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Review article

Feature Extraction and Classification Techniques of MODI Script Character Recognition

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ABSTRACT

Machine simulation of human reading has caught the attention of computer science researchers since the introduction of digital computers. Character recognition is the process of recognizing either printed or handwritten text from document images and converting it into machine-readable form. Character recognition is successfully implemented for various foreign language scripts like English, Chinese and Latin. In the case of Indian language scripts, the character recognition process is comparatively difficult due to the complex nature of scripts. MODI script - an ancient Indian script, is the shorthand form for the Devanagari script in which Marathi was written. Though at present, the script is not used officially, it has historical importance. MODI character recognition is a very complex task due to its variations in the writing style of individuals, shape similarity of characters and the absence of word stopping symbol in documents. The advances in various machine learning techniques have greatly contributed to the success of various character recognition processes. The proposed work provides an overview of various feature extraction and classification techniques used in the recognition of MODI script till date and also provides evaluation and comparison of these techniques.

Keywords: Classification techniques, feature extraction techniques, handwritten character recognition, MODI script OCR, offline character recognition survey

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INTRODUCTION

In recent years a lot of work is done towards the digitization of physical documents as it facilitates better searches, modification and quicker addition. And this brings a need for software which automates the process of

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extracting, analyzing, recognizing and storing the information from physical documents. Automatic recognition of either printed or handwritten text from document images and the conversion of it into machine-readable form is called as Optical Character Recognition (OCR) (Chaudhuri et al., 2017). Over the years researchers have worked in this area and have contributed in developing efficient character recognition for various languages (Jayadevan et al., 2011; Capin & Pulli, 1990). Indian language scripts are generally complex in nature, and hence recognition system for Indian scripts is comparatively difficult. Though technical challenges and lack of commercial market makes it difficult for OCR related research for Indian language, it is the need of the hour (Jayadevan et al., 2011). The character recognition process can be categorized into offline character recognition and online character recognition. In the case of the online method, the recognition process is done at the time of writing the character. In offline methods, the recognition is done on the scanned image of the character (Capin & Pulli, 1990). The focus of this work is offline character recognition of MODI script.

The process of character recognition involves five major steps such as Pre-processing, Segmentation, Feature Extraction, Classification and Post-processing. A detailed discussion of each step is given in section 2.

Historical Importance of MODI Script

MODI script was developed in Devagiri in the 12th century. Hemadri Pandit also known as Hemadpant, a famous leader of Yadav dynasty, introduced MODI script. He was inspired by the cursive Sinhalese script and was instrumental in developing a similar one for Marathi which involves less lifting of hand while writing and which can be written very fast (Ramraje, 2013). MODI was easy to write and was commonly used as an official script for writing Marathi until 1950, and there are vast amount of documents preserved in various libraries (Khillari, 2008; Thakre, 2016). Because of the difficulty in printing MODI script, its usage was stopped, and Devanagari was used for writing Marathi. In addition to Marathi, there are other languages like Urdu, Kannada, Gujarati, Rajasthani, Hindi, and Tamil which used MODI script for writing (Pandey, 2011). The bulk of documents and correspondence from before Chhatrapati Shivaji's times are written in MODI Script. Large volumes of MODI documents are preserved in India as well as other Asian and European countries. Bharat Itihas Sanshodhan Mandal in Pune, Tanjavur's Saraswati Mahal, Rajwade Sanshodhan Mandal and Dhule (Maharashtra) known to have large collections of such documents (Khillari, 2008). The Pune division of the State Archive Department also has a very valuable collection of oldest and rare manuscripts dating back to the Peshwa dynasty and times of Chhatrapati Shivaji (Deshpande, 2013). Goa's Directorate of Archives and Archaeology also have a collection of MODI documents as land and revenue records of various talukas of the state. These are loose manuscripts which are archived

in the form of books. The archive has 13,000 pages in 113 books of one taluka itself and other loose manuscripts which are yet to be documented. It is observed that some of the MODI documents which are archived in various places are on the verge of degradation due to improper facilities. Digitization of these documents will help to preserve this large repository of knowledge. Realizing the fact, that it is impossible to study Maratha history without knowing MODI script, researchers and enthusiasts work towards keeping the script alive (Times, 2014; Savant & Rakshana, 2005). It has been observed that there is strong effort to revive MODI script by publishing articles written in the script. In addition, several institutions now offer tutorials for learning MODI. Workshops and formal courses conducted by the Maharashtra State Department of Archives and Bharat Itihas Samshodhak Mandal (BISM) in Pune are examples of such courses. In parallel with the revival of the script the effort to catalogue and manage large volumes of MODI documents stored at various libraries are also taking place. Script Encoding Initiative (SEI) of the University of California, Berkeley, has initiated and completed a project to encode the script, and currently is supported in Unicode (Berkeley-Linguistics, 2018). The Government of India has initiated the work of cataloguing of these manuscripts by appointing trained MODI experts for the job (Pandey, 2011). Aimed at preserving and propagating MODI script, CDAC (Centre for Development of Advanced Computing) Mumbai has done a considerable amount of work on MODI script and has developed MODI script software. CDAC made a website enabling users to convert text from Devanagari script to MODI and *vice-a-versa* (CDAC, 2016). In a project funded by the Government of India, Tamil University has taken steps to digitize and catalogue MODI documents by converting them into a Portable Document Format (Chen & Wang, 2000). In the year 2013, the Govt. of Maharashtra allocated 80 Lakhs for the digitization of MODI manuscripts. The reports state that there is a serious effort to keep MODI scripts alive (Hindu, 2007, 2013). In addition to that individual researchers have carried out researches in MODI script character recognition using various methodologies.

Description of MODI Script

MODI script is an ancient script which was used in the 12th Century for writing Marathi. This script was widely used between the 12th century and 20th century. The name 'MODI' believed to be derived from the Marathi verb moḍaṇe (Marathi: मोडणे), which means "to bend or break" (Pandey, 2011). The script was written by 'Boru' or 'lekhan'. 'Lekhan' was a pen created with the 'Bamboo'. MODI script is derived from the Nagari family of scripts and intended for continuous writing. Although MODI is based upon Devanagari, there are some significant differences. The differences are evident in letter forms, rendering behaviors, and orthography of both the characters. The behaviors of these characters in certain environments, such as consonant-vowel combinations and in consonant conjuncts

that are standard features of MODI orthography and is different from Devanagari script. The MODI script has 46 distinctive letters, of which 36 are consonants and 10 are vowels (Figure 1). MODI was written as characters hanging on a horizontal line which are drawn across the page. Termination symbol for sentence or word was not used in MODI script and hence word segmentation is a very difficult task in the case of MODI script documents. The speed of writing was increased due to the elimination of these symbols as it avoided the lifting of the "Boru' too often (Kulkarni et al., 2015a).

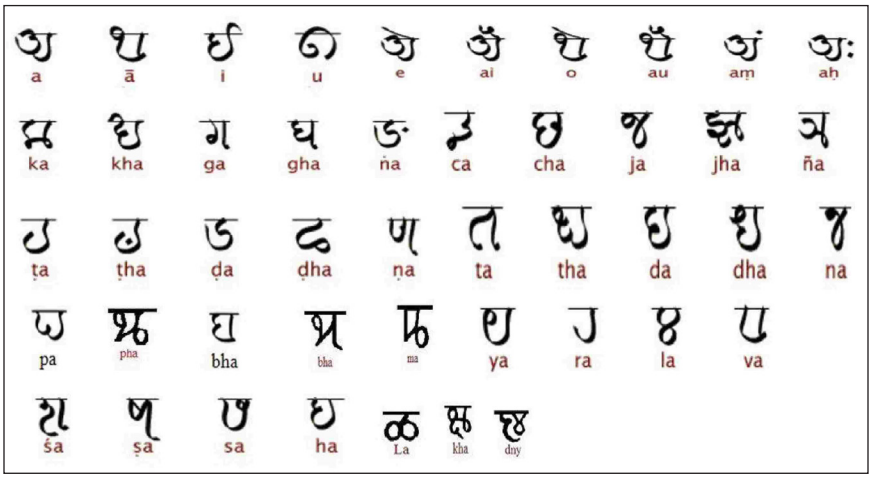

Figure 1. Basic character set of MODI script

The review of literature reveals that there are several styles of the MODI script based on the era. The different styles of the script are as follows:- Adya Kalin (proto-MODI) of 12th century, Yadav Kalin of 13th century (Yadav dynasty), Bahamanikalin which was during 14th to 16th century, Sivakalin of 17th century, Chitnisi of 18th century, Peshvekalin which lasted till 1818, and Anglakalin which was popular during 1818 to 1952 (Figure 2). Among the various styles, Bahamanikalin, Chitnisi, Peshvekalin and Anglakalin are found to be commonly used in historical manuscripts (Pandey, 2011). The Anglakalin is on the messier side while the Peshvekalin has a more aesthetic flow. In addition, a style of MODI was used in the primary school books (Figure 2) produced during the 19th and 20th centuries. Interaction with the experts of MODI scripts reveals that in the Bahamanikalin MODI documents there is a tendency of Parsi word usage.

In this paper, an effort is carried out to review various feature extraction and classification techniques used in the recognition of MODI Script till date (August 2018), which will promote MODI script related research. The remaining part of the paper is organized into four sections. Section 2 deals with the various stages of the handwritten character recognition process and the commonly used methods for the same. Section 3 deals with a detail discussion on MODI character recognition with an emphasis on various

feature extraction as well as classification techniques used in MODI character recognition. Section 4 deals with current trends in character recognition. Section 5 gives the conclusion of the paper.

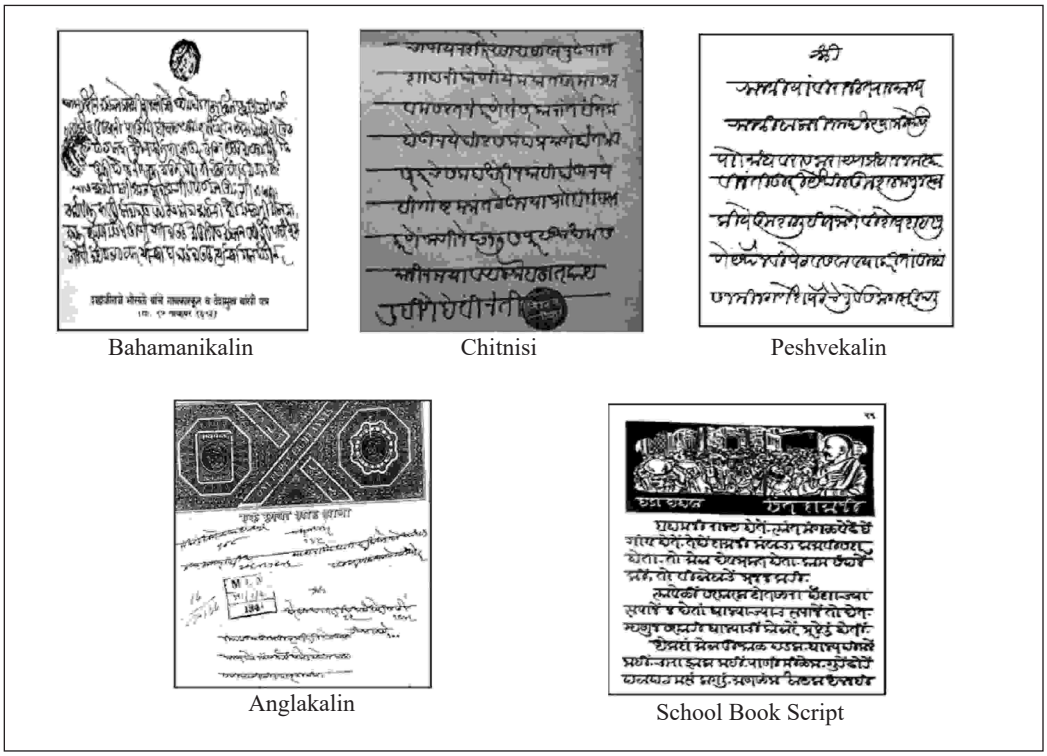

Figure 2. Various styles of MODI script

HANDWRITTEN CHARACTER RECOGNITION PROCESS

Handwritten character recognition involves Pre-processing, Segmentation, Feature Extraction, Classification and Post-processing as shown in Figure 3.

Pre-processing is used to eliminate the noise of the document. There are various pre-processing techniques such as Noise Reduction, Filtering, Morphological operations, Skew detection and Normalization can be used at this stage (Arica & Yarman-Vural, 2001). Skew detection, skew correction, and shirorekha extraction was performed on MODI documents and achieved an accuracy of more than 90% (Tamhankar & Kolhe, 2018).

In the segmentation step, the document is subdivided into components like words, lines, and characters. The accuracy of this stage affects the accuracy of the entire process. An experiment for line segmentation of MODI documents yielded 91% accuracy in the segmentation of overlapping lines and 94% accuracy in extracting touching lines (Kulkarni et al., 2017). The segmentation of connected handwritten character is the main bottleneck

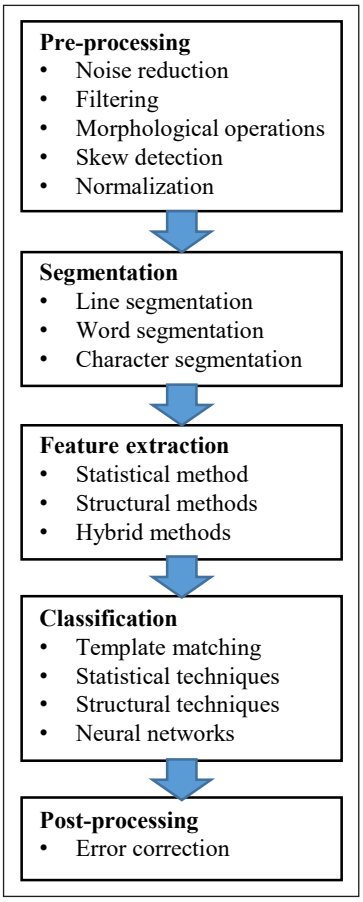

Figure 3. Various stages of the character recognition process

in the OCR system (Chen & Wang, 2000; Dhaka & Sharma, 2015). A performance analysis of character segmentation approach for cursive script recognition is carried out in which the geometric features of the character are analyzed for the segmentation (Rehman & Saba, 2011). An algorithm using top profile projections is efficiently implemented to segment touching characters in the upper zone of printed Gurmukhi script and has achieved a recognition rate of 91% (Jindal et al., 2009). A fuzzy multifactorial analysis is used for the segmentation of touching printed characters of Bangala and Devanagari (Garain & Chaudhur, 2001). A Pixel Plot and Trace and Re-plot and Re-trace (PPTRPRT) technique is used for segmentation of Devanagari handwritten scripts for extracting text regions (Dhaka & Sharma, 2015). Word segmentation in handwritten documents is a difficult task as the gap between words is not uniform. MODI script documents do not have any space between words as the characters are continuously written in the line. Though word segmentation is not been experimented in MODI Script, researchers have experimented word segmentation of for various other scripts.

The extraction of the most representative information from the raw data is called as feature extraction. A feature point is the distinguishing feature of the character image, and such features will be recognized at this stage, with a fixed number of feature variables (Chacko et al., 2012). The extracted features of each class are used for distinguishing it from the other classes. The feature extraction is the most important step in the character recognition process as it highly influences the recognition rate of the entire process. There are various feature extraction methods available for the selection of important features. Identifying the suitable feature extraction method is essential in achieving an excellent recognition performance. The feature extraction methods for character recognition can be broadly classified as statistical and structural methods. In the case of statistical feature extraction, the feature extraction is based on the statistical distribution of points which

includes zoning, histograms and moments. Structural features are based on the appearance of the character or its geometrical shape like directions of the stroke and intersection of strokes etc. (Jayadevan et al., 2011). It is observed that neither the structural nor statistical information can represent a complex pattern alone (Goswami & Sharma, 2013). Therefore an approach integrating both statistical and structural features is also implemented by many researchers. Research in the field of character recognition indicates that the recognition accuracy depends heavily on the feature extraction methods and classification methods used in the recognition process. The commonly used feature extraction techniques used for MODI character recognition are based on Statistical methods such as Zernike moment, Hu's seven invariant moments, Chain Code Histogram and Intersection/Junction. The efficiency of the Zernike feature extraction method was tested for MODI Script character recognition by various researchers (Kulkarni et al., 2014, 2015b; Sadanand et al., 2015a, 2015b). The observations made by them indicate that the use of Zernike Complex moments features with zoning increased the performance. A similar method was used for Oriya alphabets (Tripathy, 2010), Devanagari (Marathi) Compound Character Recognition (Kale et al., 2014), and Arabic character (Oujaoura et al., 2012) and achieved good performance. The performance of Chain Code histogram and Insertion junction feature extraction methods was tested on MODI as well as Devanagari script (Chandure & Inamdar, 2016). Chain Code Histogram based feature extraction method is used for handwritten Bangla characters (Bhattacharya et al., 2006) and resulted in acceptable recognition performance. Feature extraction using AMIs (Affine Moments Invariants) technique has been proposed for MODI character recognition in order to increase the recognition accuracy and reliability (Patil, 2016). A hybrid approach for feature extraction which combines two techniques: Moment Invariant and Affine Moment Invariant is reported to have achieved an average recognition rate of 89.72% (Gharde & Ramteke, 2016). They claim that the hybrid technique also resulted in extracting minimum features. A similar approach is used for Farsi Character Recognition System as well (Alavipour & Broumandnia, 2014). Their research achieved an accuracy of 96.5%.

The classification stage is instrumental in mapping an unknown sample into a predefined class. The quality of the extracted features determines the performance of the classifier. Various methodologies of pattern recognition are used at this stage for the classification purpose. The techniques for Character Recognition can be categorized in four general approaches of pattern recognition as template matching, statistical techniques, structural techniques and neural networks (NNs) (Jain et al., 2000). This classification is not distinct as a technique in one approach may also be classified as a member of other (Arica & Yarman-Vural, 2001). There exist various methods in each of these approaches. An analysis of different classification methodologies used in OCR of various languages was carried out in which the author discusses various classification algorithms used

for pattern recognition (Sharma, 2013). The author discussed methods such as Support Vector Machine, Artificial Neural Network, K Nearest Neighbor, Naïve Bayes Classifier, Decision Tree, Linear Discriminant Analysis (LDA), Quadratic Discriminant Analysis (QDA), and Maximum entropy classifier for pattern classification. An insight into different learning based classification methods such as SVM, Artificial Neural Network (ANN) and various statistical methods were discussed in Liu & Fujisawa, (2008). A survey on offline recognition of handwritten Devanagari scripts gives an insight into various algorithms used in offline handwritten recognition (Ramteke & Rane, 2012).

In the post-processing stage, the errors are corrected and the ambiguities of the OCR are resolved. Post processing is done at the word level, sentence level, and semantic level.

MODI SCRIPT CHARACTER RECOGNITION

Though handwritten character recognition is successfully implemented for various foreign language scripts, most of the Indian language scripts still need attention. The development of OCR for such script is difficult due to the complex nature of scripts (John et al., 2011). MODI being an ancient script and not in the list of scheduled official scripts of Indian languages, very limited work is done towards the handwritten character recognition of MODI script compared to other Indian scripts. Character recognition of MODI script is a difficult task due to the fact that characters in MODI are cursive, continuous, unconstrained, and the existence of highly similar shaped characters. Segmentation is another challenging task of MODI character recognition process. Major challenges are caused due to noise and degradation, the presence of multiple skews, fluctuation in illumination, uneven alignment, slanting lines, overlapping lines and touching lines (Gharde & Ramteke, 2016). Research in this field indicates that MODI character recognition needs a different approach/ method as compared to other Indian script character recognition. Unlike other scripts, MODI script document does not have any termination symbol for words or sentences, and therefore word segmentation techniques cannot be applied on MODI manuscripts.

Review of the literature indicates that only thirteen published works are available on the character recognition of MODI script which is discussed in the following section. In addition there are few studies which deal with the theoretical analysis, survey, and analysis of various algorithms used in MODI script, etc. A study carried out on reviewing the various feature extraction techniques conclude that feature extraction methods of MODI character recognition are still in the infancy stage compared to other Indian languages. The study states that segmentation is the most concerned part in the case of MODI manuscripts, especially as there are overlapping characters and lines in ancient MODI documents (Kulkarni et al., 2015a). An analysis of some of the existing systems on handwritten character recognition system of Indian Script with a focus on MODI script gives an insight

to the various methods which can be used for MODI script recognition (Balbudhe et al., 2016). A theoretical analysis of MODI Script character recognition gives an insight into the basic features of the ancient script (Besekar, 2013). A comparison of the character recognition process of MODI, Devanagari, and Roman scripts was performed in this work and found that in the case of MODI script structural features were difficult to extract. This study reveals the complexities occurring in MODI script character recognition and also states that the recognition process is more difficult compared to other Indian languages. Cursive natures of the character, complex structure of some of the characters, inconsistency in writing style, shape similarity of characters, etc. are some of the factors which make the recognition task extremely difficult. A feature extraction technique using Affine Moment invariant has experimented with a fuzzy logic classifier in (Patil, 2016). This study stated that the classification got a higher accuracy rate if the deformation between the template and the unknown character was approximately affine. MODI character recognition and an attempt to convert it into corresponding English character are carried out in (Rathi, 2015). This study listed out different steps of the image processing which could be used for MODI script character recognition. A work towards skew detection, skew correction and segmentation of MODI document is carried out in which a novel algorithm is implemented for the shirorekha extraction from the image (Tamhankar & Kolhe, 2018). The experiment resulted in an accuracy of 93% in skew detection and in the case of shirorekha extraction the accuracy was 90.27%. In another experiment on skew detection of MODI document (Deshmukh et al., 2017), the authors experimented with a horizontal projection based approach, for the detection of skew angle in old MODI documents. They have also performed a comparison of the proposed algorithm with the benchmarking techniques illustrated by Mahnaz and Maher, (2015), and claim that the proposed method resulted in better accuracy, with an average success rate of 96.49% as compared to 95% in the benchmarking techniques. A study on various Thresholding Technique used in the ancient document images is discussed in (Jyoti & Kumar, 2016). The authors had evaluated fourteen different Thresholding Techniques which could be used for degraded image binarization and concluded that each technique had its own benefits and limitation.

MODI script character recognition involves all the five stages, as illustrated in the previous session. The focus of this paper is the feature extraction and classification techniques used by various researchers in the process of MODI script character recognition.

Feature Extraction Techniques used in MODI Script Character Recognition

In MODI script character recognition both structural, statistical as well as a hybrid method of feature extraction are used by various researchers. The most commonly used are Statistical based methods

Zernike and Zernike Complex Moments. The moment-based approach is found to be more commonly used in the recognition of MODI characters as well as numerals and found to have achieved better accuracy compared to the rest of the methods used. The efficiency of the Zernike feature extraction method was tested for MODI Script character recognition by various researchers (Kulkarni et al., 2015a; Sadanand et al., 2015a, 2015b) The observations made by them indicated that the use of Zernike Complex moments features with zoning increased the performance. Zernike complex moments in combination with Decision Tree was found to achieve an accuracy of 97.68 % (Kulkarni et al., 2016). A similar method was used with different zoning patterns (Sadanand et al., 2015a) and Euclidian distance classifier and achieved an accuracy of 94.92 (using Zernike moments), and 94.78 (using Zernike complex moments). Every character was divided into six zoning patterns with thirty-seven zones. The zoning patterns were created using geometrical shapes. Hu's Seven Moments and Zernike was used for the recognition of MODI numerals in (Kulkarni et al., 2015a) and achieved an accuracy of 70% in the case of Hu 's seven and 86.6 in the case of Zernike moment. When the Zernike moment feature is used in combination with Euclidean distance classifier for the recognition of MODI character, the accuracy is 82.61% (Sadanand et al., 2015b). The observation made by them indicates that the Zernike moment performs more efficiently compared to Hu's 7 moments.

Chain Code based Approach. A recognition model based on image centroid and Chain code was used in MODI Script character recognition (Besekar, 2012). The accuracy achieved was 65.3% to 73.5% in combination with a two-layer Feed Forward Neural Network classifier in the case of MODI Script vowels. The same method was experimented in the recognition of the entire character set of MODI script as well as for Devanagari Script, in combination with BPNN, KNN and SVM. The accuracy achieved was 37.5%, 60% and 65% respectively (Chandure & Inamdar, 2016). It has been reported that Devanagari script dataset yielded better performance in the same experiment, with an accuracy of 70%, 87.5% and 87.5% respectively, in combination with BPNN, KNN and SVM. The observation from this experiment was that the misclassification of similar shaped vowels affected the performance in the case of MODI script.

Zone-based Approach. A zone-based feature extraction technique was used in Besekar and Ramteke (2012) for the recognition of MODI script Numerals. The feature set used in this experiment was created with the help of 4 equal square zone of size 15 x 15 and their polar co-ordinates, Variance, Theta, and Rh distance. The recognition accuracy achieved was 93.5%.

Structure Similarity Approach. A Structure Similarity Approach was experimented in combination (Ramteke & Katkar, 2013) for MODI Script character recognition. Image quality was measured using the Structural Similarity method. The classification method used in the experiment was Kohonen Neural Network & Back Propagation Neural Network (BPNN) and yielded a recognition accuracy of 91% to 97%.

Heuristic Approach. A feature extraction method using empirically determined heuristics is implemented for the character recognition of MODI script and resulted in an average recognition rate of 91.2% (Maurya & Maurya, 2018). In this case, a hybrid feature space was created using normalized chain code shape descriptions. It was reported that this hybrid approach had an advantage that allowed more flexible inputs such as the character of varying sizes. The experiment was done on thirty-three characters of MODI script with a data size of 3200 characters.

Hybrid Approach. A Hybrid approach was experimented by combining two methods in the recognition of MODI script (Gharde & Ramteke, 2016). Invariant and Affine invariant moments were combined for the feature extraction purpose. Eighteen features were extracted from a single numeral/character. The recognition accuracy achieved was 89.72 with SVM classifier. The highlight of this work was that with minimum features, high accuracy was achieved. The original manuscript of MODI script was used as the dataset in this case.

The Percentage of average accuracy of various Feature Extraction Techniques used in the recognition of MODI character data set is shown in Figure 4.

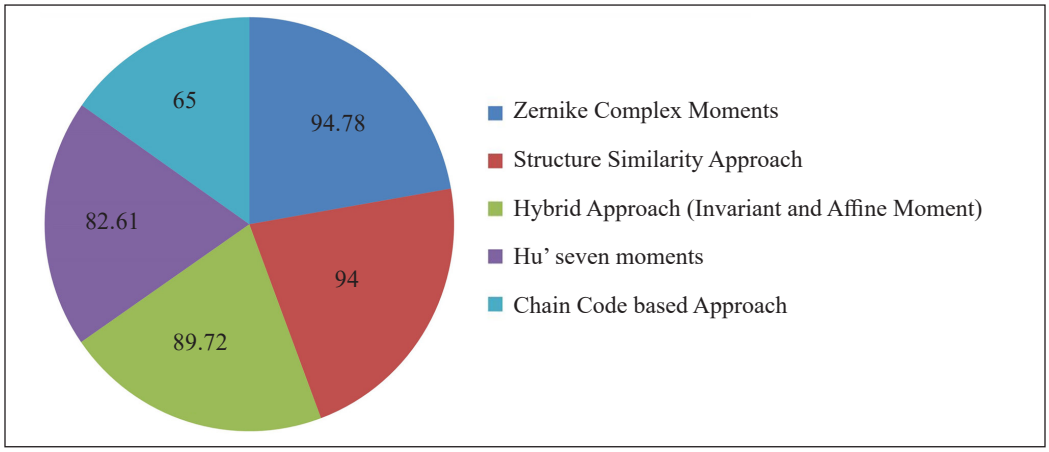

Figure 4. The performance (% of accuracy) of various feature extraction techniques used in MODI script character recognition

The Classification Techniques used in MODI Script Character Recognition

Decision Tree. There are various methods experimented by researchers for MODI script character recognition, within which, Decision Tree classifier was found to achieve the highest recognition rate. Zernike and Zernike complex moments in combination with Decision Tree was found to achieve an accuracy of 97.68% (Kulkarni et al., 2016).

Euclidean Distance Classifier. Euclidean distance classifier is the most commonly used method for MODI character recognition. Zernike and Zernike complex moments in combination with Euclidian distance classifier has achieved 94.78% (Sadanand et al., 2015a). In another experiment Euclidean distance classifier is implemented with the Hu's seven and Zernike features for the MODI numerals (Kulkarni et al., 2015a) as well as MODI characters (Sadanand et al., 2015b). In the case of MODI numerals the recognition accuracy was 86.6%, and in the case of MODI script character, the recognition rate was 82.6%.

Support Vector Machine. Support Vector Machine-based classification is implemented by two researchers for MODI script character recognition. In the first case (Chandure & Inamdar, 2016) the SVM classifier with chain code features achieved an accuracy of 65%, and with intersection junction feature the accuracy was 47.5 %. In the second case (Gharde & Ramteke, 2016) SVM classifier was used with Moment Invariant and Affine Moment Invariant feature and the accuracy was 89.72 %.

Back Propagation Neural Network. Back Propagation Neural Network based classification technique was used for the recognition of MODI characters in two experiments. It was used in combination with a feature extraction method of structure similarity and the accuracy rate was 91% to 97% (Ramteke & Katkar, 2013). In the second case it was implemented using Chain code histogram and achieved an accuracy of 37.5%, and with intersection junction feature the accuracy was only 15% (Chandure & Inamdar, 2016).

Kohonen Neural Network. Kohonen Neural Network based classification method was implemented by two researchers. With structural similarity feature extraction method the accuracy achieved was 91 to 97% (Ramteke & Katkar, 2013). In the second case, it was used in combination with Otsu's Binarization Algorithm for recognition of 22 MODI characters, and an overall character recognition rate of 72.6% was achieved (Anam, 2015).

Feedforward Neural Network. Feedforward Neural Network Classification technique was implemented on MODI vowels (Besekar, 2012) with chain code histogram based classification method and the recognition rate achieved was 65.3% to 73.5% with Zernike moments based features and the recognition rate achieved was 97.68%.

K-Nearest Neighbor Classifier. K-Nearest Neighbor classifier was implemented for MODI Character recognition (Chandure & Inamdar, 2016) in combination with Chain Code histogram based feature extraction and achieved an accuracy of 60%.

Variance Table. Variance Table was used for classification of MODI numerals (Besekar & Ramteke, 2012) and achieved a recognition rate of 93.5%. The feature set used for this experiment was created with the help of 4 equal square zone of size 15 x 15 and their polar co-ordinates, Variance, Theta, and Rh distance.

The average recognition accuracy of the various classification techniques used in the recognition of MODI character data set is shown in Figure 5.

The character recognition of MODI script implemented by the various researchers is consolidated in the Table 1. The data set for the experiment includes MODI Characters, MODI Numerals and a subset of MODI characters.

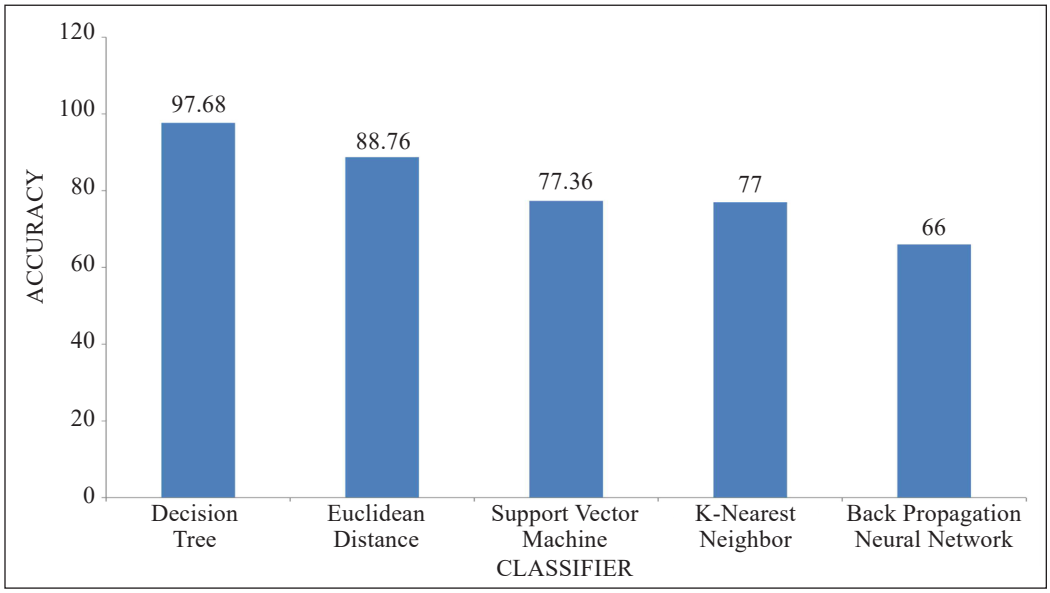

Figure 5. Average recognition accuracy (%) of various classifiers in MODI script character recognition

Table 1
List of methods used in MODI Script Recognition and comparison of the results achieved

Sr. No	Author	Feature Extraction	Classification	Data type	Accuracy
1	Kulkarni et al., 2016	Zoning, Zernike and complex Moments	Decision Tree	Characters	**97.68%**
2	Kulkarni et al., 2015a	Zoning, Zernike Moments and Zernike complex moments	Euclidian Distance	Characters -	**94.92% (Zernike) & 94.78% (Complex)**

Table 1 *(continue)*

Sr. No	Author	Feature Extraction	Classification	Data type	Accuracy
3	Ramteke & Katkar, 2013	Structure Similarity	KNN, BPNN	Characters	**91% to 97%**
4	Gharde & Ramteke, 2016	Hybrid–Combination of Invariant and Affine Moment Invariant	SVM Classifier	Characters	**89.72%**
5	Sadanand et al., 2015b	Hu's and Zernike moments	Euclidian Distance	Characters	82.61%
6	Chandure & Inamdar, 2016	Chain Code Histogram & Intersection/Junction features.	KNN, BPNN and SVM classifier	Characters	**KNN-60% BPNN-37% SVM-65%**
7	Maurya & Maurya, 2018	Chain Code	Empirically determined heuristics	33 Characters	**91.20%**
8	Anam, 2015	Chain Code	Kohonen Neural Network	22 characters	**72.60%**
9	Besekar, 2012	Chain code histogram and normalized chain code histogram	Feedforward NN	Vowels	**65.3% to 73.5%**
10	Besekar & Ramteke, 2012	Zoning - Variance of theta, Rh distance and centroid of the zone	Variance table	Numerals	**93.50%**
11	Kulkarni et al., 2014	Hu's and Zernike moments	Euclidian Distance	Numerals	**86.66%**
12	Kulkarni et al., 2015a	Hu's invariant features and Zernike moments	Euclidean' distance	Numerals	**70% & 86.6%**

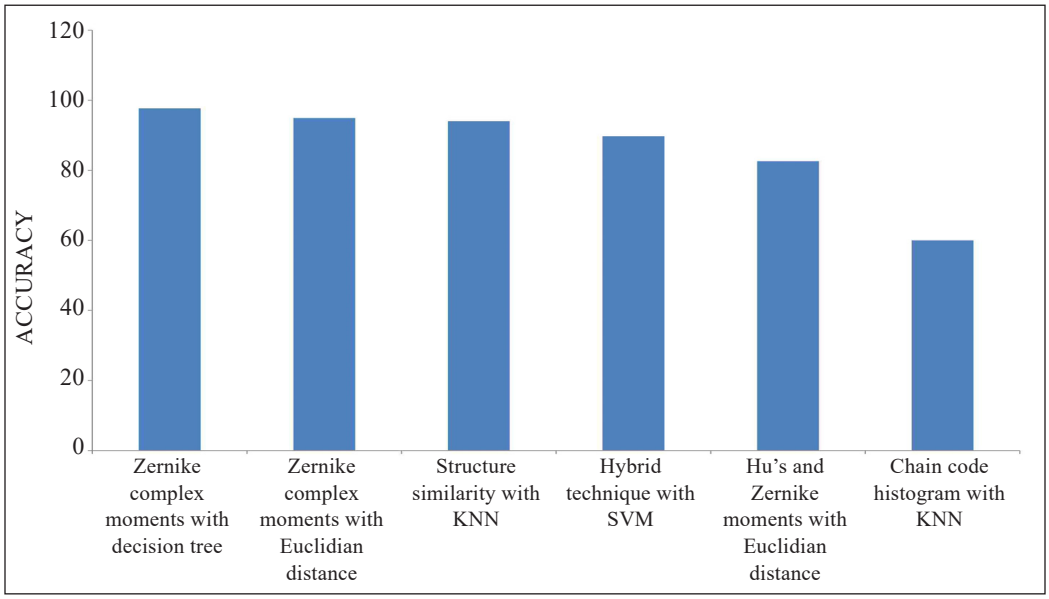

Figure 6. Various feature extraction techniques and classification techniques used in MODI script character recognition and their performance

The consolidated list of all the feature extraction and classification techniques used by various researchers in MODI character recognition is shown in Figure 6. The dataset used is forty-four MODI characters. The feature extraction techniques used by various researchers in MODI Script recognition are Zernike and Complex Moments, Structure Similarity, Hybrid Technique by combining Invariant and Affine Moment Invariant, Hu's and Zernike Moments and Chain Code Histogram. The classification techniques used are Decision Tree, Euclidian Distance, KNN and SVM.

CURRENT TRENDS IN CHARACTER RECOGNITION

Genetic Programming based Algorithms, Deep Learning based Algorithms, Wavelet Energy Feature (WEF) and Extreme Learning Machine (ELM) are effectively used in the recognition of various Indian languages. The GP algorithm is widely used in signal processing and pattern recognition (Jindal et al., 2009). Metric learning based Recognition Algorithm called Genetic Programming Metric Learning (GPML) is successfully implemented for Persian/Arabic character recognition (Sepahvand et al., 2017). It is learnt that this algorithm was efficient in extracting the differentiating geometric shape of the characters and thus producing a minimum set of features. A combination of Wavelet energy feature (WEF) and Extreme Learning Machine (ELM) is used effectively and yielded high recognition accuracy in handwritten recognition of Malayalam scripts (Chacko et al., 2012). The wavelet energy (WE) which is derived using wavelet transform is a new and robust parameter. Character recognition of Marathi compound characters is implemented using wavelet approximation features and modified wavelet features and neural network classifier (Shelke & Apte, 2011). In this study, it is observed that recognition accuracy is increased due to the modified wavelet feature extraction method. Deep learning which was first presented by Geoffrey Hinton et al (Hinton, 2007; Hinton et al., 2012) is gaining popularity in the recent years for various pattern recognition tasks and is efficiently implemented by various researchers (Bengio, 2009; Deng, 2014; Hinton & Salakhutdinov, 2006; Larochelle et al., 2007). The multiple layers in this kind of networks can efficiently handle more complicated functions than shallow ones.

Convolutional Neural Network (CNN) is another method which is gaining popularity for the feature extraction as it is one of best performing character recognition (Cires et al., 2011) (Maitra et al., 2015) algorithms. CNN is effectively used for handwritten characters (MNIST Dataset) (Cires et al., 2011), and Multi-script Numeral Dataset (Maitra et al., 2015) and yielded a high level of accuracy and is in the upfront of best-performing character recognition algorithms. The deep Convolutional Neural network is implemented for the character recognition of Hangul Script (Kim & Xie, 2015) and to improve upon the performance of the networks. A framework using Recurrent Neural Network (RNN), for the recognition and drawing of handwritten Chinese characters is reported to have

achieved a new state-of-the-art performance. It is used for online character recognition as it can directly deal with the raw sequential data, unlike the CNN based method where some image-like representations are required (Zhang et al., 2018). RNN classifier is also used effectively for offline character recognition of Arabic and Latin scripts (Chherawala et al., 2016). A weighted vote combination of RNN classifiers each trained with a particular feature set is used in the experiment.

CONCLUSION

The primary objective of this work is to review the literature to identify the methodologies used by various researchers, in the character recognition of MODI script with an emphasis on the feature extraction and classification techniques. It is observed that MODI script character recognition is still in its initial stages. MODI being an ancient script and not in the list of scheduled official scripts of Indian languages, contributes to the fact that limited research work has been done towards it, compared to other Indian scripts. Research and development in MODI script are necessary to extract the information on MODI manuscripts which are stored in various parts of India and abroad. Though handwritten character recognition is successfully implemented for various foreign language scripts, most of the Indian language scripts still need attention. The development of OCR for such script is difficult due to the complex nature of scripts. Research in this field indicates that MODI character recognition needs a different approach/method as compared to other Indian script character recognition. Pattern recognition of MODI script is tedious because of various factors like the shape similarity of characters and inconsistency in writing style. Unlike other scripts, MODI script document does not have any termination symbol for words or sentences, and therefore word segmentation techniques cannot be applied on MODI manuscripts. Only a few works have been published so far and all the published work has been reviewed in this study. Segmentation is found to be a difficult stage in the case of ancient MODI documents and many of the published work of MODI script character recognition, segmentation methods used were unclear. In most of the work which is done on MODI script character recognition, the data set is specially generated in a controlled environment. But the documents which are available in various libraries are ornamental MODI script, and the recognition process of those documents is a difficult process. There is a need for more effort to unveil the historic information written in various MODI manuscripts. Implementation of more efficient methods at the various stages of the character recognition process will increase the performance of character recognition of MODI script. The purpose of this paper is to set a foundation for those who want to carry out research in this field.

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