International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 12 (2018) pp. 10246-10255

Invariant Feature Representation in Indian Sign Language for Variant Illumination and Posture

***Sarita D. Deshpande, Yashwant V. Joshi**

Progressive Educations Society's, Modern College of Engineering, Pune, India.
Shri Guru GobindSinghji Institute of Engineering and Technology, Nanded, India.

Abstract

Sign language representation has been the main source of communication for the disabled person. To bring a bridge between the normal and disabled individuals, an automation system is in need. This paper presents a development of automation system for sign language representation for Indian sign language based on image processing application. In the approach of sign language representation, external illumination and capturing mode plays a vital part in representation and categorization. The segmentation process and representation of feature reveals the actual details of the sign language representation and classification. The presented approach gives a significant improvement in classification performance under variant illumination and segmentation performance as compared to the conventional recognition approaches. A normalized singular value normalization factor is developed for the normalization of illumination and an invariant feature representation using spectral mapping for the region segmentation and feature representation.

Keywords: Indian sign language recognition, Illumination effect, Singular normalization, Invariant Feature Representation, Sign Language, Variant Illumination, Posture, SVD.

INTRODUCTION

The important mode of communication between the common person and the disabled is Sign language. In individuals, development communication plays a major role whereas; a disabled individual is segregated to apart of this progress. Disability was observed in various formats in our society, individuals with limb defects, vocal defects, auditory defects etc. are being observed. Wherein defects with limbs are overcome by artificial limbs, vocally disabled are provided with sign language. Sign language is a common interface for vocally disabled individuals; however, when they need to communicate with common individuals, this sign language is a constraint. Hence sign language is more convenient to vocally disabled individuals. To overcome this limitation, the new interface needs to be developed towards bridging this gap.

In[1], a hand gesture identification process proposed to recognize the alphabets of Indian Sign Language. Between the proposed processes there are 4 modules: hand segmentation, extraction, gesture recognition and real-time hand tracking. Cam shift strategy and Hue, Saturation, intensity (HSV) color model are utilized in this strategy for hand tracking and segmentation. Genetic Algorithm is utilized for gesture identification. An automated recognition system was proposed in[2], to perform the recognition of two-handed signs of ISL. In this approach, the hand segmentation was done through Otsu's algorithm. Scale Invariant Feature Transform (SIFT) and Histogram of Oriented Gradient (HOG) was used at feature extraction stage to compute feature vector. A More than one-class Support Vector Machine (MSVM) was used at classification stage. A combined algorithm was proposed in[3] by combining the Dynamic Time Warping (DTW) and IS algorithm. Neuro-Linguistic Programming (NLP), a division of Artificial Intelligence which entails usual Language Processing and Neural Networks. The IS invokes a set off when the present atmosphere changes dynamically, DTW handles gesture transformation mapped with identical patterns.

A novel hand gesture identification procedure using Discrete Wavelet Packet transform (DWPT) used to be proposed in[4]. It presents more exact frequency determination and bigger flexibility than DWT which helps to obtain the invariant aspects. Dynamic hand signals are mixed in a consistent heritage and variable mild stipulations. The vital component analysis has been utilized for dimensionality discount and extracting the tremendous features. The categorization manner includes exceptional distance metrics and Artificial Neural Network (ANN) which presents a corresponding evaluation of quite a lot of types of classifiers.[5]Proposed way to address the issues of local and global uncertainty recognition and inner-class variability improvements every hand gesture recognition. The hand is segmented and identified via YCbCr skin color model reference. The principle Curvature founded area detector was used for shape extraction, Wavelet Packet Decomposition (WPD-2) and difficulty fault algorithms were used for texture and finger point's extraction. Multi-type non-linear support vector machines (SVM) was utilized for categorization. An approach to sending the Indian signal Language (ISL) hand gestures inside appropriate text message was once supplied in[6]. The hand gestures equal to ISL English alphabets are obtained through a webcam. In the captured frames the hand is segmented and the state of fingers is utilized to admire the alphabet. The facility corresponding to attitude made between numbers of fingers that are thoroughly opened, wholly closed or semi-closed fingers, and study of each and every finger is utilized for realization. In[7], dynamic gesture recognition was proposed for ISL by considering the global as well as local information and also the strokes. This is also termed as a phonemic representation of signals. The local information was included in this approach by considering the shape of the stroke of each and every finger. Maximum Curvature Points (MCPs) are used as features.

In[8], authors analyze the exact characteristics of complex Zernike moments. This approach considers the magnitude and orientation of hand gestures for recognition. Database of complete 720 images of five signs (C, I, L, T, V) is utilized here. Experiment units are designed to shape detailed, orientation variant and orientation invariant. In[9], a dynamic gesture recognition approach was proposed such that it was used to translate dynamic as well as static features of ISL. This approach considers the features such as temporal racing and skin tone detection to obtain the motion print, nothing but the power spectrum of the gesture, unique for each gesture. The exact classification of hand gestures plays a vital part in the development of hand gesture recognition systems. In[10], an approach was proposed using HOG features of gesture. The gesture was obtained through the web camera. This approach attempted to recognize the alphabets (A, Z) and also numerical (0, 9) wherein these features are used as representative features. The large dimension of the descriptive feature leads to processing overhead. To optimize the operation performance, dimension reduction techniques were used.

In[11], a gradient-based key frame extraction was proposed with the help of both the hands for continuous ISL gesture recognition system. These key frames are valuable for splitting steady sign language gestures into the series of indicators as well as for taking out non-informative frames. Later breaking of gestures, all signs have been handled as a remote gesture. Aspects of pre-processed gestures are obtained making use of Orientation Histogram (OH) with Principal Element Study supplied for reducing the dimension of points bought after OH. In[12], an ISL transformation system was proposed to perform the recognition of hand gesture using ISL, also to recognize the 26 gestures from ISL. This system was processed in four phases: pre-processing, segmentation of and, feature extraction, recognition of sign, sign to text and sign to voice conversion. In[13] this system, Principal Component Analysis (PCA) was used at the stage of gesture recognition and conversion of gesture to text and voice format.

A novel mixture of vision based services with the intention to increase the identification of underlying indicators is provided in. Three aspects are chosen to be mapped to those 4 Elements. Two of those elements are newly presented for American signal Language consciousness: kurtosis role and PCA. PCA is utilized here as a descriptor that represents a world photo facility to furnish calculates for hand configuration and hand orientation. Kurtosis is utilized as a neighborhood facility for demonstrating edges and reflecting the condition of articulation examination. The 0.33 function is motion chain code that represents the hand task. On the foundation of those points, a prototype is outlined and its performance is evaluated. It includes skin color detector, connected component locator and dominant hand tracker, a feature extractor, and a Hidden Markov mannequin classifier.

A gesture recognition system was proposed in[14] using PCA as a statistical technique to reduce the dimensions of data, the data having many variations, using the correlation between the features. The reduced data set was having only principal components so that the first few features carry most of the variation in the old data variables. The new dataset with principal components is calculated using computing the Eigenvectors and Eigen values of the original dataset's covariance matrix.

In[15] the procedure for naked hand gesture identification in proposed scheme is utilizing database-driven hand gesture realization. It is established upon skin color model strategy and thresholding technique together with a mighty template matching which can also be without problems utilized for human robotics functions and equal different purposes. Beginning, hand neighborhood is segmented through applying skin color model in YCbCr color area. An Otsu thresholding is utilized to separate background and foreground. In recognition, a template established matching procedure is developed utilizing Principal Component Analysis (PCA).

[16] Proposed an HCI system able to present gesture identification from the ISL. In this, Neural Network (NN) was proposed at recognition. Extra it is proposed that quantity of finger pointers and the space of fingertips from the Centroid of the hand can be utilized together with PCA for robustness and efficient outcomes. Inside[17], a Type-2 Fuzzy HMM was proposed with the aim of static hand gesture recognition. The features used in this approach are the Singular Value Decomposition (SVD). In this procedure, the elemental HMM arithmetic operator through few ample style-2 fuzzy operators that permits for us to loosen up the additive constraint of probability calculates. Thus, T2FHMMs are capable to maintain both random and fuzzy uncertainties universally in the sequential knowledge. Towards the classification of the sign language based on the recognition approaches and the features extracted, different classifier models were developed. These classifiers are developed with learning approaches as well developed with artificial intelligence coding such as the neural network. In[18], a method was proposed to recognize the ISL and also to translate them into text format. Structural shape descriptor and Hu invariant parameters are used to form a new feature vector. In this approach, by considering the advantages of Speeded-up Robust Features (SURF) and Hu, a new combination feature set was formed to increase the recognition accuracy. This approach finally used a combination of KNN and SVM classifier at classification stage.[19] Determines a gesture divinations records which will classify a big type of hand gesture in a view headquartered setup. Given that the photos are from only one capturing unit, it appears to be hardware difficulty; however, it wants a high accuracy classifier for categorization and responsiveness motive. In the decision making work employs fusion procedure for three classifiers specifically SVM, MLP and to divide signal language remote signs. The method contains two layer deviations. At first, coarse categorization is done according to only one classifier and the second categorization is fusion centered on concatenation strategy. In observation of these approaches observed in past, it is observed that less effort is put on to the minimization of surrounding effect on

the classification performance under variant lighting or segmentation performance.

In this paper, a new singular normalization strategy is suggested for image normalization and spectral feature mapping for feature selection. The paper is organized as follows. The proposed approach of normalization is outlined in section 3. Section 4 outlines the feature representation and its representation. The simulation result obtained is a presentation in section 5. Section 6 gives the conclusion for the developed strategy.

OUTLINE OF CUE SYMBOL RECOGNITION SYSTEM

Sign languages can be analyzed at the grammatical, structural, lexical levels and phonologic levels. There is difference sat each and every level between distinct sign languages. There are various sign languages: FSL (French Sign Language), ASL (American Sign Language) and ISL (Irish Sign Language), etc. all over the world. Several of the world's sign languages are valid detected in country constitutions or are denoted in the laws of various nations, thus as associates to justice, education and so more. But sign language is not detected as completely-mature language. It is also not applied to written languages like another language of the world. The issue of necessarily sign language detection can be put over as provided a video of a scheme (sign) language sentence interrogative can we detected the sign in the interrogative and redeveloped interrogative? The answers to this difficulty of sign language recognition are more than one experimental analysis.

An automation of Sign language is required necessarily to interact with the major population which can hear and talks i.e. a normal population. Sign language recognition is necessary to raise the quality of life of the unhearing person. As an example, the use of revolutionary computer technology can deliver an answer to the predicament a secure screener in efforts to interaction with people passengers in the direction of regular enterprise moves. Additionally, it could be useful in different locations like the court, conventions or maybe a grocery store. On any other note, HCI (Human-Computer Interaction) is step by step shifting toward a modality where speech detection will play a main function. Even as speech recognition has made fast advances, gesture detection is lagging in the back of. With this slow shift to speech based input-output devices, there is a danger that persons who depend entirely on sign languages for conversation can be disadvantaged until there are important advances in automatic recognition of sign languages. Secondly, the problem of automatic sign language recognition it is also profitable from a scientific and technological point of interest, given that advances on this problem would, in reality, impact the general problem of automated gesture popularity, which is at the center of designing next-generation man-machine interface. Within the technique of sign language transformation, the past research shows that various format of recognition approach, classifier models, and representative features were proposed. Dimensional reduction and real-time usage were also seen. However, the applicability of sign language transformation over Indian sign language is yet to be improvised. The processing accuracy under input variant conditions, such as illumination, pose, scaling, rotation, noises etc. were not observed. Towards improving the robustness in processing sign language a robust sign language transformation based on Indian sign language is focused. For the development of Indian sign language recognition, the system architecture proposed is shown in figure 1.

The basic system process is performed in two operation stages of training and testing phases. In the process of training, a set of hand gesture representing all the character of Indian sign language is read. These samples are preprocessed for uniform dimensionality and content enhancement. The images are reshaped to a uniform dimension and the image content is filtered for content enhancement with gray pixel extraction. These preprocessed data is coded for region localization.

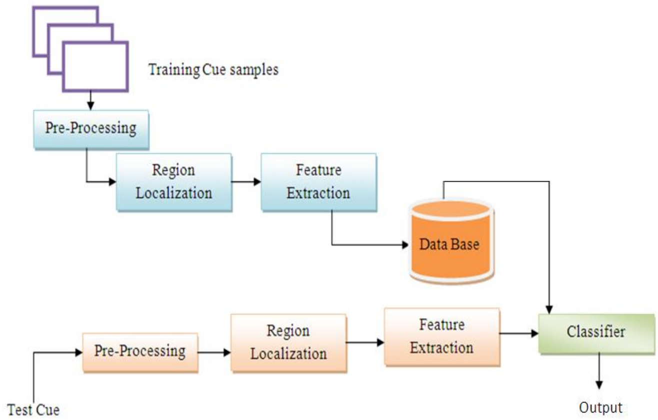

Figure 1. Generic System architecture for Sign language recognition

DISCUSSION OF DATASET

For the analysis of the innovative technique, a set of database and test images is captured. The images are captured for Indian sign language where alphabets from A to Z and numbers from 0 to 9 are captured using different real-time capturing devices. The capturing environment is varied with illumination and background images for the evaluation of the robustness of the proposed approach. 8 distinct classes are developed. The developed database is as outlined in following figures.

Class a: female hands_brightness_digicam

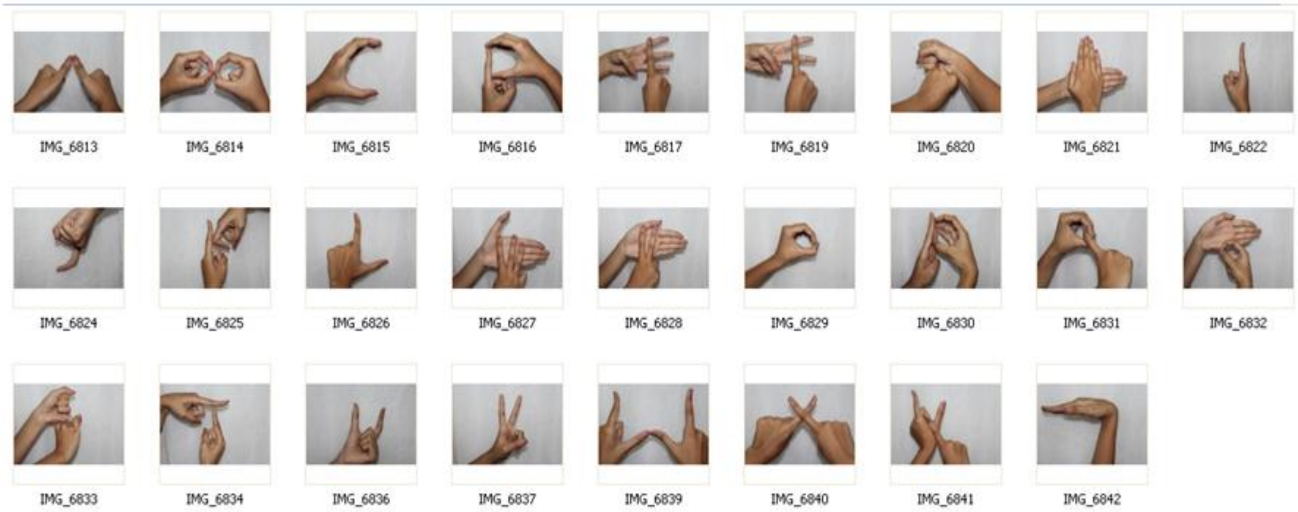

Figure 2. Images of alphabet A to Z

Figure 3. Images of number 0-9

Class B: Laptop

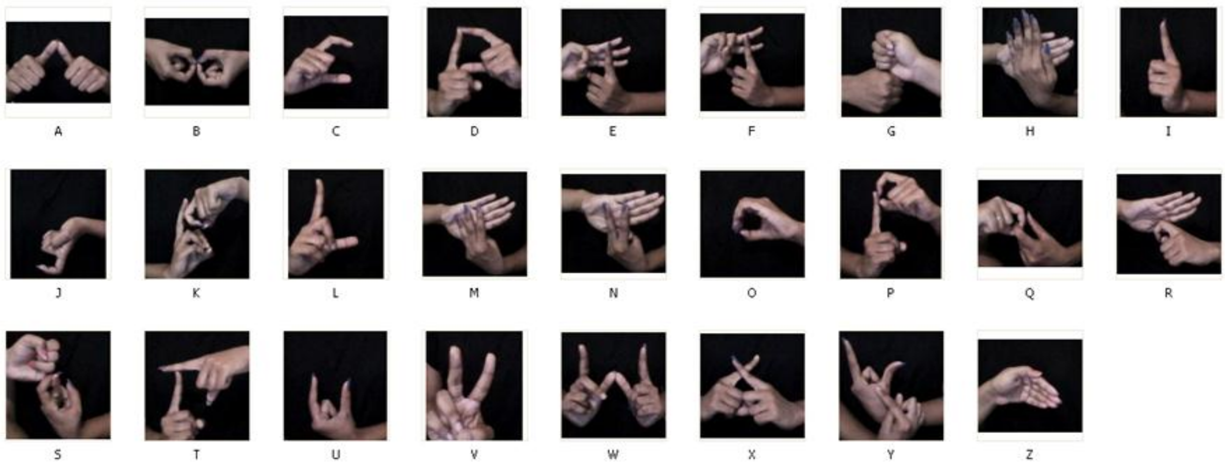

Figure 4. Images of alphabet A to Z

Figure 5. Images of number 0-9

Class c: mobile_brightness

Figure 6. Images of alphabet A to Z

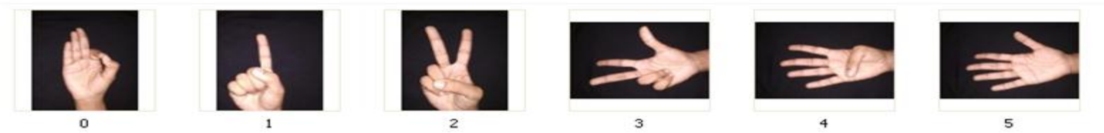

Figure7. Images of number 0-9

Class d: with brightness_digital cam

Figure 8. Images of alphabet A to Z

Figure 9. Images of number 0-9

Class e: with brightness_digitalcam_blackwhite_bk

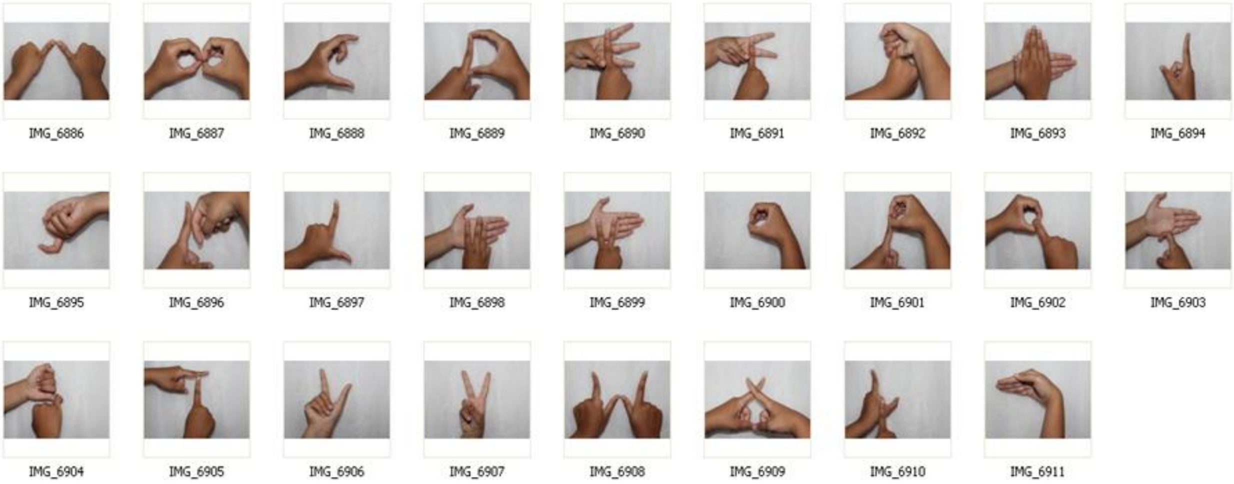

Figure 10. Images of alphabet A to Z

Figure 11. Images of number 0-9

Class f: with brightness_digitalcam_blackwhite_bk_diffrent person

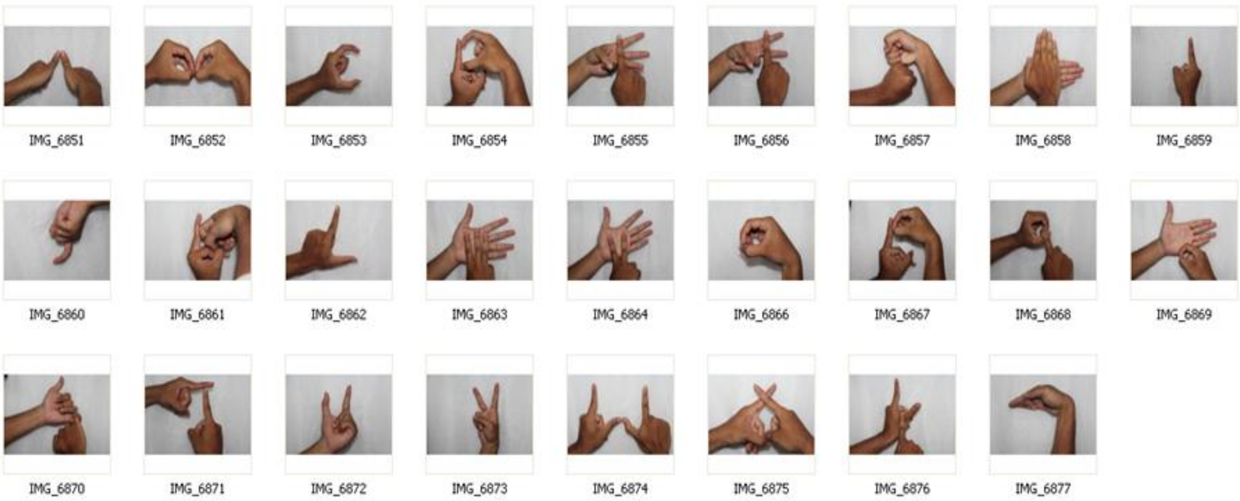

Figure 12. Images of alphabet A to Z

Figure 13. Images of number 0-9

Class g: with some shaddoweffect_digicam

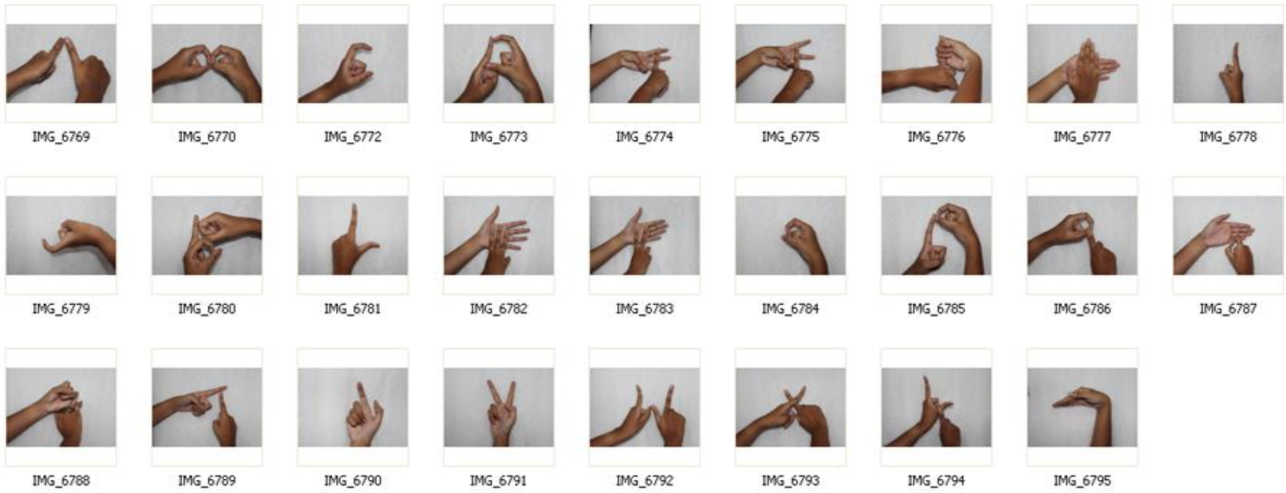

Figure 14. Images of alphabet A to Z

Figure 15. Images of number 0-9

Class h: without brightness_digicam

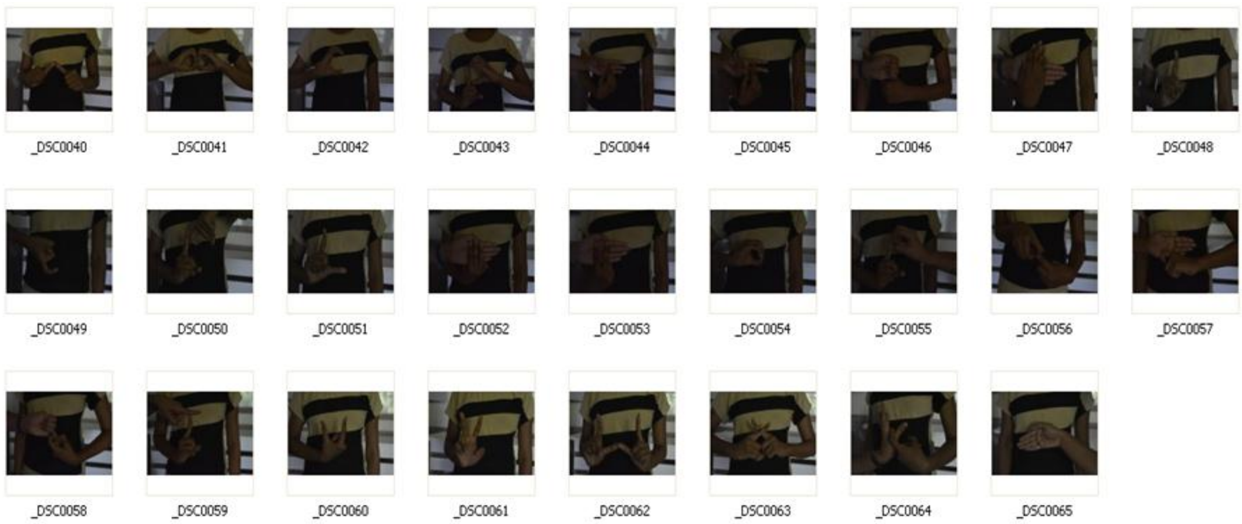

Figure 16. Images of alphabet A to Z

Figure 17. Images of number 0-9

SINGULAR NORMALIZATION IN SIGN LANGUAGE

In the representation of sign language, the sign language accuracy is a primal need. In the capturing of image data, the retaining of illumination homogeneity is a difficult task. The surrounding effect and the image accuracy are very difficult to maintain in such case. Images are captured randomly and passed to the system. It is hence, needed to develop a recognition model based on the normalization and recognition process with invariant feature and normalized feature vectors. In this paper, a new strategy of feature representation based on singular normalization and spectral feature representation is presented. The process of normalization is as outlined below. The process of normalization is preformed over a singular decomposed data using SVD [17] operation. The singular value decomposition is an outcome of linear algebra. It plays an interesting, fundamental part in more than one distinct application. One of the applications is in digital image processing. SVD in digital programs furnished a robust approach of reserving massive photos as smaller, greater affordable statistics. This is carried out via reproducing the actual image with all successful nonzero best one value. Moreover, to reduce the size of an image, it may approximate with the use of fewer singular values. The singular value decomposition of a matrix ‘A’, of m x n matrix, is given as

$$A = USV^T \quad (1)$$

Where $'U'$is an $m \times m$orthogonal matrix; ‘V’ an $n \times n$ orthogonal matrix, and *‘S’* is an m x n matrix containing the singular values of *‘A’*. The superscript ‘T’ indicates matrix transposition.

The singular values (S_i) are organized inside a random series of values0>S_i+1. The obtained individual value of an image ‘A’ does not keep consistency, which impacts at the time of extraction from the provided image; this is known as a diagonal line issue. To resolve the variant condition, a singular normalization approach is proposed, termed as the N-Singular feature. In the obtained values of SVD, the matrix ‘S’ represent the diagonal elements representing the variation in a given coefficient. The variations for this coefficient are noticed to components a non-linear distribution. This non-linearity is minimized via amplifying the ‘S’ matrix by the amplified parameter ‘γ’. To gain the amplification to the Singular matrix, the amplification B is denoted by; $B = US^{\gamma}V^T$ (2) This amplified parameter ‘γ’ is varied in the range $0 \leq \gamma \leq 1$. This range of value linearizes the *‘S’* matrix to one common level. These normalized coefficients are then used for feature extraction, wherein the magnitudes of the S matrix coefficients are minimal. To optimize the normalizing amplification parameter ‘γ’, a mean square variance parameter is optimized. The mean square variance is defined as the ratio of aggregated deviation in the variance level for each image under different illumination effect.

$$MSV = \frac{1}{c}\sum_{i=1}^{n}(S_i)^2 \quad (3)$$

Here, c is the diagonal variance in the matrix S and S_i is the singular element. The optimality of γ_{opt} is derived on the satisfaction of selection criterion,

$$\gamma_{opt} = arg\big(min(MSV)\big) \quad (4)$$

The normalized parameters are then passed for feature representation where a spectral domain feature selection based on spectral density is performed.

REGION MARKING AND FEATURE REPRESENTATION

In this strategy, Wavelet coefficients were processed. Over the normalized coefficients rather than to linearly applying feature extraction, coefficients with lower energy density are selected. The assumption is made based on the observation that hand region spectral density is developed due to skin color which is represented as the lower spectral color region in the spectral plot. In this strategy, a power spectral density (PSD) is calculated for low variation areas.

For the selection of the selective coefficient of the selected spectrum, a coefficient selection algorithm is proposed. The developed approach is termed as “Energy interpolated Invariant coding” (EIC). The process of EI coding is as outlined; For the Normalized image obtained from the above-stated approach, a decision of coefficient selection is made based on spectral magnitude. This strategy of coefficient selection, outcomes in the selection of coefficients, at lower frequency level considering only the regions illustrating in skin color region. To compute the spectral magnitude of the band coefficient a power spectral density (PSD) is computed. PSD is defined as a density operator which denotes the variation of power over distinct content frequencies, in a given image *x (t)*.

The Power spectral density (PSD) for the given matrix *‘x’* varying with *‘t’* is denoted as,

$$PSD, P = \lim_{T\to\infty}\frac{1}{2T}\int_{-T}^{T}x(t)^2\, dt \quad (5)$$

Taking the selected coefficients C_{Ni}as reference, a PSD for each coefficientPC_i is computed. The PSD coefficients for the normalized matrix of dimension m x n is defined by,

$$PC_{i,j} = PSD\big(C_{Ni,j}\big) for i = 1\ to m and j = 1\ to n \quad (6)$$

The PSD per coefficient is defined as,

$$PC_{i,j} = \lim_{T\to\infty}\frac{1}{2T}\int_{-T}^{T}C_{Ni,j}(t)^2\, d \quad (7)$$

Here, *i, j* are the corresponding row and column, which are read over a time period of ‘t’,*‘t’* is the time taken to read the whole set of C_{Ni}matrix. The selected spectral coefficients are taken as feature value for sign symbol representation.

SIMULATION RESULTS

To analyze the functional performance of the represented model, normalization and spectral representation of segmentation method are developed. The classification operation is carried out over a set of training and testing sample. The observations carried under different cases are illustrated below. The variation in the optimal selection of γ_optis carried out using the different value of γ. The effectiveness of the proposed approach is evaluated using the various performance metrics. The observation for this developed strategy is calculated in concepts of specificity, correctness, sensitivity, and precision. The correctness of the proposed strategy was denoted via the standard confusion matrix. The evaluating parameters are listed as TN (True Negative), TP (True Positive), FN (False negative) and FP (False Positive). The reactivity of the model is calculated as the TP (true positive) ratio to the addition of TP (True positive) and FN (False Negative). Specificity is measured as the TN (True Negative) ratio to the addition of TN and FP. Precision is denoted as the ratio of TP to the addition of TP and FP while Recall is the ratio of the TP to the addition of TP and FN. The performance metrics are calculated according to given formulae.

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (8)$$

$$Sensitivity = \frac{TP}{TP+FN} \quad (9)$$

$$Specificity = \frac{TN}{TN+FP} \quad (10)$$

$$Recall = \frac{TP}{TP+FN} \quad (11)$$

$$Precision = \frac{TP}{TP+FP} \quad (12)$$

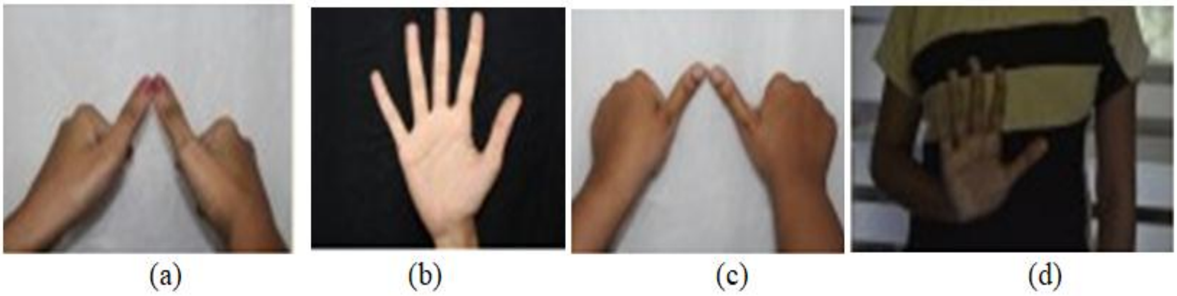

Figure 18. (a) S1, (b) S2, (c) S3, (d) S4

Table 1: Comparison of accuracy for the proposed approaches

Test Sample	Edge	Contour	N-Singular	NS-EIC
S1	68.24	71.52	77.17	82.16
S2	67.25	70.42	78.52	84.68
S3	69.45	73.21	79.54	82.24
S4	71.25	73.54	79.12	80.64%

Table 2: Performace of proposed approaches according to metrics

Test Sample	Method	Accuracy	Sensitivity	Specificity	Recall	Precision	Time
S1	SVD [17]	41.353608	0.72	0.285319	0.72	0.523784	0.347383
	N-Singular	50.225258	0.58	0.242766	0.58	0.421769	0.138035
	NS-EIC	70.081237	0.92	0.458809	0.91	0.645803	0.125998
S2	Curvature	51.524536	0.60	0.405255	0.60	0.512772	0.259342
	N-Singular	61.134021	0.88	0.542915	0.87	0.654667	0.147938
	NS-EIC	72.155464	0.72	0.287872	0.72	0.523706	0.162521
S3	Curvature	50.763608	0.72	0.247319	0.73	0.525687	0.358719
	N-Singular	65.254021	0.90	0.541915	0.85	0.663667	0.147317
	NS-EIC	74.041237	0.92	0.475809	0.88	0.678803	0.142396
S4	Curvature	52.743608	0.72	0.241319	0.72	0.545723	0.366849
	N-Singular	67.564021	0.90	0.585915	0.87	0.642667	0.178043
	NS-EIC	75.481237	0.92	0.456809	0.91	0.645803	0.152812

CONCLUSION

This paper outlines a new method of invariant representation and extraction of feature based on singular normalization and spectral feature representation. The developed approach illustrates the robustness of region extraction and illumination variant under the different possible cases, where images are normalized using singular distribution in the singular matrix of SVD operation. The proposed amplification operator minimizes the operational enhancement of the recognition performance, wherein the spectral feature map is observed to be highly effective in the extraction of hand region and mapping under classification operation. The retrieval performance illustrates a higher degree of classification accuracy as compared to the conventional retrieval methods.

REFERENCES

Journal article:

[1]Agrawal, s. C., jalal, a. S., &bhatnagar, c. (2012, december). Recognition of indian sign language using feature fusion. In intelligent human computer interaction (ihci), 2012 4th international conference on (pp. 1-5). Ieee**.**

[2]Ahuja, m. K., &singh, a. (2015). Hand gesture recognition using pca. International journal of computer science & engineering technology (ijcset), issn (print), 2231-0711.

[3]Baranwal, n., singh, n., &nandi, g. C. (2014, july). Indian sign language gesture recognition using discrete wavelet packet transform. In signal propagation and computer technology (icspct), 2014 international conference on (pp. 573-577). Ieee.

[4]Bhople, s., itkarkar, r. R., &bhoir, p., (2015). Indian sign language recognition", international journal of electrical electronics & computer science engineering, 2(3)

[5]Chourasia, n. S., & barman, s., (2014) hand gesture spotting using sign language through computer interfacing. International journal of engineering science and innovative technology (ijesit), 3(3)

[6]Deora, d., &bajaj, n. (2012, december). Indian sign language recognition. In emerging technology trends in electronics, communication and networking (et2ecn), 2012 1st international conference on (pp. 1-5). Ieee.

[7]Darwish, s. M., madbouly, m. M., &khorsheed, m. B. (2016). Hand gesture recognition for sign language: a new higher order fuzzy hmm approach. International journal of engineering and technology, 8(3), 157.

[8]Geetha, m., aswathi, p. V., &kaimal, m. R. (2013, december). A stroke based representation of indian sign language signs incorporating global and local motion information. In advanced computing, networking and security (adcons), 2013 2nd international conference on (pp. 62-67). Ieee.

[9]Karthick, p., prathiba, n., rekha, v. B., &thanalaxmi, s. (2014). Transforming indian sign language into text using leap motion. Int. J. Innovative res. Sci. Eng. Technol.(an iso 3297: 2007 certified organization), 3(4), 10906-10910.

[10]Krishnaveni, m., &radha, v. (2012). Classifier fusion based on bayes aggregation method for indian sign language datasets. Procedia engineering, 30, 1110-1118.

[11]Lekhashri, b., &pratap, a. A. (2011, february). Use of motion-print in sign language recognition. In innovations in emerging technology (ncoiet), 2011 national conference on (pp. 99-102). Ieee.

[12]Rekha, j., bhattacharya, j., &majumder, s. (2011, december). Shape, texture and local movement hand gesture features for indian sign language recognition. In trendz in information sciences and computing (tisc), 2011 3rd international conference on (pp. 30-35). Ieee.

[13]Shangeetha, r. K., valliammai, v., &padmavathi, s. (2012, december). Computer vision based approach for indian sign language character recognition. In machine vision and image processing (mvip), 2012 international conference on (pp. 181-184). Ieee.

[14]Sharma, k., joshi, g., &dutta, m. (2015, february). Analysis of shape and orientation recognition capability of complex zernike moments for signed gestures. In signal processing and integrated networks (spin), 2015 2nd international conference on (pp. 730-735). Ieee.

[15]Sawant, s. N., &kumbhar, m. S. (2014, may). Real time sign language recognition using pca. In advanced communication control and computing technologies (icaccct), 2014 international conference on (pp. 1412-1415). Ieee.

[16]Tavari, n. V., &deorankar, a. V. (2014). Indian sign language recognition based on histograms of oriented gradient. International journal of computer science and information technologies, 5(3), 3657-3660.

[17]Tripathi, k., &nandi, n. B. G. (2015). Continuous indian sign language gesture recognition and sentence formation. Procedia computer science, 54, 523-531.

[18]Yang, h. D., & lee, s. W. (2013). Robust sign language recognition by combining manual and non-manual features based on conditional random field and support vector machine. Pattern recognition letters, 34(16), 2051-2056.

[19]Zaki, m. M., &shaheen, s. I. (2011). Sign language recognition using a combination of new vision based features. Pattern recognition letters, 32(4), 572-577.