Artificial Neural Network based Indian Sign Language Recognition using hand crafted features

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Abstract*— *Sign language is a medium of communication of Divyangjans (Deaf and mute people). Sign language can be used for effective communication only if understood by both the people trying to communicate. When one person is unaware of meaning of the sign gestures an interpreter is required who can translate the gestures into spoken language. This article presents a methodology to recognize Indian Sign Language (SL) gestures and translate them into English. SL Recognition systems can be useful for facilitating the conversation. There are various systems developed by researchers for implementing a SL recognition system. Being in its developing stage, the grammar rules of Indian Sign Language (ISL) are not documented making the recognition process a challenge. This approach employs hand crafted feature extraction technique and uses Artificial Neural Network for classification of the gestures. The accuracy of model achieved is as high as 98% using this methodology.

Keywords*—Indian Sign Language Recognition, Artificial Neural Network, Gesture Classification, Fourier Descriptors*

I. INTRODUCTION

"Language" is an essential part of communication. It contains sub units as alphabets, words, phrases, sentences etc. One can not convey their thoughts without use of language. Our needs, opinions, attitude, expressions, knowledge all of these require a channel in order to reach the other people. Language acts as a medium of communication. However, there is one part of this world who are not equipped as rest of the world in terms of this medium. According to World Health Organization (WHO, 2017), 5% of world population has hearing loss. These people who have difficulty in hearing, can not effectively communicate. Approximately 360 million people are hearing handicapped and struggle to communicate on daily basis. The deaf and mute people only lack in the ability of hear and/or talk. Apart from that they can lead the regular life as others. The only thing separating them from the normal people is communication [1]. The way for this is "Sign Language". Sign Language (SL) is a gestural language of communication of deaf and mute people. Just as others use oral communication and sound patterns, divyangjans use signs in visual space for communication [2]. SL involves hand/ arm gestures as well as facial expressions and various body postures have their semantic meaning. Sign language got its recognition in linguistic studies after 1970s [3]. Sign language symbols are able to indicate all the sign parameters that include hand shapes, movement, location and palm orientation [2]. The classification of SL symbols is shown in Fig. 1. One handed signs as name suggests make use of only one hand for making a gesture. Two handed signs make use of both the hands while making a gesture, both dominant and non dominant hand. One handed signs can represent any static sign or sign in motion. Two handed gestures are categorized further in Type 0 (Fig. 2) and Type 1(Fig. 3) signs.

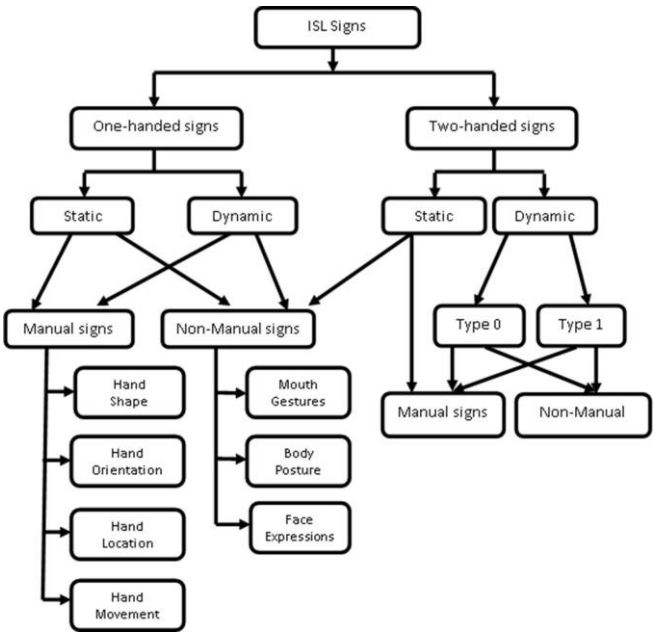

Fig. 1 Classification of Sign Language Symbols [4]

In type 0, both the hands are equally active while as in type 1, dominant hand is more active than the non dominant.

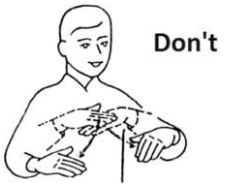

Fig. 2 Type 0 Sign[2]

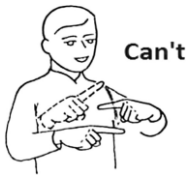

Fig. 3 Type 1 Sign[2]

Apart from the above categorization, SL has categories like manual and non manual signs too [5]. Manual signs are those that only use hands for making a gesture while non manual signs make use of facial expressions, eye gaze, body postures too.

More than 1 million of adults and 0.5 million children in India make use of Indian Sign language [6]. According to Indian Sign Language Research and Training Center (ISLRTC) of Govt. of India, there are only 250 qualified ISL interpreters listed all over the country. Finding an interpreter every time when one needs is difficult as well as expensive task. Thus technology can be utilized to overcome the communication barrier. A video-audio interface [7] can be used as a machine interpreter that can replace the need of human interpreter.

Developing such system is a challenging task for researchers and has been area of interest for many for last few decades. Machine translation of SL is performed by two ways: (i) Sensor based signal processing approach and (ii) Image Processing based vision approach. In the first approach a pair of sensor gloves is used to capture signal from finger movements. In the second approach a 2D camera sensor is used to capture visual data of the signs made. 2D time varying approaches produce better processing compared to 1D approach as sign language is characterized as a visual language model, which involves signers hand shapes, hand movements with respect to each other, head, face and the torso [8].

In this paper, we present one such system that is implemented to recognize ISL gestures based on imaging approach. The system developed by us makes use of a simple digital camera to capture gestural videos and later makes use of hand crafted feature extraction techniques to extract features from the videos. A classic Artificial Neural Network Classifier is implemented to recognize the gesture in order to translate it into English Text. In section II we have presented various SL recognition systems that we studied before proposing our methodology.

II. Sign Language Gesture Recognition Systems

Sign Language Recognition has been a domain of research for last few decades. In the very beginning, the research began in the field of signal processing. A data glove was used that had sensors in the glove to detect finger movements [9] and pass this information to a computing system. Though the system showed high accuracy, it is cumbersome to the user as well as costly. Another limitation of such systems is that it only has information about hand movement and thus suitable only for manual signs. There have been varied approaches used to employ gesture recognition system [10]. To name few they include mathematical models based on Hidden Markov Models (HMM) [11], tool based soft computing [12], filtering techniques like Kalman filtering [13], advanced particle filtering, connectionist models such as Time delay Neural networks(TDNN) [14], Radial basis function network(RBFN), Multilayer perceptron(MLP)[15]. To implement gesture recognition system use of various hardware devices is essential for tracking of gestures. This includes imaging or computer vision techniques, data gloves with embedded sensors, markers based on optical trackers, body suits, styli, infrared or ultrasound detectors. Rekha et al. [16] have developed double handed ISL recognition system. With the database of 26 signs (Static as well as dynamic). Support Vector Machines (SVM) were used for static signs and for dynamic sign classification Dynamic Time Warping technique was used. Agrawal et al. [17] proposed a system used for double handed signs. This vision based system uses 235 images of 36 signs. For feature extraction fusion of shape descriptors, HOG and SIFT is employed. Adithya et al. [18] presented a recognition for single handed as well as double handed signs. The database includes alphabets and number image. These images were segmented using skin color in YCbCr color space. Rahaman et al. [19] developed a real-time camera based sign language recognition system for Bengali signs. Classification is done using KNN. Coloured gloves are used in this case. However the system is unable to segment hand area accurately in case of skin color appears. Mehrotra et al. [20] proposed a system using Microsoft Kinect for recognition of ISL. Features are extracted from specific skeleton joints. Classification is done using multi-class SVM with 81% accuracy. Kishore et al. [21] presented ISL recognition in sentences. With the dataset of 580 signs, optic flow hand tracking and hand shape features were extracted. The results show that the recognition rate of 90.17% was achieved. Naglot and Kulkarni [22] presented an ANN based ISL recognition of numbers using Leap Motion Controller (LMC). They used Multilayer Perceptron (MLP) for classifying single handed dynamic signs and achieved 100% accuracy. Following are the few methods that have been extensively studied while reviewing the relevant literature.

A. 3D sign language recognition with joint distance and angular coded color topographical descriptor on a 2 – stream CNN [23]

In the proposed methodology, authors have developed a system that performs Human Action Recognition (HAR). Authors use a database captured using – 3 D Motion Capture System (Vicon Motion System Ltd) that captures 59 upper body joints, they have incorporated existing dataset of human activity captured using Kinect sensor (NTU Human Activity) which makes use of 25 body joints, as well as a MOCAP system that uses 41 joints. In the existing methodologies authors propose to add a new feature that is Joint Angle Topographical Descriptor (JATD) this input is given to a two stream CNN. This two steam CNN architecture is trained for 500 different classes of Mocap sign language data. Validation is done using above mentioned pre-existing datasets. The proposed methodology shows improvement in prediction accuracy with reduced training time.

B. Motionlets Matching With Adaptive Kernels for 3-D Indian Sign Language Recognition[24]

In the mentioned article, authors have explained the various approaches that have been employed for recognition of SL. 1D, 2D and 3D data, where 1D refers to the sensor based technology, 2D refers to RGB vision based technology and 3D refers to the Depth images. The authors have proposed a technique which used motionlets for recognition of SL. In the presented paper, they have developed a motion capture system that results in 3D motion data in terms of Moving and Non Moving joints. (MJ and NMJ) the relation between MJ and NMJ can describe the features of the captured images. Four classes have been defined here that are: Single-hand_Face-Head, Two-hand_Face-Head, Single-hand_Chest, and Two-hand_Chest. The capture system includes 8 IR cameras and 1 video camera. In phase I of implementation structures database is created. In phase II shape and orientation motionlets are extracted. And finally with the Adaptive Kernel Matching approach classification is done. The proposed methodology is compared with existing techniques and produced 98.9% recognition accuracy with 98.3% precision.

C. Selfie video based continuous Indian sign language recognition system[25]

While most of the ISL recognition systems are either sensor based or Kinect and depth image based, the above titled method used RGB image based methodology that can be employed on mobile platform for ISL recognition. Videos used for this methodology and simple single handed signs that

are captured using a selfie stick. Pre-filtering is performed for noise removal, then using simple image processing techniques like sobel edge operator image is enhanced with morphological operation. The hand and head counter shape is extracted. For extracted features from the videos, discrete Cosite transform (DCT) is performed, for optimization, Principle Component Analysis (PCA) is employed. Finally classification is based on Minimum Distance Classifiers (MDC). The accuracy in terms of word matching score is 93.2% of the proposed system.

After reviewing above systems we propose our methodology in following section that makes use of RGB videos as database. Pre-processing is done in order to extract region of interest that defines signing space of the signer. Next step is to extract features that is done using combinational algorithm [26]. The codebook is created using vector quantization and the quantized features are fed to an Artificial Neural Network (ANN) for classification.

III. Proposed Methodology for ISL Recognition using Hand Crafted Features and ANN Classifier

The reviewed literature shows that though research on ISL has been going on for last few years, the researchers have not yet concluded any one methodology which can be prove to be the most accurate over others. Most of the researchers are working on images that are captured using Kinect, Motion Systems or Leap motion sensors. These images are termed as depth images. However using such systems in daily life is not feasible. If one is aiming to make the ISL Recognition system for benefit of the deaf community, it has to be the one that can easily be used by everyone without any expensive gadgets or capturing mechanisms. Hence we are proposing a system that will use simple RGB image data. The database that is used in present article is captured using a Sony Digital Camera but can also be replaced by any webcam or mobile camera. The proposed methodology is explained in following figure Fig. 4.

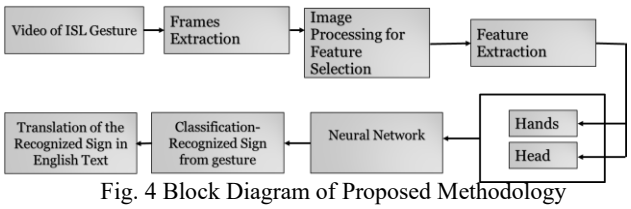

Fig. 4 Block Diagram of Proposed Methodology

A. Database Creation:

The first step of the implementation begins with database creation. Unlike the western sign languages like American Sign Language(ASL), British Sign Language (BSL), Irish Sign Language the standardized dataset for ISL is not available. Main reason behind this is the ISL directory is still in its developing phase. The grammar rules are not yet completely released by ISLRTC. As of now (in 2020), ISL has published more that 6000 word directory of ISL, however the work is still not completed. The directory that has been released has a single iteration of every sign. This is insufficient for carrying out any experiment. Hence the first stage of the implementation is database creation. The data used for this experiment is captured at "Ali Yavar Jung National Institute of Hearing Handicapped" used in [3] and [26] our earlier work. The database includes 500 videos of 10 different sign gestures made by 10 deaf signers in 5 iterations. To maintain randomness we have included both male and female signers, the signers from various regions, age group between 16 to 35 and both right and left handed signers. Videos are captured using Sony Coolpix camera. After capturing the videos, the frames are extracted from the videos in order to be processed. These frames are named serially according to their sequence. The frames have been given a name as Oi, where O stands for original frame. And i stands for current count of the frame. The frames are then cropped in order to focus on region of interest. The cropping is performed manually by providing the (X,Y) coordinates.

B. Image Pre-Processing

The image processing is the crucial step as the output of this leads to feature extraction. The image processing is done in order to achieve hand tracking of the gesture. The steps are followed according to the methodology explained in paper [26]. Hand tracking is based on a combination algorithm. The steps of combination algorithm are described in Fig. 5

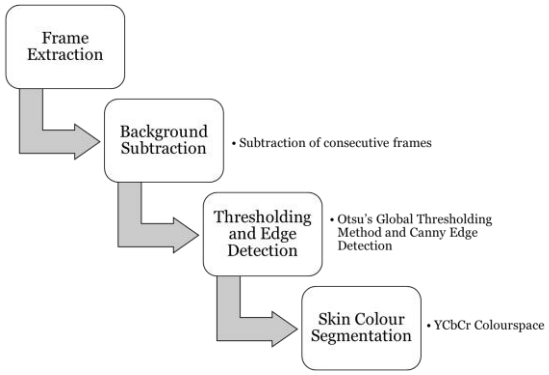

Fig. 5 Combination Algorithm

This begins with background subtraction by subtracting two adjacent frames from each other. This difference algorithm [26] retains only moving part of the gesture and subtracts the stationary background. Simultaneously skin colour model has been employed in YCbCr colour space. Chai et al [28] have proposed a method that focuses on the spatial characteristics of skin color. With help of chrominance component a skin color map is obtained and skin pixels are determined. After this, regularization is done to reinforce skin regions to detect face region. In YCbCr space they have found that the range of Cb and Cr most representatives for the skin – color reference map given by Eq. (1).

$$77 \leq Cb \leq 127 \; and \; 133 \leq Cr \leq 173 \qquad (1)$$

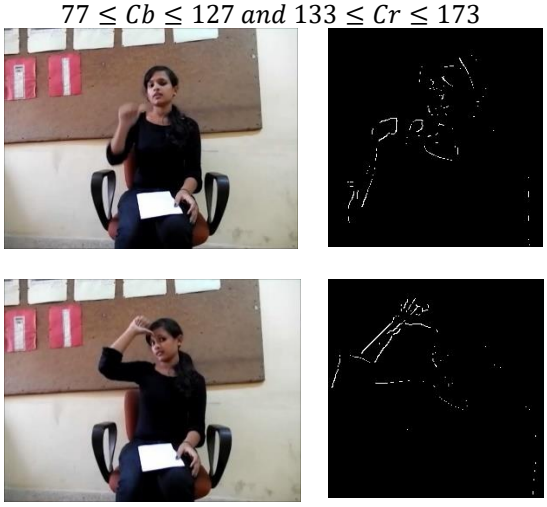

Fig. 5 Original frames of gesture and its processed output after applying combination algorithm

Above two methods are combined in order to track the hand movement, after that next step is to obtain the boundaries of the captured hand movement. This is performed using thresholding followed by edge detection. The threshold value is selected by taking several trail and errors and edge detection is done using Otsu's global thresholding algorithm. The last step is to combine the output of above three steps. The detailed results are documented in our previous work [3,26] In Fig. 6 we can see the original frame and its corresponding processed frame, in case of a gesture India.

C. *Feature Extraction:*

Feature extraction is of much importance in case of pattern recognition. When database is gestural, it is quiet large for processing and also consists of redundancies. Hence input data is reduced. The transformation has to follow a set of features. The feature extraction process represents large set of accurate data in a simplified way. The features can be several. Most common approaches of feature extraction are Principle Curvature Based Region (PCBR) and wavelet Packet Decomposition (WPD) [16], Principle Component Analysis (PCA) [29], or Scale Invariant Feature Transform (SIFT) [30] Fourier descriptors [31] is another successful approach used for feature extraction purpose. To extract the external boundary points of a hand shape the contour following algorithm [32] is used. To represent the boundary points, first the Fourier series were calculated using Fast Fourier Transform (FFT) algorithm. For feature extraction purpose, 28 Fourier descriptors per each frame of video gesture are considered after making several trails. These 28 x 28 Fourier descriptors are quantized using Vector Quantization technique in terms of a codebook created. Vector quantization (VQ) is a non-uniform and many-to-one mapping lossy compression. Based upon equivalence relation, multiple vectors are mapped to a single region [32]. VQ process is implemented in three parts viz. codebook generation, encoding and decoding [33]. The type of VQ employed is popularly known as Linde- Buzo- Gray (LBG) type of vector quantization.

D. *Classification*

Once features are extracted from the video gestures, the following step is usually recognition or classification which is the last step of the recognition system. In literature review we have seen various techniques that are employed for classification which include MDC, KNN, Adaptive kernel matching etc. The approach implemented in this article is with the help of Artificial Neural network. A multiclass classifier is employed here that has 10 different output classes. The architecture of the neural network is as shown in Fig. 6

The neural network is employed in tensorflow using Keras at backend. The sequential model is used. The model is trained for various number of hidden layers and found that 3 hidden layers give better performance. In case of single hidden layer, the model is overfitting as database is small. Out of 500 videos, 300 videos are used for training the model. Table 1 describes performance of model for various number of hidden layers. The activation function is Relu , the batch size is 32 and epoch is 50.

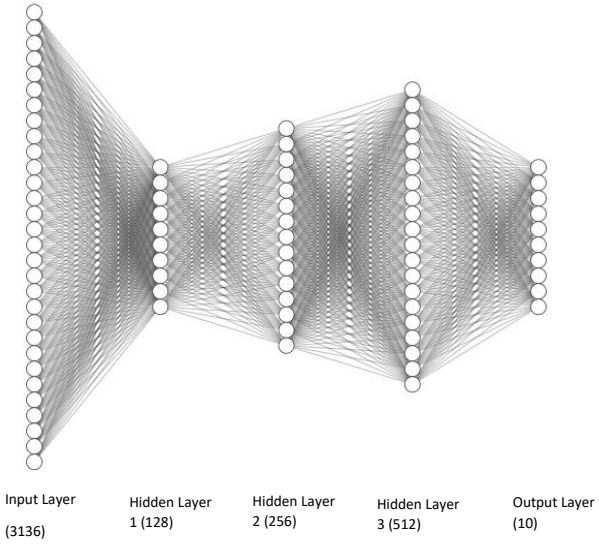

Fig. 6 Neural Network for Classification of ISL

Table 1: Performance Parameters of Neural Network

No.	Model Details	Performance (Accuracy %)
1	Hidden Layer- 1	Training- 100% (From 15th Epoch) Validation – 22%
2	Hidden Layers-2	Training- 84% Validation- 54%
3	Hidden Layers-3	Training- 96% Validation- 63%
4	Hidden Layers-4	Training- 98% Validation- 48%
5	Hidden Layers-5	Training- 77% Validation- 40%
6	Hidden Layers-6	Training- 11% Validation- 3%

From the Table 1 we find that from hidden layer 2 onwards, the performance gets better in terms of training accuracy till 4 hidden layers. In case of 1 hidden layer, though the output shows 100% training accuracy, the model however is overfitting. Also, validation accuracy is poor. Training accuracy is best with hidden layers are 4, however validation accuracy is better with 3 hidden layers, and training accuracy is comparable too. Hence we have selected a model with hidden layers 3 for our recognition system. The graph mentioning the accuracies is as seen in Fig. 7.

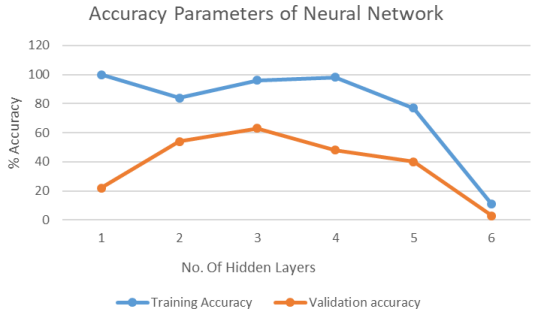

Fig. 7 Accuracy Parameters of Neural Network

In addition to this we also compared models in terms of its accuracy trend per epoch. The Fig. 8 shows accuracy graph of model with only 1 hidden layer, we can see that accuracy is not stable over epochs for training as well as testing, similarly Fig. 9 that shows accuracy trend of model with 6 hidden layers too shows a lot of fluctuations, implying the model definitely fails in both the cases.

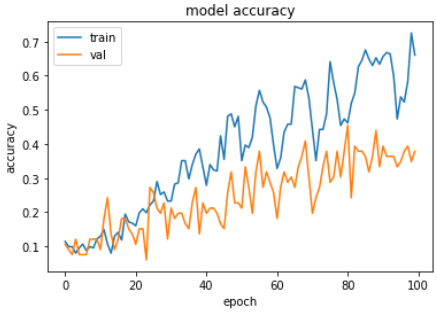

Fig. 8 Accuracy in case of model with 1 hidden layer

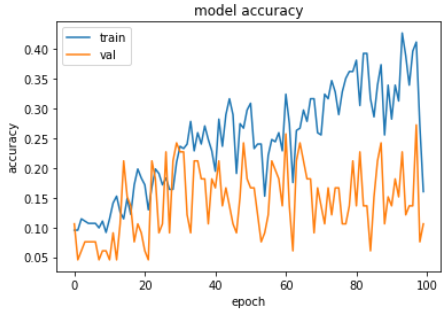

Fig. 9 Accuracy in case of model with 6 hidden layers

In contrast to above two cases, when graph was plotted for our selected model, that is the one with 3 hidden layers, the accuracy as seen in Fig. 10 was seen steady and increasing over epochs, also the plot of loss as seen in Fig. 11 shows exponential decrease in case of training loss, however test loss is not decreasing upto the mark, the reason being less number of samples available for testing.

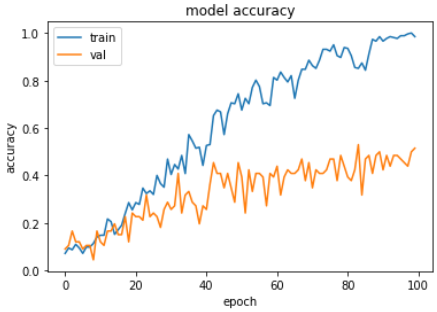

Fig. 10 Accuracy in case of model with 3 hidden layers

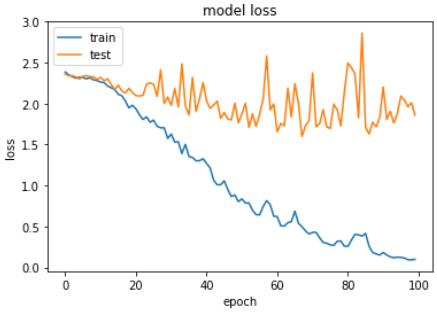

Fig. 11 Loss in case of 3 hidden layer model

IV. Conclusion and Future Scope

This papers presented a methodology for ISL recognition that makes use of Vision based technique. The proposed method is different than other available techniques in terms of that, it makes use of RGB image based method in contrast to other methods that make use of depth images or output from leap motion sensor. Images here are captured using digital camera, but can be in future replaced by mobile camera. The hand crafted features, make use of Fourier descriptors after pre-processing the image using combinational algorithm. Classification is performed using multi class neural network classifier. The training accuracy obtained here is as high as 98%. Validation accuracy is 63% which is at par with other activity recognition systems, however the database has to be increased in order to obtain better idea of the system performance. Without doubt, the limitation of proposed system is the small database used for implementation. In future, the system can be implemented with larger dataset and depending on the performance, the system can be updated.

Acknowledgment

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