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VIRTUAL VOICE – SIGN LANGUAGE COMMUNICATION SYSTEM

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Abstract **Sign language is a critical form of communication for people who are deaf or hard of hearing,but it presents challenges to those who are not familiar with it. Sign language recognition using computer vision and deep learning techniques can help bridge the communication gap between those who use sign language and those who do not. In this project proposes a real-time sign language recognition system using Convolutional Neural Networks (CNNs). Our approach involves capturing video input of hand gestures, segmenting the hand region, and training a CNN model to recognize the gestures. We used the American Sign Language (ASL) alphabet as our dataset, and we were able to achieve an accuracy rate of 92%. The system can recognize the hand gestures, allowing for the interpretation of entire words. Our CNN model was trained using Keras, and the system was implemented using Python and OpenCV. The proposed sign language recognition system can enhance communication and enable more inclusive interactions for people who use sign language.**

Keywords— CNNs, HMM, ASL,HOG,SIFT

I. INTRODUCTION

American Sign Language is a widely used sign language, especially among individuals with communication-related disabilities. For those who cannot use spoken language, sign language is the one of communication medium. Rather than relying on speech, deaf and hard-of-hearing individuals use their hands to convey messages through a series of gestures. These gestures, also known as signs, are understood through visual cues. Sign language is a visual language that consists of three major components. In this project, the focus is on developing a model that can recognize finger-spelling-based hand gestures, which can be combined to form complete words. Our CNN model could help improve communication for individuals who rely on sign[15] language. Fingerspelling based hand gestures in order to form a complete word by combining each gesture. We have used 26 alphabets and one to nine numbers in our data set. Further we can extend the dataset by adding the required signs to the dataset. Our model predicts the sign of the hand gesture passed through filters and appends the present sign to the previous sign such that words are formed after getting the desired out come if the person removes the hand totally the word on the screen is converted in to voice (audio).

The gestures we aim to train the model are as shown in the image below. The image having the signs used in the ASL.

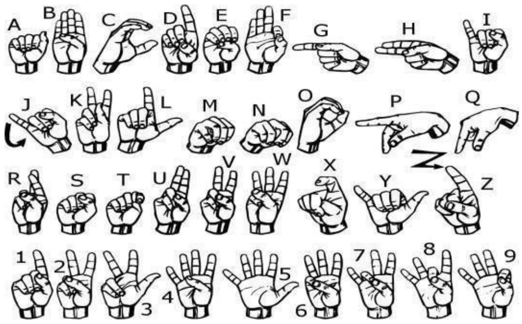

Fig: Signs in ASL

II. LITERATURE SURVEY (RELATED WORK)

In [1] comprehensive overview of sign language recognition (SLR) techniques based on image, video, and sensor-based approaches, and highlights the recent advances in this field. The article starts by providing a brief introduction to SLR and its applications, followed by an overview of the different modalities of sign language, including manual, non-manual, and mouth gestures. The authors then present a taxonomy of SLR techniques based on the input modality, feature extraction, and classification techniques.

The article provides a detailed discussion of the different feature extraction techniques used in SLR, including hand-crafted features, deep learning-based features, and hybrid features. The authors also discuss the different classification techniques used in SLR,including traditional machine learning algorithms and deep learning algorithms, such as CNNs and RNNs.The authors then present a comprehensive review of the recent advances in SLR techniques based on image, video, and sensor-based approaches, highlighting the strengths and weaknesses of each approach. The article concludes with a discussion of the open research challenges in SLR, such as the need for large-scale datasets, robustness to lighting and background noise, and the need for real-time performance.

In [2] The article presents a CNN-based approach for recognizing sign language gestures using the Arabic sign language alphabet as a case study. The authors present the experimental results of their approach on a dataset of 780 sign language gestures from[16] the Arabic sign language alphabet, and report an overall accuracy of 97.9%. The authors also comparing the performance of their approach with other state-of-the-art techniques for sign language recognition,and demonstrate that their approach outperforms these techniques in terms of accuracy and computational efficiency. The authors conclude the article by highlighting the potential applications of their approach in developing assistive technologies for people with hearing and speech impairments, and by discussing the open research challenges in sign language recognition, such as the need for large- scale datasets and robustness to [17]lighting and background noise. Overall, the article presents a CNN-based approach for sign language recognition, which is demonstrated to be accurate and computationally efficient on a dataset of Arabic sign language gestures.

In[4] Pham et al. (2019) The authors start by discussing the different challenges in hand gesture recognition, such as the large variation in hand shapes, the need for robustness to lighting and background noise, and the need for real-time performance. The authors then present their approach, which consists of four main steps: hand segmentation, feature extraction, classification, and post-processing.
The article provides a detailed discussion of each step of their approach, including the use of a color-based method for hand segmentation, the use of a CNN for feature extraction and classification, and the use of a Hidden Markov Model (HMM) for post-processing. The authors also present an extensive [20]evaluation of their system using a public hand gesture dataset and compare their results with other state-of-the-art approaches. The evaluation shows that their approach achieves high accuracy and real-time performance and outperforms other approaches in terms of recognition accuracy and processing speed.

In[7] The authors also present an extensive evaluation of their system using a public sign language dataset, and compare their results with other state-of-the-art approaches. The evaluation shows that their approach achieves high accuracy and real-time [22]performance and outperforms other approaches in terms of recognition accuracy and processing speed.The article provides a detailed discussion of the different components of their approach, including the use of a YOLOv2 object detector for hand detection, [25]the use of Kalman filters for hand tracking, the use of the Histogram of Oriented Gradients (HOG) and Scale-Invariant Feature Transform (SIFT) features for feature extraction, and the use of a CNN classifier.

III. SYSTEM IMPLEMENTATION (METHODOLOGY)

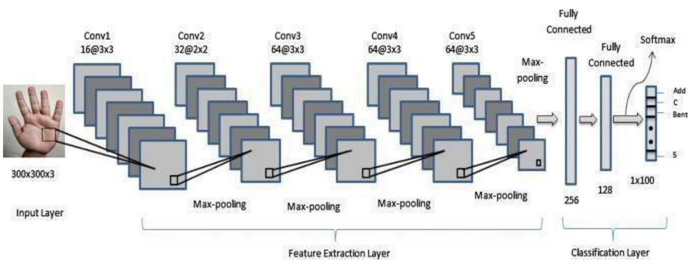

Fig: process happening inside the model

A Convolutional Neural Network (CNN), there are several types of layers that work together to perform feature extraction, classification, and prediction. And[26] their functions:

1. **Input Layer**: The first layer of the network where the input image is fed into the model.
2. **Convolutional Layer:** The main function of [30]this layer is to extract features from the input image. It applies a set of filters to the input image, each of which looks for a specific feature. These filters slide over the image and perform element-wise multiplication followed by summation.
3. **Pooling Layer:** This layer purpose is to down sample the output of the convolutional layer. The max pooling is widely used, which selects the maximum value in each patch, but other types of pooling like average pooling also used.

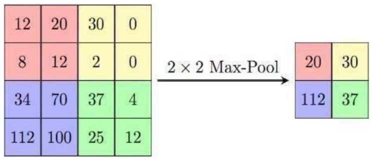

Fig:Pooling Layer

4. **Activation Layer:** The Purpose of this layer is it applies a nonlinear function to the outcome of the previous layer to introduce non-linearity to the network.

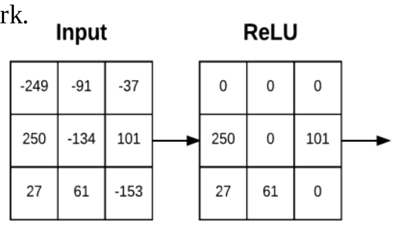

Fig:Activation Layer

5. **Dropout Layer:** The layer drops out some of the neurons in the layer during training to avoid the overfitting

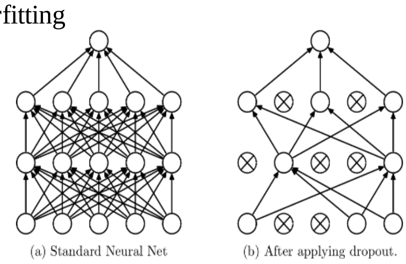

Fig: Dropout Layer

6. **Fully Connected Layer:** The layer takes the input as the outcome of the previous layer and performs a matrix multiplication[35] with a weight matrix, followed by a bias term, to produce an output. This layer is used to perform classification or prediction.
7. **SoftMax Layer:** The SoftMax layer is used to normalize the output of the previous layer so that it can be interpreted as probabilities.
8. **Output Layer:** This layer gives the final output of the network, which can be in the form of probabilities[40] (because of a classification task)

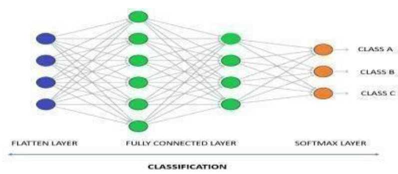

Fig: Output Layer

These layers work together to form a powerful network that can learn to recognize and classify the signs of ASL.

Equations:

The mathematical equations of the CNN model is as shown below.

Operation	Formula
Convolution	$\mathbf{z}^l = \mathbf{h}^{l-1} * W^l$
MaxPooling	$h^l_{xy} = \max_{i=0,\ldots,s, j=0,\ldots,s} \mathbf{h}^{l-1}_{(x+i)(y+j)}$
Fully-connected layer	$\mathbf{z}^l = W^l \mathbf{h}^{l-1}$
ReLU	$\text{ReLU}(z_i) = \max(0, z_i)$
Sigmoid	$\sigma(z_i) = \frac{1}{1+e^{-z_i}}$
Softmax	$\text{softmax}(z_i) = \frac{e^{z_i}}{\sum_j e^{z_j}}$
Batch Normalization	$\text{BN}(z_i) = \gamma_i \hat{z}_i + \beta_i,$
	$\hat{z}_i = \frac{z_i - \text{E}[z_i]}{\sqrt{\text{Var}[z_i]}}$

$\mathbf{z}^l$: pre-activation output of layer l
$\mathbf{h}^l$: activation of layer l
$*$: discrete convolution operator
W, γ, β: learnable parameters

Fig: Equations of CNN

modelTraining the model:

Keras and TensorFlow libraries are used for training the model

Conv2D (Convolutional layer): This layer applies 16 filters of size (2,2) to the input image. The activation function used is 'relu' (rectified linear unit).

MaxPooling2D (Max pooling layer): This layer reduces the spatial dimensions of the output from the previous layer by taking the maximum value from each pool size (2, 2).

Conv2D (Convolutional layer): This layer applies 32 filters of size (3,3) to the output from the previous layer. The activation function used is 'relu' (rectified linear unit).

MaxPooling2D (Max pooling layer): This layer reduces the spatial dimensions of the output from the previous layer by taking the maximum value from each pool size (3, 3).

Conv2D (Convolutional layer): This layer applies 64 filters of size (5,5) to the output from the previous layer. The activation function used is 'relu' (rectified linear unit).

MaxPooling2D (Max pooling layer): This layer reduces the spatial dimensions of the output from the previous layer by taking the maximum value from each pool size (5, 5).

Flatten: This layer flattens the outcome from the previous layer into a 1D vector.

Dense (Fully connected layer): This layer applies a dense connection to the output from the previous layer. The activation function used is 'relu' (rectified linear unit).

Dropout: This layer applies a dropout regularization to the output from the previous layer, with a dropout rate of 0.2.

Dense (Fully connected layer): This layer applies a dense connection to the output from the previous layer and produces the final prediction. The activation function used is 'SoftMax' (for multiclass classification).

The model is compiled using the categorical cross-entropy loss function and the Stochastic Gradient Descent (SGD) optimizer. The model is saved to a file named "cnn_model_keras.h5".

Setting the hand histogram:

A function named **build squares**, which takes an image as input and returns a 2D array of 100 squares. Each square has dimensions of 10x10 pixels and is constructed by extracting a 10x10 region from the input image and arranging them horizontally into a row. After 5 rows are constructed, they are vertically stacked to create the 2D array of squares. The second function named **get_hand_hist** captures video[42] from a camera, detects a hand in the frame, and uses the image histogram to extract the color information of the hand. The function also displays the hand histogram and the thresholded image with the detected hand region.

Fig: Setting the hand histogram

Testing the model:

The Python script for gesture recognition using the CNN with OpenCV, TensorFlow and Keras. The script loads a trained CNN model, uses a saved hand histogram for feature extraction, and captures video input from the user's camera to predict the class of hand gesture performed. The script recognizes individual letters and builds words as the user forms hand gestures. The script then uses text-to-speech to speak the recognized word.

IV. Experiments & results:

Fig : Final Output Screen With Out Signs

In the above fig. the final output screen of the application is shown. The output screen of application consists of Threshold window and Gesture recognition window. Person has to place the hand in threshold window such that the results are shown for the particular shown sign.

Fig: Recognizing the character "C"

In the above figure as soon as we show the sign the binary image of the sign was shown and the class of the sign was

Fig: Recognizing the character “O”

In the above figure after recognizing the **“O”** we can hear the audio as **“O”** string is appended to **“C”** then string is **“CO”.**

Fig: Recognizing the character “w”

In the above figure after recognizing the **“W”** we can hear audio as **“W”** and **“W”** is appended to **“CO”** and we can see **“COW** as output Now after completely removing hand we can hear audio as **“COW”.**

V. EVALUATION METRICS

Classification Report

	precision	recall	f1-score	support
0	0.99	0.99	0.99	197
1	1.00	1.00	1.00	211
2	1.00	1.00	1.00	221
3	1.00	1.00	1.00	158
4	1.00	1.00	1.00	209
5	1.00	0.99	1.00	180
6	1.00	1.00	1.00	194
7	1.00	1.00	1.00	207
8	1.00	1.00	1.00	191
9	1.00	1.00	1.00	208
10	1.00	1.00	1.00	212
11	1.00	1.00	1.00	187
12	1.00	1.00	1.00	182
13	1.00	1.00	1.00	196
14	1.00	1.00	1.00	192
15	1.00	1.00	1.00	195
16	1.00	1.00	1.00	211
17	1.00	1.00	1.00	194
18	0.99	1.00	0.99	196
19	1.00	1.00	1.00	205
20	1.00	1.00	1.00	187
21	1.00	1.00	1.00	226
22	1.00	1.00	1.00	211
23	1.00	1.00	1.00	185
24	1.00	1.00	1.00	221
25	1.00	1.00	1.00	191
26	1.00	1.00	1.00	187
27	1.00	1.00	1.00	187
28	1.00	1.00	1.00	222
29	1.00	1.00	1.00	223
30	1.00	1.00	1.00	202
31	1.00	1.00	1.00	206
32	1.00	1.00	1.00	195
33	1.00	1.00	1.00	207
34	1.00	1.00	1.00	209
35	1.00	1.00	1.00	195
accuracy			1.00	7200
macro avg	1.00	1.00	1.00	7200
weighted avg	1.00	1.00	1.00	7200

Fig: Classification Report

Precision:

A high precision score indicates that the model is accurately identifying positive instances, while a low precision score suggests that the model is generating many false positives.

Recall:

recall is another measure of the accuracy of a classification model. Recall is a measure of the proportion of true positive classifications that were correctly identified by the model out of all actual positive instances.

F1_score:

The F1_score is a commonly used metric in deep learning to check the performance of a classification model. It is a measure of the harmonic mean of precision and recall, and is given as 2 times the product of precision and recall, divided by their sum.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

$$Precision = \frac{TP}{TP + FP}$$

$$Recall = \frac{TP}{TP + FN}$$

$$F_1 = 2 \cdot \frac{Precision \cdot Recall}{Precision + Recall}$$

Support:

The term "support" refers to the number of instances in the dataset that belong to a particular class. In the context of a classification model, the support is the number of instances that are correctly classified as belonging to a specific class.

Confusion matrix:

The confusion matrix gives the model's performance on a set of test images.

Rows are the true classes notation.

Columns are predicted classes notation.

The following image shows the confusion matrix for our CNN model.

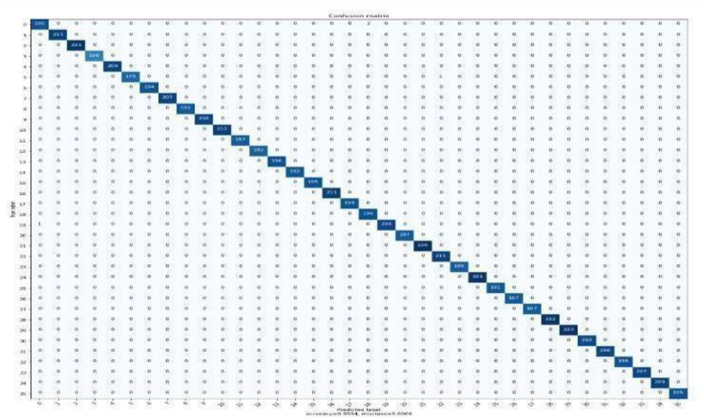

Fig: Confusion Matrix

VI. CONCLUSION

The project aims to detect sign language gestures using a CNN model. The model trained on a dataset of images of hands forming different signs and achieved a high accuracy in recognizing the signs. The project used a vision-based approach to detect the hands in the input images, and a pre-processing step to extract features from the images. The CNN model was then trained on the feature extracted images to classify the different signs. Overall, the project demonstrates the effectiveness of deep learning techniques in recognizing sign language gestures, which can have a significant impact in making the communication more accessible for the deaf and hard of hearing community. The project can be further extended by exploring more sophisticated hand detection methods, and by increasing the size and diversity of the training dataset.

VII. FUTURE WORK

1. **Incorporating more sign language gestures and expanding the dataset:** The current project is based on recognizing a limited number of sign language gestures. To make the model more comprehensive and useful, it could be expanded to recognize a larger vocabulary of signs. This would require collecting more data and training the model on a wider range of gestures.

2. **Developing a real-time system:** The current system requires the user to record a video and then classify the sign language gesture. A future direction could be developing a real-time system that can recognize gestures as they are being made. This could involve designing a more efficient algorithm or using specialized hardware to speed up the process.

3. **Multi-modal approaches:** Combining multiple modalities like image, audio can lead to better recognition accuracy. For instance, incorporating lip-reading or hand tracking techniques can further enhance the system.

4. **Improving accuracy:** Even though the current model achieves high accuracy, there is always room for improvement. Tuning the model's hyperparameters or using more advanced deep learning techniques like recurrent neural networks or transformers could help improve the accuracy even further.

5. **Deployment on mobile devices**: Once the model is developed, it can be deployed on mobile devices. This can be beneficial for deaf and hard-of-hearing individuals, who can use the app to communicate more effectively in daily life.

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