VGG-16 BASED INDO-PAKISTANI SIGN LANGUAGE INTERPRETER

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Abstract

The use of machine learning algorithms such as Convolutional Neural Networks (CNN) with transfer learning can greatly improve the accuracy and efficiency of sign language recognition systems. Transfer learning involves using pre-trained models and fine-tuning them for a specific task, in this case, recognizing sign language gestures. This approach can reduce the need for large amounts of data and time-consuming training, making it easier and more cost-effective to develop such systems. The VGG-16 architecture is a popular choice for transfer learning in computer vision tasks, including sign language recognition. It has been shown to achieve high accuracy in image recognition tasks and can be adapted for use in sign language recognition systems. In addition to the CNN model, a user interface (UI) can be developed to interact with the system, allowing users to input their sign language gestures and receive a text or speech output. The UI can be designed to be user-friendly and accessible, ensuring that it is easy for both hearing and hearing-impaired individuals to use. Overall, the development of a real-time sign language recognition system using machine learning and a user interface can greatly improve accessibility and communication for individuals with hearing impairments. It can help bridge the communication gap between hearing and hearing-impaired individuals, ensuring that everyone has equal access to information and experiences.

In summary, this project aims to develop a vision-based real-time recognition system for Indian Sign Language, using machine learning techniques to recognize gestures. By leveraging the power of Convolutional Neural Networks and a user-friendly interface, the system can bridge the communication gap between hearing and hearing-impaired individuals, promoting equal accessibility for all.

Keywords: *IPSL, VGG-16, Deep Learning, Transfer Learning, Computer Vision.*

1. Introduction

Sign language interpreters play a vital role in facilitating communication and promoting accessibility for individuals with hearing impairments. However, advancements in technology have opened up new possibilities for enhancing communication between hearing individuals and the deaf and hard-of-hearing community. By leveraging software translators, even individuals without hearing impairments can now connect and communicate more effectively with their deaf counterparts. This project aims to further improve accessibility by developing a real-time recognition system for Indian Sign Language, capable of recognizing both alphabets and digits (A-Z and 0-9).

The idea of using technology to aid in the communication of individuals with speech or hearing disabilities is not new. There have been several attempts to develop such systems in the past, ranging from simple text-to-speech systems to more complex ones that incorporate computer vision and machine learning techniques. An effective method for creating such a system involves employing computer vision techniques to identify various gestures used in sign language and translate them into textual or spoken form. This can be done using a camera to capture the sign language gestures, which are then analyzed by the system to recognize the meaning of the gesture. One alternative method involves the utilization of wearable gadgets like intelligent gloves, designed to be worn by individuals experiencing speech or hearing impairments. These gloves are equipped with sensors that can detect hand gestures and convert them into text or speech.

The advantage of using wearable devices is that they are portable and can be used anywhere, making communication easier and more efficient. In recent years, there has been significant progress in the field of artificial intelligence and machine learning, which has led to the development of more accurate and efficient sign language recognition systems. These systems can recognize not only simple hand gestures but also more complex ones, making it easier for individuals with speech or hearing disabilities to communicate more effectively. Overall, the development of a system that can recognize and translate sign language gestures can greatly improve the communication of individuals with speech or hearing disabilities.

The ultimate goal of this project is to bridge the communication gap between individuals with hearing impairments and the general population. By developing a vision-based real-time recognition system for Indian Sign Language and incorporating machine learning techniques, we aim to ensure fair and equal accessibility for all individuals, regardless of their hearing abilities. Through this endeavor, we strive to promote inclusivity and foster better understanding and communication between different communities.

2. Motivation

- Studying and understanding sign language is important for promoting awareness and sensitivity towards the deaf and hard of hearing community. It can also help break down communication barriers between hearing and hearing-impaired individuals, allowing for better socialization and inclusion.
- Choosing Indo-Pakistani Sign Language (ISL) over American Sign Language (ASL) is a challenge as ISL is not as widely explored as ASL. However, developing a recognition system for ISL can greatly benefit the Indian deaf and hard of hearing community, as it can improve communication and accessibility for them in their daily interactions.
- Developing manpower for using and teaching ISL can also help promote

bilingualism and improve communication between hearing and hearing-impaired individuals. This can lead to a more inclusive and accepting society, where everyone has equal access to information and opportunities.

- Overall, the development of an Indian Sign Language translator can greatly improve communication and accessibility for the deaf and mute community, breaking down communication barriers and promoting inclusivity.

3. Objectives

The research aims to achieve the following objectives:

- Create a dataset of Indian Sign Language Alphabets (A-Z) and Numbers (0-9) with various backgrounds to train and test the model. The dataset should be diverse and inclusive, representing the various signs used in Indian Sign Language.
- Implement a model using VGG-16 architecture with transfer learning to recognize the sign language gestures accurately. The model should be trained on the created dataset to recognize the Indian Sign Language gestures in real-time.
- The main objective of the research is to translate sign language to text so that normal human beings can understand. The system should be able to accurately recognize Indian Sign Language gestures and convert them into text, facilitating communication between hearing and hearing-impaired individuals.

By achieving these objectives, the proposed system will be able to recognize Indian Sign Language gestures accurately, enabling hearing-impaired individuals to communicate effectively with the hearing community. The system will also promote inclusivity and accessibility, making communication barrier-free.

4. Related Work

Researchers have indeed worked intensively on sign language recognition, aiming to develop systems that can accurately interpret and understand sign language gestures. Some notable research areas and achievements include: Shagun Katoch et al. have developed the model using Support Vector Machine and CNN for classification with the accuracy of 99.17% and 99.64% respectively [1]. Shanmukha Swamy et al. proposed optimized approaches for implementing the Viola-Jones algorithm with LBP features for real time hand gesture recognition as an android application and tested with real time data [2]. J.Ekbote, et al. aimed to create a computerized recognition system for numerals (0-9) in Indian Sign Language using Artificial Neural Networks (ANN) and Support Vector Machine (SVM) classifiers and compared various feature extraction techniques such as HOG, shape descriptors, SIFT, and PCA [3]. Yogeshwar I. et al. proposed the ANN Model with an accuracy of 94.37% and for SVM with 13 features 92.12% utilizing a total of 848 images, each with dimensions of 320x240 [4]. Anuja V. Nair et al. explored various classification methods used for sign language recognition, including Artificial Neural Networks (ANN), Support Vector Machine (SVM), and Hidden Markov Models (HMM) emphasizing the importance of developing a suitable segmentation scheme capable of extracting the hand and face regions

[5]. Akshatha Rani K et al. presented a dynamic sign language recognition system implemented based on SVM where the training folder of dataset consists of 26 folders of ASL alphabet with one folder of 'space' characters [6]. S. Goyal et al. proposed an algorithm enabling the recognition of various signs by analyzing images of both the left and right palm sides achieving a 95% accuracy rate when analyzing images of 9 alphabets, captured from various angles and distances [7]. Purva A. Nanivadekar et al. initiated the project by developing a comprehensive database of Indian Sign Language, recording videos of signers performing hand gestures [8]. Karishma Dixit et al. proposed the methodology combining Hu invariant moments and structural shape descriptors to create a new feature vector for signature recognition with high recognition rate 96% [9]. P. Subha Rajam et al. developed a method defining a set of 32 signs, each representing the binary 'UP' and 'DOWN' positions of the five fingers identifying the fingertip positions in static images [10]. A. S. Shitole et al. proposed a Physical Location Monitoring System by comparing Decision Trees, K-Nearest Neighbors (KNN), Naive Bayes, and Random Forests [11]. Manoj Devare et al. discussed about the industry changing technology of cloud computing and it's innovations in the industry [12]. Manoj Devare et al. explored the convergence of Manufacturing Cloud (CMfg) with Cloud computing, Industrial Internet-of-Things (IIoT) [13]. Lean Karlo et al. employed a CNN Model for image classification, achieving an accuracy of 93.44% for number recognition and 97.52% for static word recognition, the CNN Model was trained using a GT-1030 GPU [14]. Wadhawan A. et al. developed a vision-based system utilizing a dataset of 35,000 images and comparing various CNN models and optimizers achieving the highest training accuracy of 99.72% on colored images and 99.90 on grayscaled images [15]. Ashok K Sahoo et al. highlighted the challenges associated with sign language recognition, including the complexity of sign languages themselves, variations in signing styles among individuals, and the necessity for robust and efficient recognition algorithms [16]. Thangali A et al. focused on the challenging task of inferring handshapes in American Sign Language videos by capitalizing on phonological constraints, which are linguistic rules governing the structure and organization of signs in ASL [17]. Wang S. et al. proposed the use of tensor-based methods to recognize sign language gestures [18]. Kiani Sarkaleh et al. conducted a study focused on developing a sign language recognition system specifically tailored for Persian sign language [19]. Mekala P. et al. contributed to the development of recognition system by leveraging neural network techniques considering the temporal dynamics of sign language gestures, aiming to provide an efficient and accurate solution for facilitating effective communication [20]. Nadgeri S. M. et al explored the application of the CAMSHIFT (Continuously Adaptive Mean Shift) algorithm for hand gesture recognition [21]. Grobel K. et al. addressed the challenges of recognizing isolated sign language gestures by employing hidden Markov models as a statistical modeling technique capturing the temporal dynamics inherent in sign language gestures [22]. Kumarage D. et al. focused on a hybrid approach that combines techniques of still-image comparison and motion recognition to

achieve accurate and responsive gesture recognition [23]. Suharjito et al. proposed the review that likely follows an input-process-output framework, which means it examines the components and functionalities of these systems [24]. Koller O. et al. combined Convolutional Neural Networks with Hidden Markov Models for continuous sign language recognition as a CNN-based feature extraction model and an HMM-based temporal modelling approach [25]. Gurjal, P. et al. described a novel real-time system for recognizing hand gestures, utilizing the Scale-Invariant Feature Transform (SIFT) algorithm [26]. Thang PQ. et al compared two machine learning algorithms, SimpSVM (Simple Support Vector Machine) and RVM (Relevance Vector Machine) providing insights into the strengths and weaknesses of each algorithm for sign language recognition [27]. Chai X et. al. addressed the challenges of sign language recognition caused by complex backgrounds and varying illumination conditions [28]. Huang J. et. al. utilized 3D Convolutional Neural Networks (CNNs) to automatically extract discriminative spatial-temporal features from raw video streams on a real dataset collected with Microsoft Kinect [29]. Wang H. et. al. proposed a framework for sign language recognition based on Hidden Markov Models (HMMs) that incorporates low rank approximation techniques [30]. Ashish Nikam et al. introduces a software prototype that aims to automatically recognize sign language, addressing the limitations of existing systems in terms of flexibility and cost-effectiveness [31]. Pooja M.R.I et al. proposed system utilizes the Histogram Oriented Gradient (HOG) feature extraction method in combination with Artificial Neural Network (ANN) algorithms [32]. Astri Novianty et al. proposed a system that employs dimensional reduction and feature extraction carried out using principal component analysis (PCA), followed by classification using the support vector machine (SVM) algorithm [33].

5. Methodology

The primary objective of the system is to identify the static characters of Indo-Pakistani Sign Language (IPSL), namely (0-9 and A-Z). The system comprises two significant components: a Convolutional Neural Network (CNN) model designed for classification and an image preprocessor used for image preprocessing.

A. Dataset

The dataset is a crucial component of any machine learning system, and for this particular system, it comprises images of gestures from the Indo-Pakistani sign language. A pre-existing dataset from Kaggle VA is utilized, and there are also intentions to create a custom dataset to improve the model’s generalization. Some sample images from the Kaggle dataset are displayed in Figure. 1.

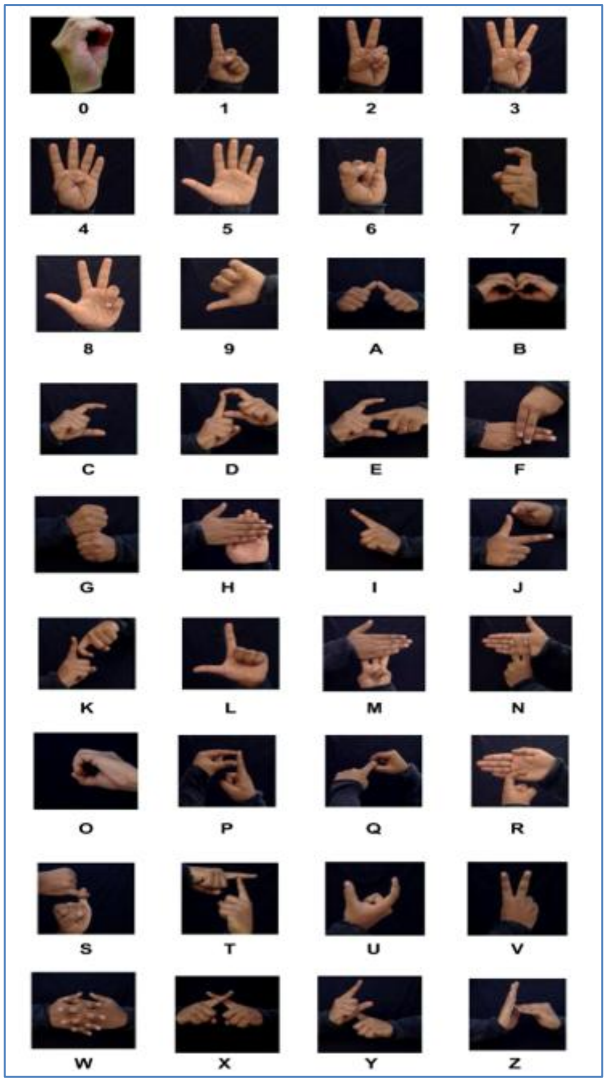

Figure 1 Dataset of 36 IPSL Characters

B. Pre-processing

The purpose of this study is to enhance the accuracy and speed of the CNN model through pre-processing techniques. The two primary methods of pre-processing used are Background

Subtraction and Gray scaling.

1. Background Subtraction

   It is a widely used technique that involves generating a foreground mask by subtracting the background model from the current frame. This helps to focus the model's attention on the user's hand, improving accuracy. Example images of Background masking are shown in Figure. 2.

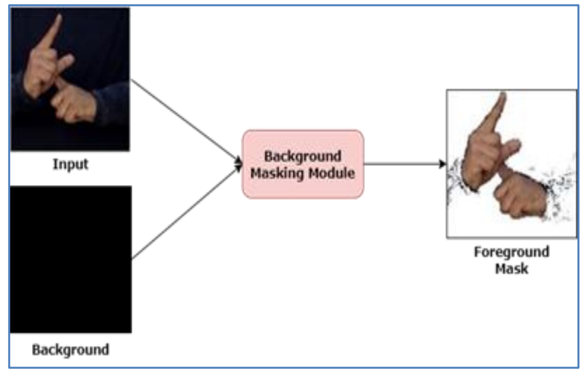

Figure 2 Example of Background Masking

2. Gray scaling

   It is another technique used to reduce the dimensionality of RGB images, which in turn increases the speed of the algorithm. An example of the gray scaling module is presented in Figure. 3.

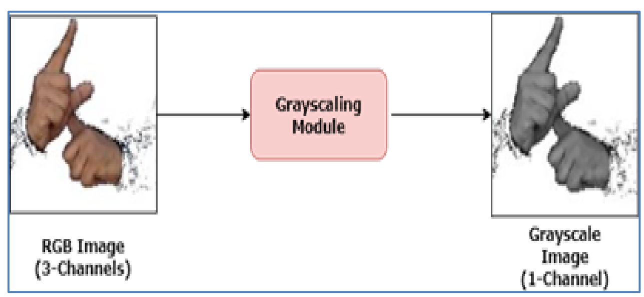

Figure 3 Example of Gray scaling

C. Convolutional Neural Network Model

Convolutional Neural Network Model: The primary element of this system is the Convolutional Neural Network (CNN) model, specifically the VGG-16 model developed by Karen Simonyan and Andrew Zisserman from the Visual Geometry Group, Department of Engineering Science at the University of Oxford. To facilitate feature extraction and classification, this model is pretrained on the ImageNet Database. Transfer learning is employed to fine-tune the top layers and generate outputs for 36 classes, encompassing alphanumeric characters from 0-9 and A-Z. The architectural details of the VGG image classification model are depicted in Figure. 4, while Figure. 5 illustrates the system's process flow. The overall system architecture of the system is shown in Figure. 6

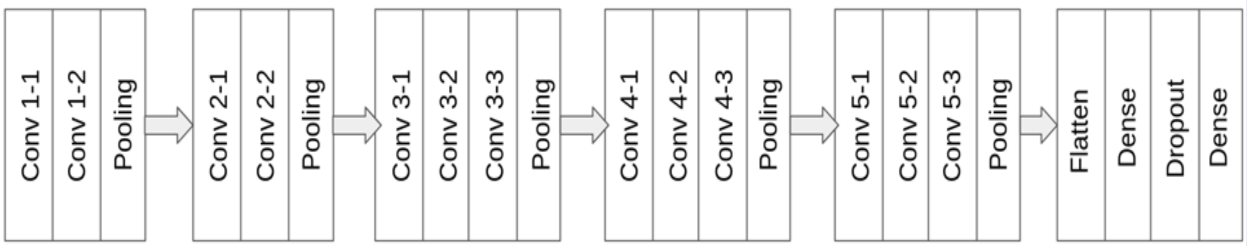

Figure 4 Model architecture of Proposed CNN Model

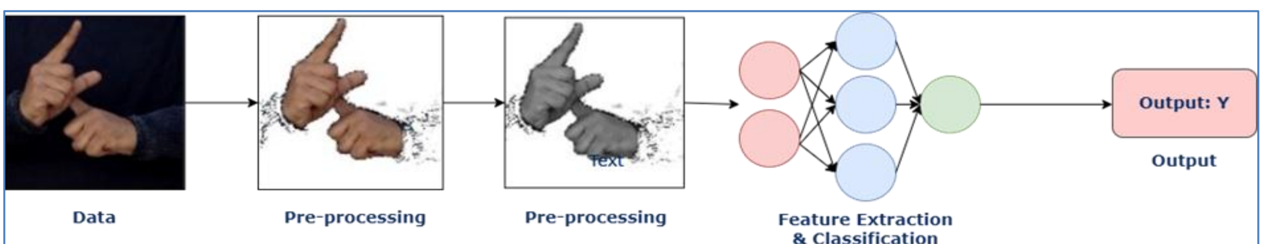

Figure 5 Process Flow of the System

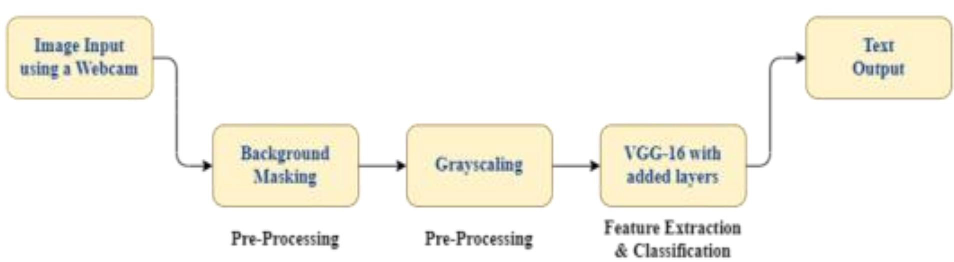

Figure 6 System Architecture of the Proposed System

D. Algorithm

The algorithm to capture and Identify gestures follows these steps:

1. Get images from webcam:

a. Initialize the webcam.

b. Continuously capture frames from the webcam.

2. Perform preprocessing:

Background masking:

i. Capture the background:

a. Capture a few initial frames without any hand gestures, ensuring the background is visible.

b. Average these frames to create a background image.

ii. Subtract from subsequent images:

a. For each frame captured after the background capture, subtract the background image from the current frame.

b. This will result in a foreground image containing only the hand gesture.

Gray scaling:

Convert the foreground image to grayscale to reduce the complexity and focus on intense variations.

3. Perform Feature extraction and Gesture classification using a trained CNN model:

a. Pass the preprocessed grayscale image through the trained CNN model.

b. Extract features from the image using convolutional and pooling layers.

c. Classify the gesture by passing the features through fully connected layers.

d. Obtain the predicted gesture label.

4. Display output to the user in real-time:

a. Overlay the predicted gesture label on the original frame or display it in a separate window.

b. Update the output in real-time as new frames are captured.

5. Repeat steps 2 to 4 for each frame captured from the webcam.

6. Result and Discussions

We present a practical implementation of a sign language interpreter utilizing the VGG-16 model. Our implementation is based on Python, PyQt5, and TensorFlow for the VGG model. Our system consists of two modes: Background and Process. The Background mode is used to capture the background for background subtraction, while the Process mode is used to recognize gestures by subtracting the background captured from the current image to obtain the foreground, which represents the hand. Our system's accuracy was evaluated using a dataset of sign language gestures. Our practical implementation offers an efficient and accurate solution for real-time sign language interpretation.

We present several snapshots of our graphical user interface (GUI) that has been developed utilizing PyQt5 framework:

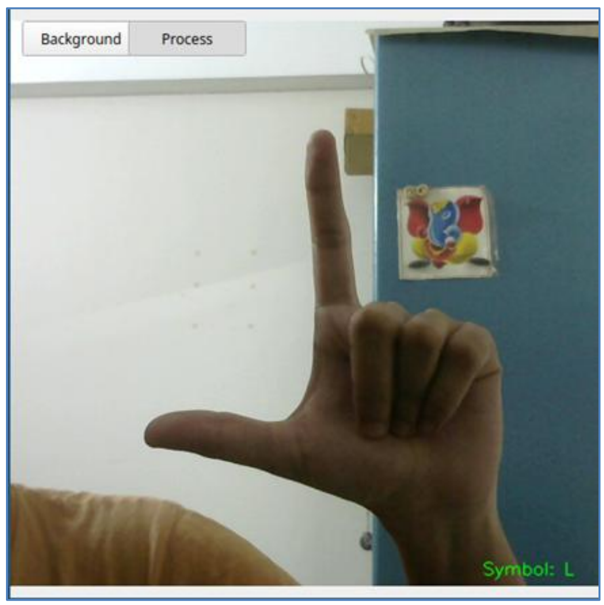

Figure 7 Interpreted Symbol: L

Figure 8 Interpreted Symbol: 7

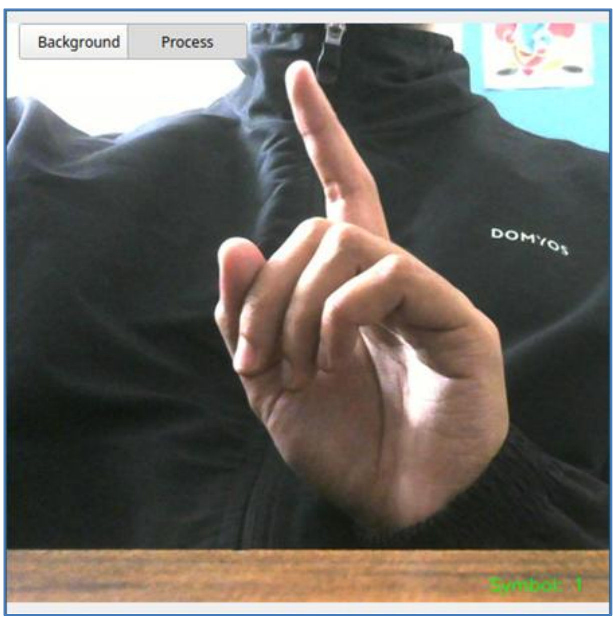

Figure 9 Interpreted Symbol: 1

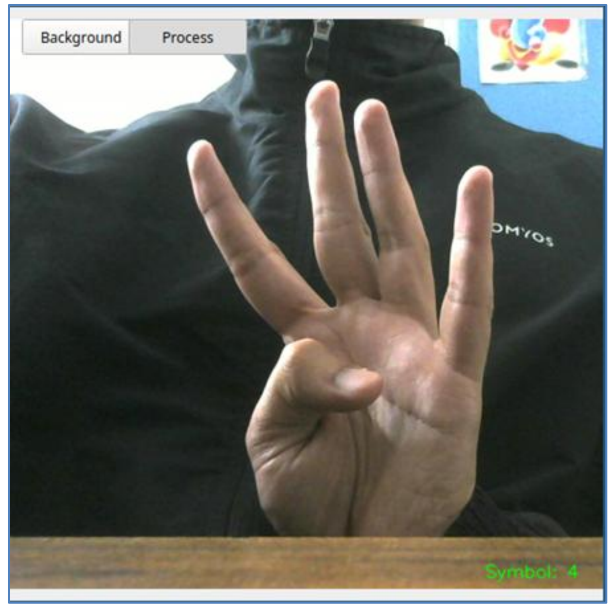

Figure 10 Interpreted Symbol: 4

The results of our sign language interpreter implementation using the VGG-16 model in Python, PyQt5, and TensorFlow are highly promising. We tested the software on a diverse set of Indo-Pakistani sign language symbols and observed near-accurate outputs for every symbol. These results indicate that our implementation can accurately interpret sign language gestures and has the potential to significantly benefit the deaf and hard-of-hearing community.

Here are some potential outcomes and results we achieved from this project:

1. User Interface Development: We successfully developed a user-friendly and accessible user interface (UI) for interacting with the sign language recognition system. The UI enabled users, both hearing and hearing-impaired individuals, to input their sign language gestures and receive text output effectively. The focus on inclusivity ensured that the system was accessible to a broader user base.

2. Bridging the Communication Gap: By recognizing and interpreting Indian Sign Language gestures in real-time, the system aims to bridge the

communication gap between hearing and hearing-impaired individuals. This outcome promotes equal accessibility, enabling effective communication between both user groups and ensuring fair and inclusive access to information and experiences.

3. Real-time Sign Language Recognition: The integration of machine learning techniques and the developed UI enabled the creation of a real-time sign language recognition system. Users could interact with the system seamlessly, bridging the communication gap between hearing and hearing-impaired individuals. This outcome greatly enhanced accessibility and communication for individuals with hearing impairments, promoting equal access to information and experiences.

4. Alphabet and Digit Recognition: The system focuses on recognizing alphabets (A-Z) and digits (0-9) in Indian Sign Language. The expected outcome is accurate recognition of these gestures, enabling users to convey letters and numbers through sign language.

5. Vision-Based Gesture Recognition: The system adopts a vision-based approach, where hand movements are captured by a camera and gestures are identified using computer vision techniques. The expected outcome is the accurate recognition of gestures based on visual inputs.

6. CNN Model for Gesture Recognition: The project utilises a CNN model architecture, specifically VGG-16 with pretrained weights trained on the ImageNet dataset, for gesture recognition. The expected result is a trained CNN model capable of accurately recognizing Indian Sign Language gestures.

7. Improved Communication and Accessibility: The overall outcome of the project was the facilitation of improved communication and accessibility for individuals with hearing impairments. By providing a system that recognizes and translates sign language gestures in real-time, the project aimed to enhance the accessibility of information and experiences for the hearing-impaired community.

8. Enhanced usability and effectiveness: The development of a user interface will ensure that the system is intuitive and easy to interact with, enabling a wide range of users, including those with limited technical expertise, to benefit from the system. The goal is to create a seamless communication experience that maximises the system's usability.

9. Advancement in sign language recognition technology: By leveraging machine learning techniques, specifically Convolutional Neural Networks (CNNs), for sign language recognition, the project contributed to the advancement of computer vision and machine learning in the field of accessibility. The project's use of CNNs demonstrates the potential of these techniques in improving sign language recognition accuracy and performance.

Overall, the project aimed to address the communication and accessibility challenges faced by individuals with hearing impairments by developing a real-time sign language recognition system with a user-friendly interface. The successful implementation of the system contributed to bridging the communication gap and promoting inclusivity for the hearing-impaired community. It’s important to note that the specific accuracy and performance of the recognition system will depend on factors such as the quality and diversity of the training data, the effectiveness of the CNN model, the robustness of the computer vision techniques, and the implementation details. Thorough evaluation and testing will be necessary to assess the system's performance and its ability to accurately recognize Indian

Sign Language gestures in real-time.

7. Conclusion and Future Scope

In conclusion, the use of machine learning algorithms with transfer learning, particularly the VGG-16 architecture, has proven to be a successful approach in developing a sign language recognition system. The system, when combined with a user-friendly interface, has the potential to improve accessibility and communication for individuals with hearing impairments, helping facilitate effective communication between individuals with normal hearing abilities and those who are hearing-impaired, thereby closing the gap between them. The high accuracy of the model and the simplicity of the GUI make it an effective tool for sign language recognition.

The sign language recognition system still has potential for further enhancement. One area of improvement could be to expand the system to recognize dynamic symbols of Indo-Pakistani Sign Language. Additionally, the system can be further developed to include more features, such as real-time translation into different languages. Moreover, the development of a mobile application for the system could make it more widely accessible and convenient for users. Overall, there is much potential for the application of machine learning in sign language recognition, and further research can lead to more advanced and accessible systems for individuals with hearing impairments.

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