International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-6, March 2020

Analysis and Recognition of Bilingual Handwritten Scripts

Panyam Narahari Sastry, G. Akhil, Vaishnavi Suthram

Abstract: ***In this work, offline handwritten character recognition (HWCR) is involved, which is an open area of research for Indian languages. The recognition accuracy for HWCR is around 60% as per the literature survey. The main obstacle for the research in this area is the non-availability of a standard database. Character Recognition (CR) is an application of pattern recognition. Pattern recognition has many applications like security services, defense organizations, banking, post offices, archeological field, weather forecasting, library automation, reading aids for the visually challenged, etc. There are very less number of users for Indian languages when compared to English and hence the research for HWCR is at early stage. In this work, transform based recognition techniques are used on two languages namely Hindi and English. The best recognition accuracy obtained for the bilingual handwritten scripts is 73.33% which is in line with the existing research publications.***

Keywords: 2D-FFT, 2D Correlation, Bilingual Characters, Nearest Neighborhood Classifier, Optical Character Recognition (OCR).

I. INTRODUCTION

Character recognition and pattern recognition are two important fields where extensive research is taking place almost every day. It can be broadly classified into online and offline character recognition. Online character recognition is one where the system identifies the character when entered from an input device like keyboard. Several algorithms are already in place for online character recognition. Offline character recognition is one where the system must identify the characters which are already written on the medium. This is relatively a challenging task because handwriting varies from person to person, which creates confusion while teaching the machine about a certain handwritten character.

Manuscript received on February 10, 2020.
Revised Manuscript received on February 20, 2020.
Manuscript published on March 30, 2020.
* Correspondence Author
Dr. Panyam Narahari Sastry*, Professor, Department of ECE, Chaitanya Bharathi Institute of Technology (A) ,Hyderabad, India.
E-mail: naraharisastry_ece@cbit.ac.in
G. Akhil, UG, Department of ECE, Chaitanya Bharathi Institute of Technology (A) ,Hyderabad, India. E-mail: g.akhil518@gmail.com
Vaishnavi Suthram, UG, Department of ECE, Chaitanya Bharathi Institute of Technology (A), Hyderabad, India.
E-mail: vaishusri98@gmail.com

This is also a very challenging task where one is teaching a machine to understand a letter which essentially can be written in several ways by each individual. In this work [1], more stress is given on various methods of offline handwritten CR. In this work considerations regarding slant, size and skew normalizations are taken which makes it more efficient. Erratic errors due to hand movements are eliminated here as well. Also, representing and recognizing data is done in many methods.

In the work [2] as well major concentration again has been given to offline handwritten CR where the recognition extends to words as well as sentences. This work also stresses on signature verifications and writer identification which forms the core of many applications in character recognition. Character recognition is important because it helps us interpret any written material like ancient scripts, palm leaves or simple hand-written notes on the paper.

The options in this area of research are so extensive and individualistic that a same algorithm may not prove to be that accurate when applied to other languages. This is because there are several ways in which a character can be written. Also, a character can either be simple or complex. A complex character is one where a consonant gets mixed with a vowel and it assumes a new pattern which can be very different in pattern from the individual vowel or consonant. These complex characters can be challenging for a machine to understand. In recent times, a lot of research has taken place in English, Chinese, Arabic and Devanagari scripts and more research is taking place in identifying them with improved accuracies. Various Indian languages and scripts like Devanagari, Gurmukhi, Tamil, etc have been worked on using OCR methods which can be seen in this work [3].

A diverse dataset is used in the work [4]. Multistage recognition using appropriate MLP architecture is used here to provide better accuracy. In the proposed work, the languages to work upon has been chosen to be on Hindi, English small and English capital letters. This database has been opted because the machine must be able to recognize pattern among a pool of different languages and at the same time small and capital letters of English has been incorporated in our database because the machine should be able to tell the difference between them even though they belong to the same language. No standard database for HWCR of Indian scripts/English are available and so a database has been generated in the laboratory environment [4, 5, and 6].

Currently, character and pattern recognition finds its application in decoding some preserved age-old manuscripts, recognizing signatures, in banks, etc.

Identification between small and capital letters can be essential for further studies where one can identify the beginning of a new sentence or to identify proper nouns. Identification among Hindi and English can be further extended to more languages in order to decode multi-lingual notes or scripts. This kind of work on CR on South Indian languages can be seen in work [4]. PCA (Principal Character Analysis) method combined with Fourier Transform is used here to identify characters from a pool of multilingual characters.

In this work [1], more stress is given on various methods of offline handwritten CR. In this paper, considerations regarding slant, size and skew normalizations are taken which makes it more efficient. Erratic errors due to hand movements are eliminated here as well. Also representing and recognizing data is done in many methods.

In paper [2] as well, it is observed that major concentration again has been given to offline handwritten CR where the recognition extends to words as well as sentences. This paper also stresses on signature verifications and writer identification.

A diverse dataset is used in paper [3]. Multistage recognition using appropriate MLP architecture is used here to provide better accuracy.

Work on CR on South Indian languages can be seen in paper [4]. PCA (Principal Character Analysis) method combined with Fourier Transform is used here to identify characters from a pool of multilingual characters. Paper [5] cites work on OCR methods on various Indian languages and scripts.

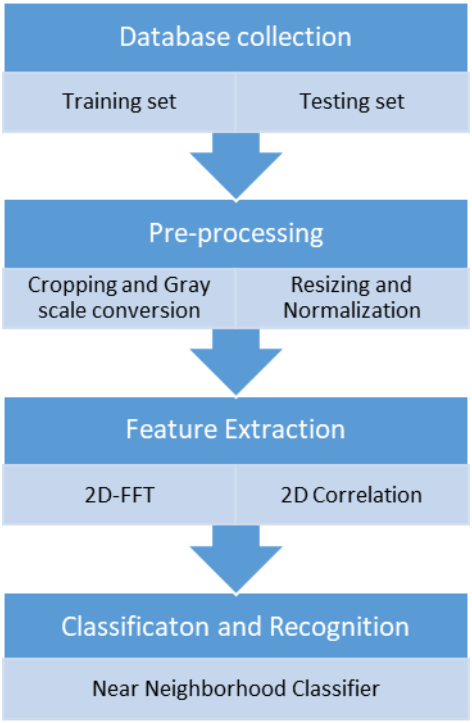

Fig.1. Proposed System of Recognition

II. RELATED WORK

Many researchers are working in the area of handwritten patterns and character recognition for different languages.

Panyam Narahari Sastry, T.R.Vijaya Lakshmi and others [6] have presented work on zoning features recognition of Telugu handwritten characters and achieved an accuracy of 78%.

K.Chowhury, L.Alam, and others [7] have used different geometric values as fuzzy features for recognition of Bangla characters and obtained nearly 77% accuracy.

Sanugula Durga Prasad and Yashwanth Kanduri [8] have presented a paper on Telugu handwritten character recognition using adaptive and static zoning methods in which they used k-NN classifier and obtained nearly 80% recognition accuracy.

Pritam Dhande and Reena Kharat [9] have presented work on recognition of cursive English handwritten characters using the SVM classifier and deals with various techniques used in optical character recognition for cursive handwriting recognition.

I.Rushiraj, S.Kundu, and B.Ray [10] have worked using weighted Euclidean distance for classification using 48 geometric features for handwritten character recognition of Odia scripts and achieved 87.6% accuracy.

Chhaya Patel and Apurva Desai [11] have presented work on segmentation of text line into word for Gujarati handwritten text in which they proposed morphological operation and projection profile based algorithm and achieved an accuracy of 89.24%.

Saleem Pasha and M.C.Padma [12] have proposed a work on ANN using structural, and wavelets transform features for Kannada handwritten character recognition and achieved 91% accuracy.

H.Nakkach, S.Hichri, and others [13] have presented work on hybrid approach to features extraction for online Arabic character recognition using different local and global features in SVM and achieved 92.43% accuracy.

H.Choudhury, S.Mandal, and others [14] have worked on online Assamese handwritten character recognition by combining HMM and SVM based stroke classifiers and obtained an accuracy of 96.17%.

Shuye Zhang, Lianwen Jin and Liang Lin [15] have used deep convolution neural networks (CNN) to identify similar Chinese characters and achieved 98.44% accuracy.

III. OBJECTIVES

1) To develop the database for handwritten English small letters and capital letters along with Hindi handwritten characters.
2) To identify and select the main features from these database images to be used for recognition/classification.
3) To develop and implement algorithms for finding out recognition accuracy for the databases.

IV. METHODOLOGY

The proposed architecture for handwritten character recognition for bilingual scripts is shown in figure 2. It contains various steps:

A. Data Collection

In the proposed approach of recognition ten basic isolated handwritten characters of English small, English capital and Hindi scripts were considered for the research work.

The characters were acquired from 50 different scribers of different profiles. Thereby, a total of 1500 (3x10x50) samples forms the database with three different scripts, with 10 classes each and each class having 50 samples. These documents were scanned at 1200 dpi and database was created. The data set contains different styles, varied size of the characters. This data set was developed for HWCR in the laboratory due to nonexistence of a standard database for Indian scripts [4, 5 and 6].

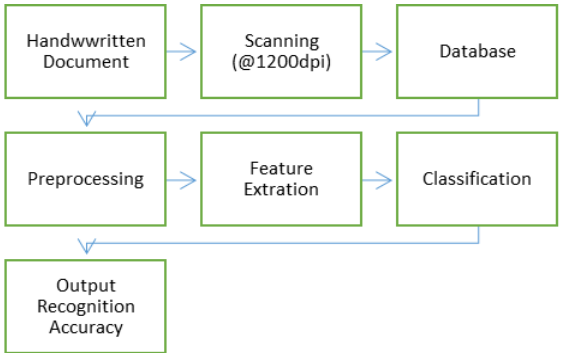

Fig.2. Block Diagram of Proposed System

B. Pre-Processing

Preprocessing is the first step of character recognition system. The raw data is captured to be preprocessed before applying it to recognition system. Character segmentation is is done fron the scanned documents by taking the vertical profile of the images. This step helps in enhancing the character recognition by eliminating noise. The segmented characters are converted to gray scale, normalized, resized (50x50 pixcels) and binarized using minimum boundary rectangular concept (applying a threshold of 0.7). The data before preprocessing and data after preprocessing are shown in figures 3 and 4 respectively.

C. Feature Extraction

A feature is the most important component in the character recognition problem. Feature extraction is a process of reduction by which an initial set of raw data is reduced to more manageable features for processing. The proposed system uses 2D-FFT and 2D correlation techniques to obtain features.

Fig.3. Original Image

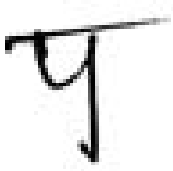

Fig.4. After Preprocessing

2D-FFT is applied to all the images including training and testing before extracting the features.

2D- Correlation: It represents the differences between two or more images at a given instant of time.

D. Classification and Recognition

Classification is the most important phase in recognition system. In classification, an unknown sample is assigned to the pre-defined class. Classifiers are used to map the feature vectors yield from the input character into one of the possible character classes that exits already. The recognition process includes training and testing phases. The proposed system uses Nearest Neighborhood Classifier (NNC) namely Euclidean distance. According to the extracted features, characters are classified and recognized. The final output from the recognition system are shown in figures 5 and 6.

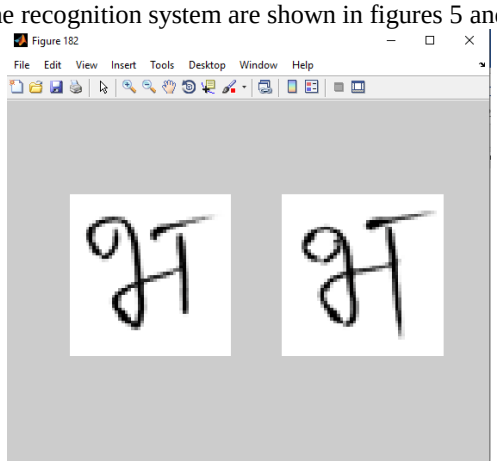

Fig.5. Correct Match

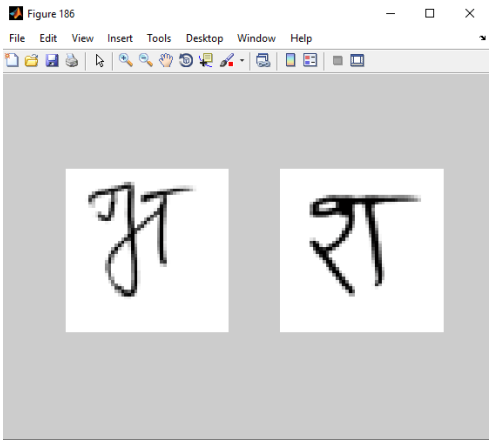

Fig.6. Incorrect Match

The left hand side images in figure 5 and figure 6 are of testing samples, whereas the right hand side images (training set) are the images to which these testing images are matched.

V. RESULTS AND DISCUSSIONS

The proposed system has dataset of around 1500 samples collected from different writers and different profiles which includes English small characters, English capital characters and Hindi characters (500 samples each). The dataset collected from different source having a varying size and thickness of symbols. All the training set and testing set are obtained by scanning the handwritten documents.

After generating a database of 500 samples of each English small letters, English capital letters and Hindi characters, these samples are normalized to the standard size of 50x50 pixels. This database is then divided into training and testing sets. Each image which is of 50x50 pixels is converted into a binary image by applying a threshold of 0.7. All the images are then applied with 2D FFT. After applying the 2D-FFT each image which is of size 50x50 (2500 pixels) will be transformed to a new matrix in which each pixel will have real and imaginary values.

The imaginary values are eliminated and not considered since only phase information is available in the imaginary part therefore is not at all useful in HWCR.

Considering only the real part in a matrix of size 50x50 for each image, the first row is converted into a column matrix and then the second row is concatenated to this, followed by third, fourth and so on. Hence the matrix size of each image which is 50x50 becomes 2500x1. This means 2500 rows and 1 column for each image. Since there are 50 images the final matrix becomes 2500x50 (for 50 images).

A. 2D FFT:

Considering 30 samples in the training set and 20 samples in the testing set and applying the algorithm to it, the matrix for training set becomes 2500x30. Similarly, for testing images matrix becomes 2500x20. Then each column of the testing matrix is compared with each column of the training matrix and corresponding Euclidean distance is calculated. Since there are 30 samples in the training set 30 different Euclidian distances are obtained. Out of these 30 Euclidean distances the minimum value is found. The algorithm also identifies the image of the training sample which has the minimum Euclidean distance.

The algorithm displays the testing image on the left hand side of the figure plot whereas this identified training image on the right hand side of the figure. In this way the first testing image is recognized. The process is applied to remaining 19 samples of the testing set. The recognition accuracy is calculated as a ratio of number of correctly matched testing samples to the total number of testing samples.

B. 2D Correlation:

Considering 30 samples in the training set and 20 samples in the testing set and applying the algorithm to it, the matrix for training set becomes 2500x30. Similarly, for testing images matrix becomes 2500x20. Then each pixel of testing image is compared with each pixel of the training sample and correlation values is obtained. For each testing image 30 correlation values are obtained since there are 30 training samples. Out of these 30 correlated values the maximum value is found. The algorithm also identifies the image of the training sample which has the maximum correlated value.

The algorithm displays the testing image on the left hand side of the figure plot whereas this identified training image on the right hand side of the figure. In this way the first testing image is recognized. The recognition accuracy is calculated as a ratio of number of correctly matched testing samples to the total number of testing samples.

Analysis of Handwritten character recognition for English small letters for different training set and testing set samples under feature extraction 2D-FFT and 2D correlation has been shown in table I. The number of training samples have been varied from 20 to 40 in the steps of 5. The maximum Recognition Accuracy for English small characters were found to be 77% and 78% by using 2D FFT and 2D Correlation respectively. Hence it is concluded that the recognition accuracy using both the methods are in line for English small letters.

TABLE I. ENGLISH SMALL LETTERS

Number of Training Samples per class	Number of Testing Samples per class	Recognition Accuracy (2D FFT)	Recognition Accuracy (2D Correlation)
20	30	58.00%	64.33%
25	25	64.00%	69.80%
30	20	64.50%	70.00%
35	15	66.67%	72.33%
40	10	77.00%	78.00%

The Analysis of Handwritten character recognition for English capital letters with varying number of training set samples ranging from 20 to 40 in steps of 5 are shown in table II. A maximum Recognition Accuracy of 81% has been observed using the 2D FFT technique and about a maximum of 80.66% by using 2D Correlation technique. The Recognition accuracy is almost same for the both techniques for English capital letters.

TABLE II. ENGLISH CAPITAL LETTERS

Number of Training Samples per class	Number of Testing Samples per class	Recognition Accuracy (2D FFT)	Recognition Accuracy (2D Correlation)
20	30	73.33%	63.33%
25	25	74.80%	68.80%
30	20	76.50%	69.50%
35	15	78.00%	71.00%
40	10	81.00%	80.66%

The Analysis of Handwritten character recognition for Hindi characters is shown in table III. A peak value of 73.33% using 2D FFT and 84% using 2D Correlation has been observed. It is also observed that recognition accuracy increases with the increase in the number of training samples in the training set. The 2D correlation technique gave better results when compared to 2D FFT technique for Hindi characters.

TABLE III. HINDI CHARACTERS

Number of Training Samples per class	Number of Testing Samples per class	Recognition Accuracy (2D FFT)	Recognition Accuracy (2D Correlation)
20	30	70.00%	71.33%
25	25	71.33%	73.60%
30	20	71.60%	75.50%
35	15	72.00%	79.33%
40	10	73.33%	84.00%

Analysis of Handwritten character recognition for Bilingual characters (combination of English small characters, English capital characters and Hindi characters) with varying number of training set and testing set samples are shown in table IV,.

Training samples have been varied from 20 to 40 gradually in steps of 5 and accuracies for each set has been found. A maximum Recognition accuracy of 69.67% for 2D FFT and 73.11% for 2D Correlation has been found out. As the number of training samples increased recognition accuracy increased.

TABLE IV. BILINGUAL CHARACTERS

Number of Training Samples per class	Number of Testing Samples per class	Recognition Accuracy (2D FFT)	Recognition Accuracy (2D Correlation)
20	30	63.33%	58.12%
25	25	64.67%	63.33%
30	20	66.16%	64.16%
35	15	66.89%	71.11%
40	10	69.67%	73.33%

The Recognition Accuracies of the proposed system increases with the increase in the number of training samples per class. This can be observed from the following graphs.

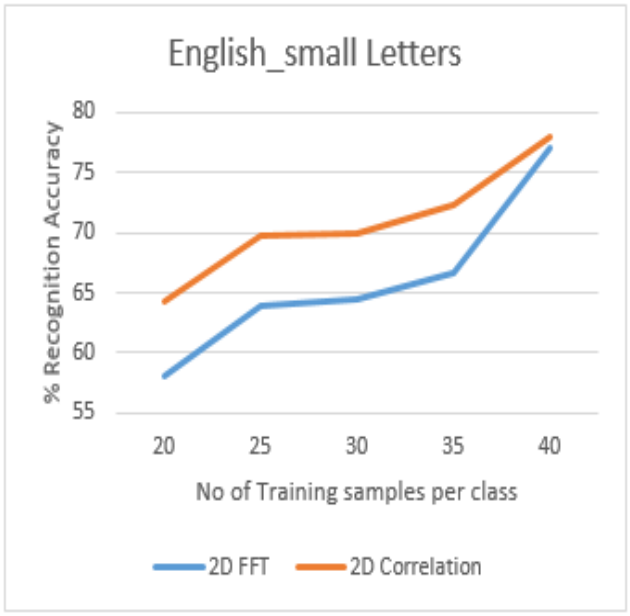

Fig.7. Graphical Representation for Analysis of HWCR for English small characters

In figure 7, a plot between number of training samples and the Recognition Accuracy has been made for English small letters. It can be observed that the training samples and Recognition Accuracy are directly proportional but the increase is not linear.

The figure 8 is a plot for English capital letters between training samples and Recognition Accuracy. It is observed that the increase in slope is almost linear for 2D FFT whereas te increase in slope is not that gradual for the 2D Correlation technique.

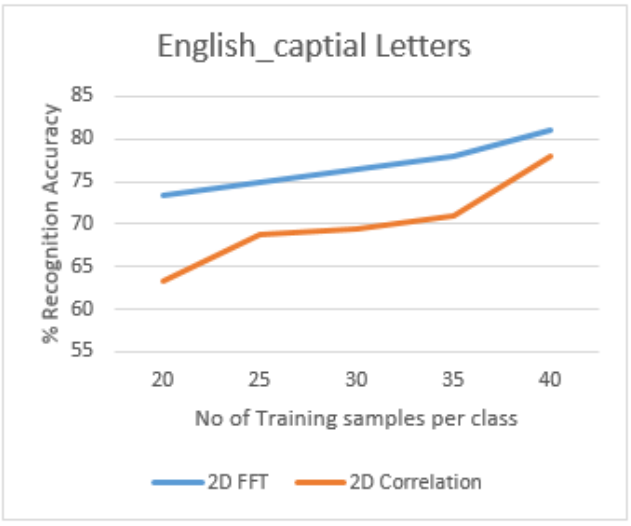

Fig.8. Graphical Representation for Analysis of HWCR for English capital characters

The figure 9 is a plot for Hindi characters between training samples and Recognition Accuracy. As the number of training samples increases, the Recognition accuracy also improves. This trend can be observed in both 2D FFT and 2D Correlation technique.

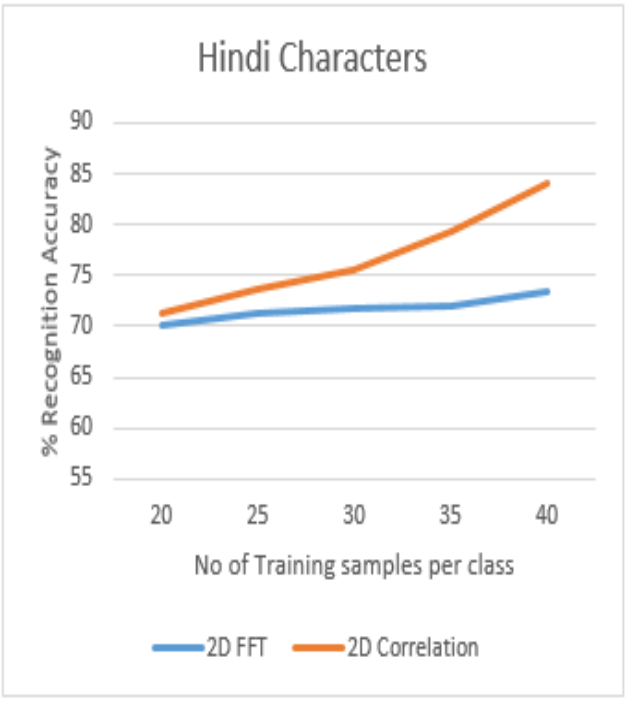

Fig.9. Graphical Representation for Analysis of HWCR for Hindi characters

A graphical representation of the Recognition Accuracy for the bilingual characters is shown in figure 10. As the number of training samples increase, we can observe an increase in the Recognition Accuracy as well. This has been done for two techniques namely 2D FFT and 2D Correlation.

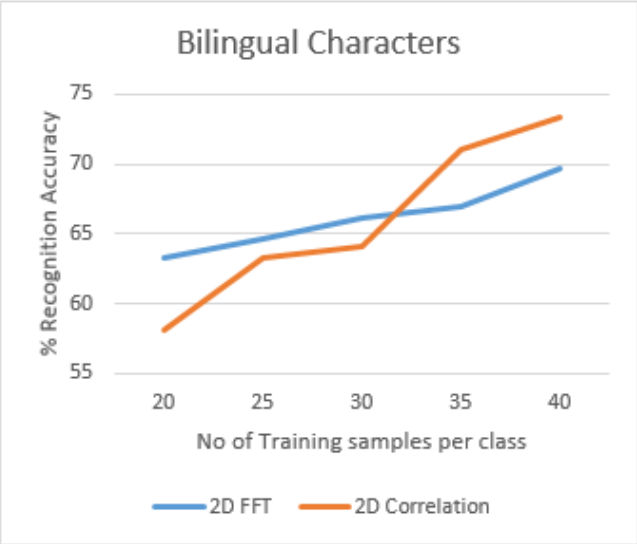

Fig.10. Graphical Representation for Analysis of HWCR for Bilingual characters.

From Table V, it is observed that the recognition accuracy is more for the proposed method. Also, the proposed method has used a bilingual dataset. The recognition accuracy for the published method was observed to be 63% and on the other hand, a recognition accuracy of about 66.144% has been observed for the proposed method.

TABLE V. COMPARISON BETWEEN PUBLISHED AND PROPOSED METHOD-1

	Published methiod [16]	**Proposed method**	
Worked On	Telugu	English, hind and bilingual characters	
Number of training samples	18,750	1200	
Number of testing samples	500	300	
Feature Extraction	2D FFT	2D FFT	
Classifier	NNC	NNC	
Recognition Accuracy	63%	Eng_small	66.034 %
		Eng_captial	76.720 %
		Hindi	71.64%
		Bilingual	66.144 %

From Table VI, it is observed that the database used by the proposed method is more and comparatively greater number of training samples as well. The recognition accuracy for the published method was observed to be 66.08% and on the other hand, a recognition accuracy about 72.54% has been observed for the proposed method.

TABLE VI. COMPARISON BETWEEN PUBLISHED AND PROPOSED METHOD-2

	Published methiod [17]	Proposed method	
Worked On	Kannada	English, hind and bilingual characters	
Number of training samples	1150	1200	
Number of testing samples	230	300	
Feature Extraction	Normalized Coordinates, Normalized Trajectory, and Normalized Deviation	2D Correlation	
Classifier	k-NN	NNC	
Recognition Accuracy	66.08% and 73.47% for k=1 and k=3 respectively	Eng_small	70.892 %
		Eng_captial	71.00%
		Hindi	77.292 %
		Bilingual	72.54%

The comparison of recognition accuracies between 2D FFT and 2D Correlation. 2D FFT is a much faster method than 2D Correlation but 2D Correlation method has a better accuracy of recognition than the 2D FFT method as shown in figure 11.

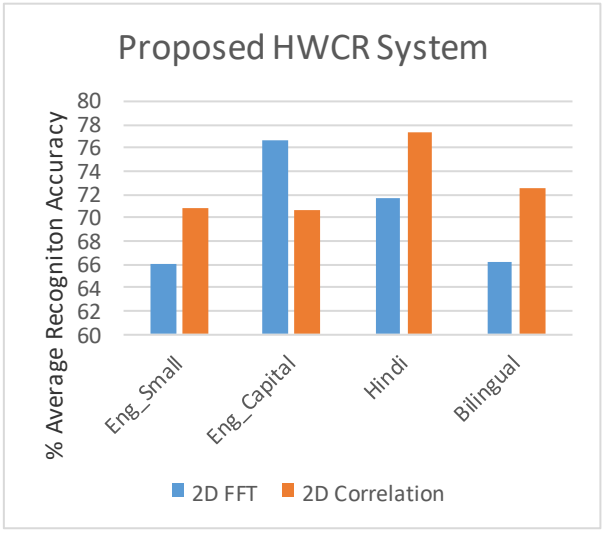

Fig.11. Average Recognition Accuracy for the Proposed System

Retrieval Number: F8538038620/2020©BEIESP
DOI:10.35940/ijrte.F8538.038620
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

VI. CONCLUSIONS AND FUTURE SCOPE

1. The database for handwritten English small letters, English capital letters and Hindi characters were successfully developed. Since as per the literature survey, there is no standard database for handwritten scripts. This database is used for both training and testing purposes.
2. The average recognition accuracy for handwritten English small letters is found to be 70.892% using 2D correlation and 66.034% using 2D-FFT. The recognition accuracy increased linearly when the number of training samples were increased from 20 samples/class to 40 samples/class. The minimum recognition accuracy obtained was 64.33% for 2D correlation and 58% for 2D-FFT, whereas the maximum recognition accuracy was recorded as 78% for 2D correlation and 77% for 2D-FFT.
3. The average recognition accuracy for handwritten English capital letters is found to be 70.572% using 2D correlation and 76.720% using 2D-FFT. The range of recognition accuracy in this case is between 63% - 80% for 2D correlation and 73.3% - 81% for 2D-FFT.
4. The average recognition accuracy for handwritten Hindi characters is found to be 77.292% using 2D correlation and 71.64% using 2D-FFT. The range of recognition accuracy while varying the number of training samples/class is from 71% – 84% for 2D correlation and 70% - 73.33% for 2D-FFT. As the number of training samples/class increased, the accuracy also increased.
5. The average recognition accuracy for handwritten bilingual (English and Hindi) database is found to be 72.549% using 2D correlation and 66.144% using 2D-FFT. The range of recognition accuracy is obtained as 58% to 73.33% for 2D correlation and 63.33% to 70% for 2D-FFT. The recognition accuracy increased when the number of samples/class increased.
6. The comparison of recognition accuracies between 2D FFT and 2D Correlation. 2D FFT is a much faster method than 2D Correlation but 2D Correlation method has a better accuracy of recognition than the 2D FFT method as shown in figure 11.
7. More classification methods can be applied to the dataset available with us. The applications of offline handwritten character recognition can be extended to words and patterns.

REFERENCES

1. Nafiz Arica, Fatos T. yarman-Vural, “An overview of character recognition focused on off-line handwriting”, *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, vol.31, issue 31, pp.216-232, May 2001.
2. R.Plamondon, S.N.Srihari, “On-line and off-line handwriting recognition: a comprehensive survey”, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol.22, issue 1, pp.63-84,2000.
3. U.Pal, B.B.Chaudhuri, "Indian script character recognition: a survey", *Pattern Recognition*, vol.37, issue 9, pp.1887-1899, September 2004.
4. Ujjwal Bhattacharya, B.B. Chaudhuri, “Handwritten Numeral Databases of Indian Scripts and Multistage Recognition of Mixed Numerals”, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol.31, issue 3, pp.444-457, March 2009.
5. V.N.Manjunath Aradhya, G.Hemantha Kumar, S.Noushath “Multilingual OCR system for South Indian scripts and English documents: An approach based on Fourier transform and principal component analysis”, *Engineering Applications of Artificial Intelligence*, vol.21, issue 4, pp.658-668, June 2008.
6. Panyam Narahari Sastry, T.R.Vijaya Lakshmi, N.V.Koteswara Rao, T.V.Ranjinikanth, Abdul Wahab, “Telugu handwritten charcter recognition using zoning features”, *International Conference on IT Convergence and Security (ICITCS)*, pp.1-4, 2014.
7. K. Chowdhury, L.Alam, S.Sarmin, S.Arefin, M.Mo.Hoque, “A fuzzy features based online handwritten bangla word recognition framework”, *18th International Conference on Computer and Information Technology (ICCIT)*, pp. 484-489, 2015.
8. Sanugula Durga Prasad, Yashwanth Kanduri, “Telugu handwritten character recognition using adaptive and static zoning methods”, *IEEE Students Technology Symposium (TechSym)*, pp.299-304, 2016.
9. Pritam Dhande, Reena Kharat, “Recognition of cursive english handwritten characters”, *International Conference on Trends in Electronics and Informatics (ICEI)*, pp.199-203, 2017.
10. I.Rushiraj, S.Kundu, B.Ray, “Handwritten character recognition of odia scripts”, *International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES)*, pp.764-767, 2016.
11. Chhaya Patel,Apurva Desai, “Segmentation of text lines into words for gujarati handwritten text”, *International Conference on Signal and Image Processing*, pp.130-134, 2010.
12. Saleem Pasha,M.C.Padma, “Handwritten kannada character recognition using wavelet transform and structural features”, *International Conference on Emerging Research in Electronics, Computer Science and Technology (ICERECT)*, pp.346-351, 2015.
13. H.Nakkach, S.Hichri, S.Haboubi, H.Amiri, “Hybrid approach to features extraction for online arabic character recognition”, *13th International Conference on Computer Graphics, Imaging and Visualization (CGiV)*, pp.253-258, 2016.
14. H.Choudhury, S.Manda, S.Devnath, S.R.M.Prasanna, S.Sundaram, “Combining HMM and SVM based stroke classifiers for online assamese handwritten character recognition”, *Annual IEEE India Conference (INDICON)*, pp.1-6, 2015.
15. Shuye Zhang, Lianwen Jin and Liang Lin, “Discovering similar chinese character online handwritten with deep conventional neural networks”, *International Journal on Document Analysis and Recognition (IJDAR)*, vol. 19, issue 3, pp.237-252, September 2016.
16. T.R.Vijaya Lakshmi, P.Narahari Sastry, T.V.Ranjinikanth, “Palm leaf telugu character recognition using hough transform”, in processdings of the *2nd International conference on Advanced Computing Methodologies, ser. ICACM’13*, pp.372-376, 2013.
17. Chaithra D, Dr.K Indira, “Handwritten online character recognition for single stroke kannada characters”, *2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)*, pp.548-552, 2017.
18. T.R.Vijaya Lakshmi, P.Narahari Sastry, T.V.Ranjinikanth, “Hybrid approach for telugu handwritten character recognition using k-nn and SVM classifiers”, *International Review on Computers and Software (IRECOS)*, vol.10, no. 9, pp.923-929 September, 2015.
19. Panyam Narahari Sastry, T.R.Vijaya Lakshmi, N.V.Koteswara Rao, Rama Krishna, “Analysis of telugu palm leaf characters using multi level recognition approach”, *ARPN Journal of Engineering and Applied Sciences*, vol. 10, no.20, pp. 9258-9264, November, 2015.
20. T.R.Vijaya Lakshmi, P.Narahari Sastry, T.V.Ranjinikanth, “A novel 3d approach to recognize telugu palm leaf text”, Engineering Science and Technology, *An International Journal*, vol. 20, issue.1, pp.143-150, 2016.
21. Panyam Narahari Sastry, T.R.Vijaya Lakshmi, N.V.Koteswara Rao, Rama Krishna, “Modelling of palm leaf character recognition system using transform based techniquies”, *Pattern Recognition Letters*, vol. 84, pp.29-34, 2016.
22. Thulasi Kishna N.P, Seenia Francis, “Intelligent tool for malayalam cursive handwritten character recognition using artificial neural network and hidden markov model”, *International Conference on Inventive Computing and Informatics (ICICI)*, pp.595-598, 2017.
23. Vishal A.Naik, Apurva A.Desai, “Online handwritten gujarati character recognition using SVM, MLP, and K-NN”, *8th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*, pp.1-6, 2017.
24. Dhara S.Joshi, Yogesh R.Risodkar, “Deep learning based gujarati handwritten character recognition”, *International Conference On Advances in Communication and Computing Technology (ICACCT)*, pp.563-566, 2018.

25. N Prameela, P Anjusha, R Karthik, "Off-line telugu handwritten characters recognition using optical character recognition", *International conference of Electronics, Communication and Aerospace Technology (ICECA)*, pp.223-226, 2017.
26. Mahendra B.Mendapara, Mukesh M.Goswami, "Stroke identification in gujarati text using directional feature", *International Conference on Green Computing Communication and Electrical Engineering (ICGCCEE)*, 2014.

AUTHORS PROFILE

Dr. P. Narahari Sastry, is working in CBIT **since 2003**, and is involved in Teaching and Research. He has recognized as Supervisor for JNTU Hyderabad, Osmania University Hyderabad and K.L. University Vijayawada. He has guided three **(03) PhD students** and also guiding four (**8) Research scholars** from Osmania university Hyderabad presently. He has published **6 SCI Journals** in the last **5 years** and 2 of them are published in the reputed journals which are "**Electrical and Computer Engineering**" and **IEEE Communication letters**. Also he has applied and published his work in Indian Journal of patents, Chennai, India. He was the **PI** for an **AICTE project** titled "Design and Development of Palm Leaf Character Recognition System" granted under RPS scheme, which was successfully completed during the period **2013-16.**

G. Akhil, is presently pursuing Under Graduation (UG) final year in the Electronics and Communication Engineering (ECE) department at Chaitanya Bharathi Institute of Technology (CBIT-A), Hyderabad, India. He has a passion for image processing, machine learning and wants to be a research scholar. Worked on projects related to communication and IoT. He is also an Executive Board member of the Robotics and Innovation club and Makers of India club at CBIT, Hyderabad for the academic years 2018-2020. He secured a gold medal in the 13th National Cyber Olympiad conducted by Science Olympiad Foundation (SOF), New Delhi. He got placed at Micron Technologies as an Engineering and Technology Development (ETD) engineer at Hyderabad, India.

Vaishnavi Suthram, is currently pursuing B.E final year at Chaitanya Bharathi Institute of Technology (CBIT-A) in the Electronics and Communication Engineering (ECE) department. She has a keen interest in the field of pattern recognition. She has previously worked on projects related to communication, IoT and Databases. She interned with DRDL (Defense Research and Laboratory), Hyderabad in 2018 with the Missile Ranging and Navigation team and Robert Bosch Automotive Electronics India Pvt. Ltd. (RBAI), Bengaluru in 2019 with the Quality Analysis. She also holds the position of Editor-in-Chief for the college newsletter called 'Transcendent'. She is placed in Deloitte, India as a Business Technology Analyst.