhibited further advances in this area. Even so, there remain uncertainties related to the robustness and flexibility of vision programming, as well as ethical implications with regard to privacy controls. Although vision systems have matured in the last few decades, glove systems nevertheless have advantages. For example, due to the wearability of the glove, hidden knowledge can be continuously streamed to be processed instantaneously by a computer. More importantly, however, there are some gestures that cannot be captured effectively by cameras but can easily be sensed by gloves, such as hand analysis methods, dihedral angles, and gestures in the occlusion [2].

7.1. Technical Limitations

The objective of this study is to develop a sign language interpretation model that can efficiently recognize hand gestures and compare them with already included hand gestures in the system, which may be static or dynamic. The proposed solution to find the results from the captured gestures is that it should be trained with images from a dataset that can be recognized later. The purpose is to recognize only hand gestures that are efficiently used across communities and for this project it is limited to static and dynamic gestures only. For this method and concept, Tensor Flow, and Keras API are used for implementing Convolution Neural Network (CNN) with Jupyter Notebook as the platform, and dlib with OpenCV for capturing the gestures in realtime [1].

First, a K-fold cross validation technique that takes 15% of the available dataset in each fold from the main training data is used to return the model accuracy after training is done on each fold. Then, kappa and AUC metrics that can interpret the rightness of predicted values are calculated to validate the model performance. With the help of these metrics, confusion matrix data are also shown with its graphical representation. So language interpretation models are implemented independently using deep learning on both static and dynamic gestures of language gestures. At the model evaluation stage, model accuracy graphs and validation accuracy as well as loss graphs are included along with confusion matrices with their equal interpretation [2].

One of the more recent advancements has been to create a glove that captures hand motion as well as finger orientation in real time. A wearer's hand movements are measured in three-dimensional space and can be directly input into a computer. The Glove uses inertial sensors combined with a gyroscope, accelerometer, flexibility, and a microcontroller, allowing gesture recognition to use a simple one-to-wear glove structure. The first challenge is how to find the hand gesture and expression time intervals when their positions are only available; this problem is solved within GraphSAGE, using a method to retrieve time intervals of sign language. The second challenge is how to extract discriminative features from large-scale video streams to perform gesture recognition and expression spotting; this is addressed by combining multi-layer CNNs and temporal pooling techniques. The model is trained end-to-end with supervised objectives, allowing it to be applicable for practical usage. [20][21]

7.2. Cultural and Linguistic Variations

The cultural specificity of sign languages constitutes a major difficulty in the development of reliable and effective sign languages recognition systems. Each signing culture has both its own Gesture and Sign Language variety. But, more than three thousand languages are spoken in the world, approximately two hundred of which are estimated to be sign languages. Even if a sign language in general is a human language using motifs of space in continuum as main means of communication, every signing culture has its own conventions for expressing abstract notions, time, numeric values, describing objects, conditions, characters, space navigation, and others. In addition, many geographical regions use particular classifiers or markers to provide meanings, which generally differ from other signing regions. For these reasons, for AS-RSL research, the construction of large dataset corpora covering a broad range of local sign languages and varied signing communities will be crucial for developing region-specific. Interpretation systems up until now can be paired or two-clause but not all aspects of signing on T/R are taken into consideration [2]. Interpretation of sign languages is a challenging task especially due to the important size of the gesture space, the balancing between the accuracy of computation and time-processing and the performance of devices. Glove is one of the natural interfacing approaches for how the communication occurs in gesture. Moreover, the glove equipped with sensors can capture the data efficiently and transfer the positions of the hand in real time. Various types of gloves sensor currently in research display the advantages and shortcomings of device selection and various methods of ASL interpretation from sign language to text. They suggest the transferring of data to the computing system through various communication signal. An ASL interpreter glove is developed with the commercial purpose but insufficient description of communication between glove devices and interpreters.

8. Future Directions

Wearable gesture recognition devices have recently received a lot of attention from researchers. Many techniques are used to achieve this goal, including image processing, machine vision, MEMS sensors, and wearable glove devices. The latter can be used in a large variety of fields, such as health care, gaming, sign language translation, surveillance systems, human-robot interaction, and many others. This interest has led to the development of different systems with various applications [2].

Currently available glove systems can be classified based on different categories, including the main sensing technology upon which they are built, field of application, processing architecture, integration method, and type of communication. The current work aims to review the recent state-of-the-art of systems-based glove technology for either Deaf or general-purpose sign recognition systems, using data-driven and rule-based approaches. The technological and performance details are discussed, as well as the limitations and challenges, including user-specific, marker and sensor calibration, finger occlusions, tracking range, background noise, and glove design. Wearable gloves used for gesture recognition and popular sign language recognition systems are listed, along with future perspectives on further developments in glove-based sign language recognition systems.

Hand gesture recognition using data gloves can have a significant impact on real-time applications. However, commercially available gloves are expensive, bulky, and lack comfort while being used. Optical-based systems that recognize gestures using video input may miss some gestures due to the lack of visual information or complicated backgrounds. Smart gloving-based gesture recognition is less expensive and can recognize a gesture without the need for cameras, but the gloves could be uncomfortable when used. The goal of this project is to develop a set of smart gloves that can recognize gestures by integrating wearable technology into a glove that can be used seamlessly without the need for auxiliary devices.

8.1. Advancements in Sensor Technology

In the last few years, there have been advancements in hardware components and available technologies for building a sign language glove. The previous system required a large amount of equipment for calibration, which was cumbersome and not user-friendly. The number of sensors was limited, needing high calibration accuracy for the constructed parameters. Other gloves were too large, requiring a large number of complex rules to express a single sign [2].

Other gloves use individually built modules, increasing total cost and setup complexity for each glove. To enhance robustness, custom algorithms need a proprietary Bluetooth chip or a specialized API access chip. The sensor fusion feature should be extensible because existing sensor fusion libraries limit the number of data inputs to three. New sensors, such as additional IMUs, can be useful to detect signs but are hard to add. These gloves lacked efficient adjustment systems, which is a problem in practice since not everyone can fit it the same way. The gloves are designed as one size fits all, but they need to be bracketed. Because of all these setbacks, a new design was proposed.

For every pneumatic actuated glove, a signal from a microcontroller or computer sends a signal to a piezo-electric valve. This provides air to actuate the finger, and when removing the sign or gesture, the signal must be sent to the compressor or small bladder pumps. The main advantage is that the glove is compact and can be powered by batteries. The microcontroller inside the glove provides an open API and simultaneously ports for other features. It contains sensor data processing and hardware-based quaternion calculation for every IMU. The glove has a built-in SD card reader, providing unlimited storage to collect quaternion data and processed information. [22][23][24]

8.2. Integration with AI and Machine Learning

Translation of sign languages into text or voice can help disabled persons communicate with general users. The sign language recognition and communication system is composed of triboelectric sensor integrated gloves, AI block, and the VR interaction interface. The triboelectric sensors interlocked on glove cuffs are used to sense hand hareketin At signin and the intelligent AI block is used to decode the glove data into text or voice output. The entire system was demonstrated in a VR environment. 50 words and 20 sentences from sign languages were recognized on the glove. Word recognition results are projected into virtual space in the forms of comprehensible voice and text to facilitate barrier-free communication between signers and nonsigners [15]. Sign language is the primary communication method for speech and hearing impaired people. Because of their special physiological structure, most general population cannot comprehend sign languages fluently. Thus, it is difficult for disabled persons to communicate with general users. Translator converting sign languages into text or voice output can help deaf mute persons communicate with general users. Keeping up with the fast development of wearable devices, many researchers began to study sign language recognition systems. Most systems are composed of gesture recognition sensors and deep learning models [1].

9. Ethical Considerations

The development of a glove-based system for sign recognition raises critical ethical considerations that must be addressed before the system can be widely used. This article examines some of the most substantial ethical issues that can potentially coerce both the development and usage of a glove-based sign recognition system.

Concern for the deaf community: The deaf community is composed of positive, proud individuals who regard their culture and language as a gift. These individuals view sign language as part of their social identity because it is different from that of the hearing world. Many people regard sign language as linguist, similar to spoken language and using a complimentary rule. Moreover, sign language is a means of acquiring a sense of belonging to their society. A glove-based sign interpretation system may pose a threat to the cultural identity of the deaf community [2]. Thus, any developer can prevent such a system from being created or maintained. System staffs should encourage deaf people to preserve their deaf culture and create an environment in which the need and use of sign interpretation are limited to their utmost.

Concern for hearing people: A glove-based sign interpretation system can also coerce hearing people. Unlike deaf individuals, hearing users may negatively perceive the system's development, believing that they remain un-empowered when communicating with deaf individuals, and may feel exhausted by this limitation. Developers need a framework specifying standard operation and detailed information on how to effectively use such a system before its release.

Consideration of globalization: A glove-based sign recognition system for one culture may be grounded in another culture. Nevertheless, on the internet, different cultural languages are irrevocably intertwined with one another. If users are only provided with a glove-based sign interpretation system from one society and therefore have to adopt that style, they may overly assimilate that culture and lose their established identity. Cultural diversity highly positively correlates with systemic resilience. As a significant part of society, this should be addressed when users are based on entirely different cultural standards. In addition to other social problems, the consideration of globalization should not be neglected. [25][26][27]

9.1. Privacy Concerns

In a recent study, Wang developed a sign language glove-based recognition system that utilized a sensor module with a Hall effect sensor array. This glove was controlled by a wireless module, enabling remote functionality. The sign glove and sign language phrase dataset were generated, and a convolutional neural network (CNN) was designed, trained, and validated using tens of thousands of sign sequences. The performance, accuracy, and generalization of the designed model were compared with various models, demonstrating high accuracy phoneme-wise performance and robustness against noise interference.

Most proposed sign language recognition and translation systems required special gloves with a larger number of sensors (i.e., more than twenty) [2]. Aiming at an easy-to-obtain/human-comfortable sign glove, Joo developed a user-friendly glove equipped with an accurate recognition algorithm that could be created using lower-cost sensors. A Waye sign glove was designed using a plastic mold and simple assembling methods, enabling a dexterous yet human-like form with low-extrusion error for optical character recognition (OCR)-based sign language recognition. A combination of density-alignment and hidden Markov models (HMM)-based motion recognition methods empowered high user adaptation with robust performance, achieving a word accuracy of up to 95% for the fine-tune recognition.

9.2. Accessibility and Inclusivity

During the past few years, the prevalence of gadgets implanted with intelligent technologies for the enhancement of daily living has increased together with engineering and computer science. Although a large part of the human population undertakes a disability-free lifestyle, there are persons with disabilities who cannot enjoy the privileges of the modernized category of human life. Deaf-mute/disabled people are among the groups who suffer from societal exclusion due to communication obstacles. With a view to mitigate the communication/death of an ability gap or a deaf-mute category lacking, several smart techniques have been proposed to assist them. Sign language (SL) is the primary method of communication for deaf-mute people and signers utilize hand gestures, body postures, and facial expressions to convey information. Yet the inability to comprehend the signers' gesture movement is a substantial concern where sign language recognition (SLR) systems are mandated to bridge the disability gap. Hand gesture recognition can be framed as direct detection of a pallid hand in a 2D scene or as interpretation of the movements of a hand contour. Hand detection/gesture recognition using computer-generated imagery or maxacme mesh models is an active area of research owing to the availability of 3D data. Nevertheless, to aim at a complexity-attenuating and manageable approach to hand gesture recognition, SL sign gesture recognition appears to be a competitive strategy. SLR systems based on sensory gloves have attracted the attentions of researchers to gain data about the shape or motion of the human hand. SLR systems can be categorized into two groups: glove-based SLR systems and video-based SLR systems. A glove comprises sensors or other acceleration detection devices for capturing finger and arm movements. Since the glove-based SLR systems encourage greater sign accuracy and are easier to use than video-based SLR systems, they are chosen as the research focus of this article. To create a complete and coherent taxonomy for a better understanding of glove-based SLR systems, all state-of-the-art glove systems built for SLR between 2007 and 2017, are surveyed and classified into four main categories: glove system development, framework of SLR using glove, other hand gesture recognition, and review and surveys [2].

10. Comparative Analysis

There are vast varieties of applications that can be developed for sign language recognition and interpretation. Some designs use simple gloves, while others utilize complex glove designs with an array of sensors [2]. Aside from gloves, it is also possible to utilize cameras, neural network models, and holograms to be able to have a complete and efficient system for sign language interpretation. Choosing a good design ultimately depends on the resources and limitations of the developers or inventors. Here is a simple comparison of different glove designs for sign language interpretation. (a) Simple glove uses only bend sensors and IMU sensors to detect joint movement and angle. Similar sensors can be used for many other applications. (b) Smart glove uses multi-sided layers with different sensor types. Input data from different sensors is transmitted in parallel systems to a microcontroller. Co-processors do post-processing and send data to the outside system. Immense processing is required and it is more costly. Other designs use complex glove designs with an array of sensors. Some designs only have depth cameras and/or RGB cameras. Others use a combination of gloves, cameras, and neural network models. Motion capture using depth cameras serves as input to be processed by a neural network model to give the output in the form of a hologram projection text-to-speech system. On the contrary, a multi-modal input system uses glove devices, RGB cameras, and IMU sensors as the input for a neural network model. The output is colored videos, money sequence videos, and text translations impacting education and media, respectively.

Comparing designs can also be a basis for future developments to improve current recognition systems. There is a wide variety of applications that can be developed for sign language recognition and interpretation. Knowledge of the advantages and disadvantages of some specific designs can help improve platforms for the deaf community as most of the old designs fall short in serving a fast-paced medium like messaging. Many of the designs are not modular and scalable as they have many processes, and CPU resources are insufficient. Consideration of space for future modifications is also limited in some designs. The gradual improvement of sign-to-text systems that use natural language description also limits the scalability of other designs.

10.1. Glove Technology vs. Traditional Interpretation

To understand the operation of SL glove, it needs to be operated on significance cores, which, when worn on the users' hands, measure a multitude of gestures generated by the movement of the fingers and hand via processing tiny sensors embedded inside them. These communications are translated into respective English speech outputs by a complementary software application on Android devices. Thereby, once it gets exclusively worn on either hand, gestures input by the user will result in corresponding English speech outputs in real-time. This occurs via Optical Character Recognition wherein an SL gesture is translated into a new index page which has hyperlinks with texts and respective audios of their English speech equivalents [1].

The Android app was designed traditionally using lower-level programming languages and libraries, but this software system was developed using a higher-level programming environment called MIT AppInventor 2. With a simple drag-and-drop Graphical User Interface (GUI), codes are rendered behind the buttons and other components when created, which are viewable in an AppInventor source code generator development IDE. In addition, the app can be published for free to the online AppInventor Gallery just requiring an associated email account; or it can simply be an exported standalone APK file as performed by this software application or on-demand development of the same. The GLOVE as an SL translator will analyze input gestures using various sensors' configurations and implementations on it for translation into respective speech syntaxes.

Advanced technologies have widely transformed event sign language interpretation in the digital world. But the use of Sign Language recognition and translation gloves has been a completely novel development prior to this work. Sign Language Modification is a novel application to do transformations on videos depicting speaker/signer's motion for Speech Sign Language interpretation or Sign Language Translation. In addition, mainstream methodologies such as subject-based features on Global Hand/Body Motion Detection would make this translation impersonately accurate [2].

10.2. User Preferences and Effectiveness

To assess the user preference of the data glove device, the efficiency of the gesture recognized by the data glove has been compared with the data recognized by the mobile application. To measure the effectiveness of the mobile application and the data glove, the percentage of recognized gestures has been tested.

As described above, the data glove consists of a flex sensor, accelerometer sensor, and an ultrasonic range finder. The gestures have been made with both the mobile application and data glove and have been recorded for evaluating the effectiveness of both devices. Data analysis tools have been used for recognizing the gesture. These tools provide the percentage of correct gestures recognized for the data glove and mobile application. In addition, visual displays have been used for showing the recognized data and gestures.

Communication is one of the most important aspects of human life. There are millions of people in the world who are unable to speak or hear speech due to old age, illness, or other circumstances. Hence, communicating with them is a big challenge. Many unheard or mute institutes are created for their basic human rights. But the modern ways of communication allow all to speak. Many applications have been developed that convert the gestures and movement of hands into spoken words, which are heard by normal people. The detection of gestures still becomes a tedious task. Many sensors have been developed to track the movement of hands and detect gestures. Glove-based systems have been developed in which many sensors are embedded in gloves. The collected data from the glove has been analyzed which resulted in less detection time to pinpoint the location of gestures.

Glove application is of less cost and portable. Many sensors are embedded that help in tracking the position of fingers and palm flat and detect the angle at which the sign has been done. A wide range of signs can be detected. Data gloves are also used in many fields like in webinars for tracking the movement of hands, in flights to check the direction of cockpit, and in some situations like helicopter shooting, and others.

11. Conclusion

Sign language is mainly used by the deaf and mute community of any country for their communication. It is a completely different language, like any other language, comprising of some hand gestures. Although some of the general population know about the sign language, there are many people who don’t understand this mode of communication and hence they find it difficult to interact with the people who use it. Because of all this there arises the need for such a technology which can convert sign language into text or speech. The designed sign language interpreter is a hand glove for the recognition of the gestures made by the hand. Using the device, the deaf people can communicate with any other person who doesn’t understand the sign language. The glove consists of various flex sensors which are placed on the glove at the respective finger joint positions. This glove records the amount of bending done by the finger joints for a gesture and this data is sent to the microcontroller. At the microcontroller, the data received is processed and compared with the databases stored in it. The gesture signature templates for the words are also trained and stored in the microcontroller by a developer. If a gesture signature pattern matches with any template signature pattern, then the corresponding text will be displayed in the LCD and its corresponding voice will be generated by the speaker. The device has been made portable so that the hardware can be worn on to the wrist and it can be used by the sign language user. There are many countries that have sign languages of their own which are entirely different from one another. This device works only for the sign language of a particular region or country. A lot of research can be conducted to eliminate the limitations, like, adding up more vocabulary for recognition, working for the other sign languages, etc., so that the device will help to communicate with the deaf and mute community at larger levels of interaction . A glove is used for the sensing of the gestures and it is used with the recognition system to detect the sign language gestures made by the user. The glove is equipped with flex sensors, which can detect the change in voltage depending on the bending of the finger joints. The data from the flex sensors, which is in volt form, is fed to the microcontroller to process it. The gesture signature templates for the letters, numbers, and words are trained and stored into the microcontroller, comparing the input gestures with the database in the controller. If any gesture signature pattern matches with the template signature pattern, then the corresponding text letters and the corresponding voice will be obtained. By these voice synthesizers, the text as displayed on LCD will get converted into a voice signal and it will be spoken out [2].

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