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Comparison of Various Algorithms for Handwritten Character Recognition of Indian Languages

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Abstract: ***In this paper, we present a comparison of various pre-processor, feature extraction methods and algorithms for handwritten character recognition of various Indian languages. Comparison of classifier, feature set and accuracy of offline handwritten character recognition of Gujarati, Devanagari, Gurmukhi, Kannada, Malayalam, Bangla and Hindi Indian languages. Comparison of classifier, feature set and accuracy of online handwritten character recognition of Assamese, Tamil, Devanagari, Malayalam, Gurmukhi, and Bangla Indian languages. Indian language wise best performance of each language is compared for both offline and online handwritten character recognition systems.***
Keywords: HCR, OCR, SVM, ANN, CNN, HMM, Online Handwritten Character Recognition, Offline Handwritten Character Recognition

I. INTRODUCTION

Optical character recognition system can be used to identify the handwritten characters. Handwritten character recognition (HCR) can be classified into two types - offline and online.

Offline handwritten character recognition system recognizes character written on paper or other such material using a pen or any device. In offline handwritten character recognition system, a character written on paper is converted into an image using a scanner or other imaging devices. The scanned image is further processed using different algorithms to remove noise, size variation etc. Preprocessed image is used to extract meaningful information from the written character. Extracted features are provided to the classifier as an input.

Indian languages have large and complex character set compare to English and other Latin scripts. Indian scripts include constants, vowels and composite characters representing a combination of constants and vowels. There is a similarity between characters of different Indian languages, mainly based on a geographic location of languages used.

Many characters in different Indian languages requires multiple strokes to write. Such a complex character set makes traditional keyboard not practical for Indian languages. Most of the Indian languages have major differences among each other and due to that, there cannot be a single handwritten character recognition system for all the Indian languages. We need to develop separate systems for every Indian language.

II. LITERATURE REVIEW

The character recognition system has training data of all character classes of a particular language. Offline handwritten character recognition is more complex compared to printed character recognition due to variation in writing style. In this system, handwritten documents are scanned and converted into digital image.

The scanned image is further processed using pre-processing methods, segmentation methods, text extraction methods, feature extraction methods and classification methods.

The character recognition system can be categorized into Offline and Online. We have compiled and compared different work of researchers of major Indian languages.

The following tables 1 to 7 shows and compare classifier, feature set and accuracy of offline handwritten character recognition of Gujarati, Devanagari, Gurmukhi, Kannada, Malayalam, Bangla and Hindi Indian languages.

Table 1. Comparison of character recognition system for Gujarati

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Gujarati	SVM Polynomial Naïve based	Chain code Zoning Projection profile	99.80%	A. Sharma [1]
2	Gujarati	DTW	grey level co-occurrence	99.40%	S. B. Sunilkumar [2]
3	Gujarati	SVM Polynomial	Aspect ratio Extent Image sub division	86.66%	A. A. Desai [3]
4	Gujarati	k-NN	Primary and Secondary	63.10%	C. Patel [4]
5	Gujarati	SVM	PCA	90.55%	Mamta [5]

Table 2. Comparison of character recognition system for Devanagari

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Devanagari	Multiclass SVM	Zernike and Legendre moment	98.30%	K. V. Kale [6]
2	Devanagari	SVM	Gradient based directional features	95.81%	M. Bhalerao [7]
3	Devanagari	ANN	Zoning	93.40%	D. Khanduja [8]
4	Devanagari	Mapping	Line & Intersection features	93.33%	R. Sharma [9]
5	Devanagari	SVM k-NN FFNN	Geometric Regional Gradient	86.34% 79.10% 91.30%	S. Ansari [10]

Table 3. Comparison of character recognition system for Gurmukhi

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Gurmukhi	Deep learning	Directional Regional	99.30%	N. Kumar [11]
2	Gurmukhi	HMM Bayesian	Zoning Directional Zernike	93.50%	M. Kumar [12]

Table 4. Comparison of character recognition system for Kannada

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Kannada	ANN	Structural Wavelet transform	91%	S. Pasha [13]
2	Kannada	Distance measuring method	FLD	68.00%	S. K. Niranjan [14]
3	Kannada	HMM	Gradient geometry Aspect ratio	66%	G. S. Veena [15]

Table 5. Comparison of character recognition system for Malayalam

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Malayalam	Cross-sectional sequence	HLH patterns	88%	A. Rahiman [16]
2	Malayalam	Two-layer FFNN	Chain code	72.10%	J. John [17]

Table 6. Comparison of character recognition system for Bangla

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Bangla	Deep Belief Network	Pixel values	91.30%	M. M. R. Sazal [18]
2	Bangla	MLP	Chain code histogram	88.74%	R. Pramanik [19]
3	Bangla	MLP ANN	Zone density Directional	88.64%	F. I. Alam [20]

Table 7. Comparison of character recognition system for Hindi

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Hindi	Two-pass dynamic programming	Directional element	91.23%	S. Ramachandra [21]
2	Hindi	CNN	Augmented	94.19%	Ajay Indian [22]

The following tables 8 to 14 shows and compare classifier, feature set and accuracy of online handwritten character recognition of Assamese, Tamil, Devanagari, Malayalam, Gurmukhi, and Bangla Indian languages.

Table 8. Comparison of character recognition system for Assamese

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Assamese	SVM	Posterior feature	99.52%	S. Mandal [23]
2	Assamese	Combined HMM & SVM	Coordinate sequence 1st & 2nd order derivative	96.17%	H. Choudhury [24]
3	Assamese	HMM SVM	1st & 2nd order derivative Baseline features	95.10%	S. Mandal [25]
4	Assamese	HMM	Pixel coordinates	93.35%	H. Choudhury [26]
5	Assamese	HMM SVM	Statistical Directional	76.24% 76.56%	S. Mandal [27]

Table 9. Comparison of character recognition system for Tamil

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Tamil	Naïve Bayes	Pixel coordinates	91.81%	R. Kunwar [28]
2	Tamil	HMM BOS	Writing direction Curvature Slope	91.80%	A. Bharath [29]
3	Tamil	Connected component	Blobs Stems features	77.84%	K. H. Aparna [30]

Table 10. Comparison of character recognition system for Devanagari

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Devanagari	SVM HMM	Pixel coordinates	97.27%	H. Swetha lakshmi [31]
2	Devanagari	HMM SVM	Zone wise slope of dominant points	93.3% 97.11%	R. Ghosh [32]
3	Devanagari	Template matching	DTW	97%	K. C. Santosh [33]
4	Devanagari	SVM	Structural Zone wise directional Zone wise slope	90.63%	R. Ghosh [34]
5	Devanagari	HMM BOS	Writing direction Curvature Slope	87.13%	A. Bharath [35]

Table 11. Comparison of character recognition system for Malayalam

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Malayalam	k-NN	Pixel coordinates Direction Curvature Aspect ratio	98.12%	M. Sreeraj [36]
2	Malayalam	HMM SVM	Pixel coordinates Direction Curvature Angular features	97.97%	K.P. Prime kumar [37]
3	Malayalam	SVM DDAG	Pixel coordinates Direction Curvature Moments	95.78%	A. Arora [38]
4	Malayalam	k-NN MLP SVM	Accurate dominant points Intersections	90.39% 93.17% 95.12%	Baiju KB [39]

Table 12. Comparison of character recognition system for Gurmukhi

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Gurmukhi	SVM	X & Y projection	99.75%	H. Singh [40]
2	Gurmukhi	SVM HMM	RDP Chain code	98.21% 98.27%	S. Singh [41]
3	Gurmukhi	K-means clustering	Direction Loops	94.69%	A. Sharma [42]
4	Gurmukhi	k-NN MLP SVM	Spatial temporal Spectral features	89.35% 89.89% 89.64%	R. Kaur [43]
5	Gurmukhi	HMM	Zoning features	88.40%	K. Verma [44]

Table 13. Comparison of character recognition system for Bangla

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Bangla	CNN	Pooling	99.40%	S. Sen [45]
2	Bangla	SMO	Mass distribution Chord length krill-herd	98.57%	S. Sen [46]
3	Bangla	SVM	COG based global & local	98.26%	S. Sen [47]
4	Bangla	MLP	Hausdorff Distance Directed HD	95.57%	S. Sen [48]
5	Bangla	SVM	Transition counts, centre of gravity, & topological	95.49%	S. Sen [49]

Table 14. Comparison of character recognition system for Gujarati

Sr. No.	Language	Classifier	Features	Accuracy	Author(s)
1	Gujarati	SVM k-NN	derivative of pixel values, zoning, normalized chain code	94.65%	Vishal [50]
2	Gujarati	SVM	zoning features dominant point-based normalized chain code	94.13%	Vishal [51]
3	Gujarati	SVM MLP k-NN	Structural Statistical	91.63% 86.72% 90.09%	Vishal [52]
4	Gujarati	SVM	zoning and chain code directional features	95%	Vishal [53]

III.RESULTS AND DISCUSSION

The comparison of various classifier, feature set and accuracy of offline and online handwritten character recognition for various Indian languages. For offline handwritten character recognition, following are the best result achieved by the researcher for various Indian languages.

1) *Gujarati:* The classification was performed using a Support Vector Machine and naïve based classifiers. The feature set included chain code, zoning, and projection profile-based features and their possible combinations as a fusion feature set. The result showed the highest accuracy of 99.80% using SVM with the polynomial kernel classifier and chain code & zone-based features. [1]
2) *Devanagari:* In the pre-processing stage, smoothing, enhancing, and filtering methods were used. In the pre-classification stage, local and global features were used. The features were extracted using Zernike and Legendre moment. Classification was performed using multiclass SVM. The result showed a maximum accuracy of 98.30% for a handwritten character. [6]
3) *Gurmukhi:* The feature set had 117 feature values which included the local binary pattern with directional and regional features. Classification was performed using deep learning classifier. The result showed an accuracy of 99.3%. [11]
4) *Kannada:* In pre-processing skew detection and correction, binarization, noise removal, normalization, and thinning methods were used. The features set had 149 feature values which included structural and wavelet transform features. Classification was performed using the Artificial Neural Network classifier. The result showed an accuracy of 91%. [13]
5) *Malayalam:* Characters were separated based on foreground and background colours. The HLH patterns featured with horizontal, vertical and cross-sectional sequence check was used to identify a character. The authors obtained an accuracy of 88%. [16]
6) *Bangla:* Deep Belief Network (DBN) was used for classification. DBN learning process has two steps, unsupervised feature learning and supervised parameter tuning. The result showed an accuracy of 91.30%. [18]
7) *Hindi:* They used augmented data set with CNN. The proposed method achieved accuracy of 94.19% with average training time/epoch 8.43s. [22]

For online handwritten character recognition, following are the best result achieved by the researcher for various Indian languages.

a) *Assamese:* The Support Vector Machine was used for classification. The feature set included class-conditional probabilities features derived from a Gaussian mixture model. The result showed an accuracy of 97.67% for upper letters & processing time of 162.34 milliseconds, and 96.05% for lower letters & processing time of 335.56 milliseconds. The extended work of English word recognition showed an accuracy of 94.66%. [23]

b) *Tamil:* The proposed algorithm was a semi-supervised method which learns from labeled and unlabeled samples. The classification was performed using the naïve Bayes classifiers and the expectation-maximization algorithm. The result showed an accuracy of 91.81%. [28]

c) *Devanagari:* Normalization and smoothing pre-processing methods were used here. Single Engine Approach using SVM, Multiple SVM Engines and HMM were used for classification. The feature set included curve and coordinate points features. The result showed an accuracy of 97.27% using SVM and 83.08% using HMM. [31]

d) *Malayalam:* They used dot detection, dehooking, smoothing, thinning, loop detection, normalization, orientation normalization and equidistant resampling for pre-processing. They used normalized x-y co-ordinates, pen up/down, aspect ratio, curvature and writing direction for feature extraction. They used k-NN for classification. They achieved an accuracy of 98.12%. [36]

e) *Gurmukhi:* The Support Vector Machine with the RBF kernel was used for classification. The zone identification was performed using the x & y projection method. The feature set included x & y points, discrete Fourier transform features, and directional features. The result showed an accuracy of 94.8% for character and 99.75% for zone identification. [40]

f) *Bangla:* Classification with different strategies. Comparison between max pooling and average pooling schemes was done. The softmax and sigmoid activation functions were also compared. The result showed an accuracy of 99.40% using max pooling and softmax function. [45]

g) *Gujarati:* Classification with multi-layer classification using SVM at first layer and k-NN at second layer. The feature set is consist of derivative of pixel values, zoning and normalized chain code. The result showed an accuracy of 94.65%. [50]

IV. CONCLUSIONS

Comparison of classifier, feature set and accuracy of offline handwritten character recognition of Gujarati, Devanagari, Gurmukhi, Kannada, Malayalam, Bangla and Hindi Indian languages and online handwritten character recognition of Assamese, Tamil, Devanagari, Malayalam, Gurmukhi, and Bangla Indian languages. For offline handwritten character recognition, Gujarati, Devanagari, Gurmukhi and Hindi language performed best among all Indian languages with SVM and deep learning algorithms. For online handwritten character recognition, Assamese, Devanagari, Gurmukhi, Bangla and Gujarati language performed best among all Indian languages with SVM and CNN learning algorithms.

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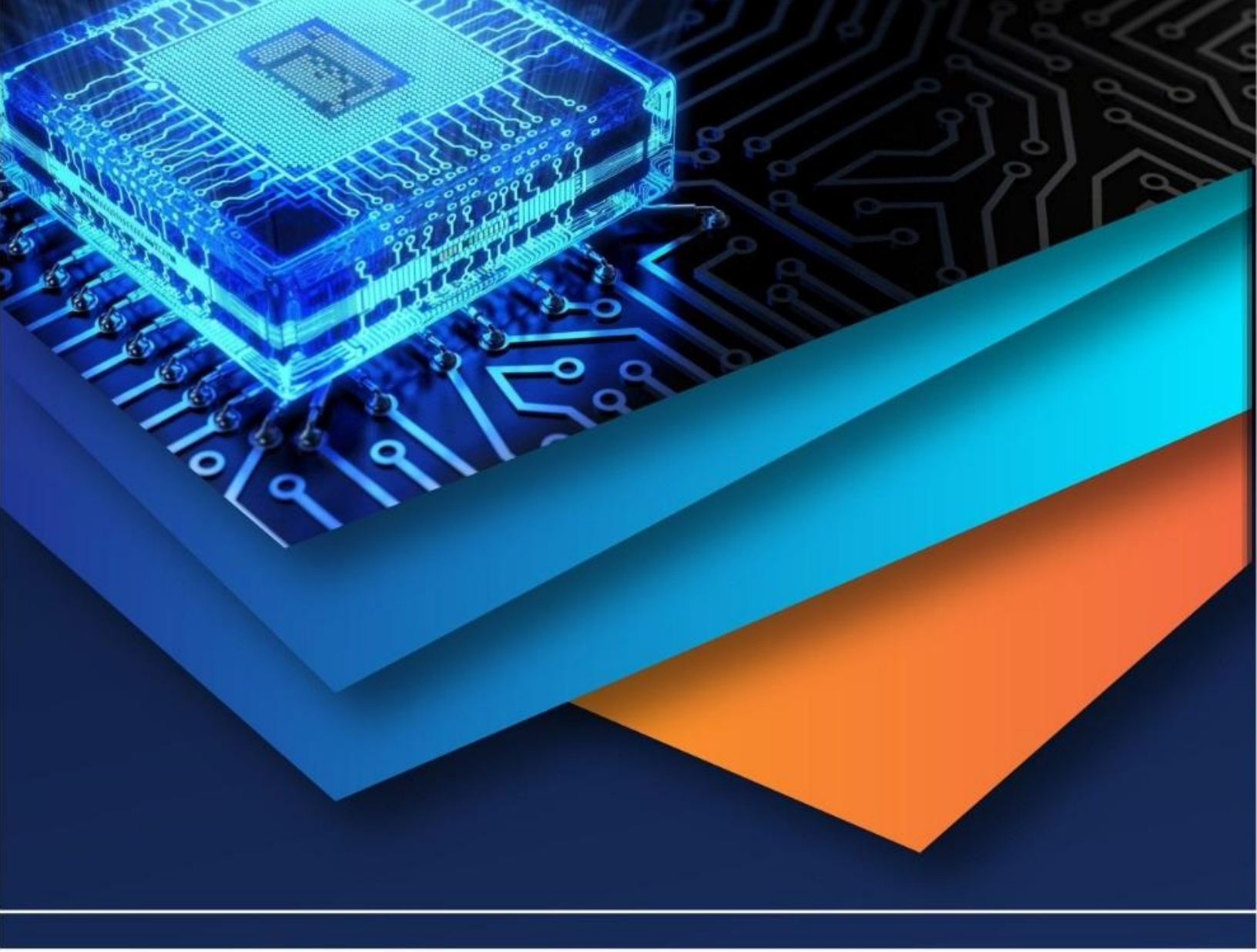

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