Discrete Cosine Transformation Based Approach for Offline Handwritten Character and Numeral Recognition

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Abstract. Handwritten Character Recognition (HCR) of Indic scripts is one of the most challenging as compared other scripts. Recognition of handwritten character is more difficult one as compares with the printed one due to their similar structure and orientation. To have a proper recognition system for handwritten characters various researchers have adapted various methods and still yet to have more feasibility and high recognition rate to achieve. Here in this proposed work we have completely focused on handwritten characters and numerals of various scripts of different regions of India such as Bengali, Odia scripts. To have a proper solution for the ambiguities that arises in handwritten one and which has been resolved using the Discrete Cosine Transformation (DCT) as feature extraction part. This transformed based featured is used to calculated GLCM values of each images of handwritten numerals and characters. To maintain the novelty of the work in simulation part we have listed up variance nature of the individual’s images. Subsequently we have also harnessed the SVM, Neural Network, and Quadratic Classifier over dataset to report the recognition rate. After validating the proposed work, we can conclude that adopted model is quite helpful in building the automatic recognition system for both handwritten character and numerals to have solution for real time problems.

1. Introduction

Pattern Recognition has great influence over various researchers to have a best solution for pattern matching real world problems. Among such pattern recognition problem Automated Character Recognition system is one of them. Usually this character recognition system has widely used providing solution over printed, handwritten characters [1]. Generally it is act of converting physical characters into its respective digital one to meet the demand of current digitization world. This recognition system has huge application in various sectors such as storage, indexing of the data and along of its retrieval. To satisfy the current demand of digital world various researcher have experimented different modules from last past years to frame a well-defined OCR model [2]. In order to have a good OCR system one should have put concerned on stages of system such as data acquisition, data pre-processing, report of feature vector and finally classifier used so to report high recognition rate [3].This automatic OCR system has been applied over both oriented and handwritten one among various scripts such as English [4], Chinese [5], Arabic [6] and Japanese [7] etc. In context to Indian script it is multilingual and multi-scripts one and to have a proper recognition system is the most challenging one [8].Here in this work we have focused on regional scripts such as Odia and
Bengali. Both the scripts are most ancient scripts and these are framed from Devanagari scripts. Mostly these two scripts are found to be spoken in East-India zones and you will both the scripts are identical to each other [9]. It has been noticed that writing skill of different individuals it’s added more complex to the structure of handwritten characters that added confusion in proper recognition of characters. In every recognition system the most important is to choose a good database and also well-defined feature extraction techniques. Such techniques are to identify the minimum unique features that will vary among the individuals. Apart from it is quite necessary to choose a well-defined classifier to report high recognition rate.

To have a proper clarity we have performed a suggestion an approach for solving the ambiguity arises to both the Odia and Bangla scripts [10]. Both the scripts were depicted from Brahm script which is one of the ancient of India. In both such scripts the most advantage is that their no such concept of uppercase and all. In numeral part both the scripts have ten digits and in Odia letter segment it has 35 consonants along with 14 vowels (in total 49). These both scripts we would find that the characters mostly in oval shape type along with most similar in orientation, size which added more ambiguity in the recognition of the characters. To have automated recognition system we have mainly focused to certain steps as preprocessing of the input image, extraction feature values, followed by classifier used for classification, and at last post processing [11]. Apart from it we have done some statistical calculation to evaluate the feature of individuals. To have well defined feature set we have converted the spatial feature into frequency components. Apart from we have also evaluate some texture calculation of each individuals as Gray Level Co-occurrence Matrix (GLCM) [13]. In addition to it we have evaluate such components as energy, entropy, contrast, homogeneity, correlation etc. for each individual images of both numerals and characters and report the desired feature vector. Sometime high feature dimension lead to add more complex in the recognition system so in order to avoid such situation we have implemented some probabilistic approach to make dimension reduction to the feature vector by Principal Component Analysis (PCA). On processing the PCA we will able to report the key feature with fewer dimensions. At in the last part we have introduced some the classifier as Neural Network (NN) and Support Vector Machine (SVM) to report the recognition rate.

In the following section of this article we have make several modules to our proposed system. In that context Section 2 depicts the work done previously, Section 3 explain the need of feature vector to report the desired feature of the characters. Result analysis has been depicted in the Section 4 as well. Lastly the Conclusion and future aspect has been drawn in the final Section.

2. Related Work Done

Optical Character Recognition can be formulated to both printed and handwritten scripts which has been evaluated among various researchers across the world at with respect to various scripts [3][4][5]. To report a good feature is the primary goal of any recognition model [6] [7]. As Odia and Bangla are the official language of State Odisha, West Bengal. And both are quite oldest scripts among Indian regional language [9][10]. In every recognition system the main task to report the good feature value of each individual so that it will lead to high recognition and this is the considerable phase of the model as well. In [8] Pal et al. have given approach which works on water reservoir based features and report the stroke analysis of the Odia characters. We have also found some momentum analysis of the character that of has been suggested by Patra et al. in [14]. Here they had reported the variant and invariant nature of the characters using Zernike, Mellin Transformation and 99% recognition accuracy reported. Once again Pal et al. in [15] had shown curvature analysis of the characters and reported in feature extraction part and also implemented PCA over it, as a classifier they had used Quadratic classifier with 94.6% accuracy. In [16] Padhi et al. had introduced thinning based approach for performing the skeletonizing of Odia characters to depict the difference between similar and distinct characters. They had also shown a zone based approach for evaluating the feature vector and achieve high accuracy over the dataset. Some directional based calculation was also done to report the feature vector by Pujari et al. in [17]. In addition to it they had also reported 95% recognition rate with the help of SVM classifier. Apart from it they had also implemented some algorithm to thinned character also to perform the recognition of the scripts [18]. Later on Nayak et al. in [19] have introduced some edge detector algorithm to the Odia character images and try to solve the conjunct one using a cellular
based approach. Similarly some conjunct based was also attempted by on Nayak et al. in [20] where they had shown a comparative analysis among the NN and GA as with 93.9% and 95.9% of recognition accuracy. Roy et al. in [21] had performed a gradient based approach over the dataset. Where they had suggested four ways of calculation along the four directions with some degree of inclination and 90.38%, 94.81% recognition rate achieved along with 1.84%, 1.31% rejection rate for NN and Quadratic classifier. In [22] Mishra et al. had successfully processed the handwritten numerals and performed some transformation based approach to the data. They had shown some cosine based along with wavelet components based transformation to the numerals and recorded 92%,87.5% recognition accuracy.

In addition to such transformation based Dash et al. in [23] had introduced stock-well transformation over the handwritten numerals and also done cross-validation to the proposed work. In addition to it later on Dash et al. in [24] had attempted over various transformation-based approaches. All these were found to be extended format of Fourier transformations such as Stockwell and Weavelet. They basically focused on the non-redundant nature of the images. Apart such method some also focused on the pre-processing step by Sethy et al. in [25].Here they had shown the Binarization procedure how effectively processed over the numeral and added some Fourier transformation analysis over the data was done successfully reported the desired feature vector. Later, they have reported 80.2% and 90 % recognition rate was achieved. Apart from Sethy et al. in [26] had successfully reported the some orthogonal transformation analysis such as Wavelet transform and along with some statistical feature also reported here. In addition to it they had also performed some dimension reduction to feature vector and reported 94.6% and 96.4% as the recognition rate for K-NN and Random Forest (RF) respectively. Subsequently Mohapatra et al. in [27] also added some orthogonal transformation analysis in recognition of Odia Characters. Once again Sethy et al. in [28] had drawn some horizontal and vertical projection termed as horizontal, vertical symmetric axis along the handwritten characters. Here they had evaluated the Euclidian distance from the centre of symmetric axis to the nearest pixel and report very good recognition rate through RBFNN. An extreme learning-based approach was reported by Das et al. in [29]. In this approach they had maintained a neural network having a one hidden layer based approach for the recognition of handwritten numerals. Some work also reported to both the Bengali numerals and character by Das and Pramanik [30]. Surinta et al. in [31] had introduced a contour based approach for handwritten character and they have evaluated the distance between along 8 direction hotspots to black pixels. They had successfully done a voting based approach through vector based approach (SVM). As feature selection is considered as the key aspect in recognition model Das et al. in [32] focused on local features and reported 97% recognition rate. Apart from all Xu et al. in [33] suggested a Bayesian approach for handwritten Bangla numeral recognition. Here they had used sparse based classifier and 94% as the recognition rate. Apart from it Sethy et al. in [34] has suggested an extended format of histogram analysis which included the rectangle components as R-HOG. These rectangle histograms based was reported in the feature selection part and also dimensional reduction was performed through principal component analysis (PCA)[24] upon high dimensional vector. These highest Pc’s score reported as the key feature set and rest work done by SVM and Quadratic classifiers respectively.

3. Suggested Recognition Model for Recognition

Here in this current section we all make a robust model to have proper recognition for Odia and Bangla handwritten numerals. After going thoroughly of various work reported by various researchers we have concluded a model and depicted in below Figure 1. The proposed model provides a robust approach for recognizing the handwritten scripts which consist of certain stage like Acquisition of data, Image pre-processing, Feature Selection and lastly the classifier used.
3.1. Used Handwritten Database & Pre-processing

To have good recognition model one should focused on choosing an appropriate dataset so as make the system qualitative one. In this segment we had collected various benchmark handwritten datasets of Odia character, numerals along with Bangla numerals to this system. All these standard databases have been reported from research institution such as IIT, NIT etc. Das et al. in [29] from NIT, RKL proposed Bangla numeral, the Odia numeral data set by from IIT, BBSR by Puhan et al. in [34] and another Odia character database has been collected from NIT, Rourkela by Mishra et al. in [20] ISI Kolkata by Bhattacharya et al. in [35]. In the numeral segment it contains 10 digits (starting from 0 to 9) and Odia characters it has 47 categories. For the proposed system we have depicted handwritten numerals collected from IIT, BBS in Figure 2 and in Figure 3, Figure 4 represents the handwritten characters and numerals collected from NIT, RKL respectively. In order to have high recognition rates we have separated the dataset at certain training and testing ratio represented in Table 1. One of the key points is above said all database is that, all the handwritten samples were collected various aged group of peoples starting from age 5 to 50 year peoples.

Figure 1. Proposed Recognition Model for Handwritten Scripts.

Figure 2. One of the Sample of Handwritten Odia Numeral Database of IIT, BBSR.

Figure 3. One of the Sample of Odia Handwritten Character Database of NIT, RKL.
After getting the desired handwritten characters and numerals, next is the pre-processing. This phase is used in preprocessing so as to get rid of the unwanted noise from handwritten image for that we have done median filter to the image. In addition to it we have also convert image to its binary values through Binarization. To have proper detection of boundary of each handwritten characters and numerals we had performed some morphological operation over the image.

### 3.2. Adopted Feature Extraction Method

As any recognition model the most important segment is the feature extraction part where it is quite helpful to report the unique feature of each character. In above both the scripts we would find some of the characters are very much similar to each other in terms of shape and size. Hence it added more complex while recognition of the characters and numerals of handwritten formats. To calculate the discriminate feature of handwritten format we had harnessed some Discrete Cosine Transformation (DCT) [24] based approach. Usually this DCT is widely used image compression. In which it provides a better mechanism in conversion of the spatial domain to its frequency components for that reason its can further categorized in one dimensional (1-D) and two dimensional (2-D). But here in this work we had implemented 2-D DCT based approach where we can easily convert the spatial to elementary frequency components and vice versa. Whenever we have applied DCT over the handwritten characters and numerals it makes the image into several parts or spectral sub bands and it is functionality is quite similar as of Fourier transformation.

\[
X(u, v) = \frac{1}{MN} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} x(m, n) \cos \left( \frac{2(m + 1)\pi u}{2M} \right) \cos \left( \frac{2(n + 1)\pi v}{2N} \right)
\]

(1)

### Table 1. Total number of Handwritten Samples

| Standard Database Collected                               | No. of categories of classes | Training Count | Testing Count | Total  |
|-----------------------------------------------------------|------------------------------|----------------|---------------|--------|
| Odia Numeral Database of IIT, BBSR                         | 10                           | 4000           | 1000          | 5000   |
| Bangla Numeral Database of NIT, Rourkela                   | 10                           | 3345           | 1000          | 4345   |
| Odia Numeral Database of ISI, Kolkata.                    | 10                           | 4970           | 1000          | 5970   |

Figure 4. One of the Sample of Bangla Handwritten Numeral Database of NIT, Rourkela.
Figure 5. Sample of one Odia Numeral in overall steps in calculating DCT feature vector

Here the respective \( X(U, V) \) is the coefficient of DCT of image having \( N \times N \) size and \( (U, V) \) represents the respective frequency components. While applying over the handwritten image we had performed pre-processing of the character image followed up by different pre-processing technique along with some morphological operation upon certain branch points along with proper boundary detection over all the handwritten images. Then further dilation of the respective handwritten characters occurred and after all this 2-D DCT is harnessed over the images. All the sequential steps are carried over both handwritten numerals and characters of both the scripts one by one. One of the sample of all the steps is shown in above Figure 5. After performing the 2D-DCT over all the handwritten character and numerals both Odia, Bengal scripts we had reported the co-efficient matrix. In order report the primary key feature we have processed the DCT Co-efficient matrix to calculate the Gray-level co-occurrence matrixes (GLCM) [36] along sub-band of second level of decomposition. This co-occurrence matrix has been used to report the some statistical feature such as the contrast, correlation, homogeneity, entropy and energy for each handwritten character numeral data images. Here we can assume that the key feature of \( M \) images along with \( N \) is the required feature so in total \( M \times N \) feature has to calculate. To report such value we had harnessed the below Algorithm 1 over the each handwritten data image report the desired feature value are reported in Table 2.

| Key Feature values to be obtained | Feature Name | Equation |
|---------------------------------|-------------|---------|
| F1 | Homogeneity | \( \sum_{i,j} p(i, j) \) |
| F2 | Contrast | \( \sum_{i,j} |i-j|^2 p(i, j) \) |
| F3 | Correlation | \( \sum_{i,j} (i,j)p(i,j) - \mu_x \mu_y \) |
| F4 | Energy | \( \sum_{i,j} p(i, j)^2 \) |
| F5 | Entropy | \( \sum_{i,j} p(i, j) \log(p(i, j)) \) |

Table 2. Reported GLCM Feature Value

Algorithm 1. Calculating Feature Matrix for Handwritten Character and Numerals
Steps: \( P \): Total no of images present in the Odia Character set present in database.
\( F[1: M, 1: N] \): Required Feature Matrix, \( Q \): no. of feature.
\( \text{Coeff\_Mat()} \): Evaluate the coefficient of level-2 DCT approximation character image.
1. For \( i \leftarrow 1..P \) Input the images (P) and perform the pre-processing of the character images.
2. Place an empty matrix \( \theta_{(1:k/8,1:k/8)} \) and vector matrix \( \text{VEC}[1:8] \).
3. For $i \leftarrow 1..M$ Apply Coeff_Mat ( ) to the images to calculate the coefficient of the decomposition level along all sub bands.

4. Assign $\omega(1:k/8,1:k/8) \leftarrow \text{coeff Mat}(M)$.

5. While

6. For $j \leftarrow 10k/8$

7. For $l \leftarrow 10k/8$ perform

8. Calculate the key GLCM values $VEC[1,i] \leftarrow \omega_{n}(j,l)$

9. End for

10. End for

11. $VEC[n,1:Q] \leftarrow \omega_{n}(j,l)$ End while.

12. End for.

3.3. Reduction in Dimension of Feature Vector

After getting the feature vector ready which is of higher dimension in nature. Reduction in dimension of such feature vector added advantages to any recognition system. By performing such operation in feature vector would able to reduce the load of the system and make the computation very fast. To make the system more efficient we have harnessed through Principal Component Analysis [37] upon the Grey Level Co-Occurrence Matrix coefficient (GLCM) obtained from above algorithm. 1. Basically the PCA provides a unique way to calculate the Eigen values over the five GLCM vector and reported the highest PC’s score value as the key feature of the respective data. Here we have successfully processed the PCA over the entire character, numeral dataset one by one. By such implementation of PCA it provides high stability to the proposed system. We have successfully proceeded to PCA to the feature vector by following the steps mentioned in the Algorithm 2. In this section we have $P \times Q$ high feature vector and want to reduce its dimension as $P \times l$.

Algorithm 2. Perform Dimension Reduction

a. Input the Feature Vector having high dimension in nature.
   P: Report the number of feature required, Q: Report the all images.
   b. Evaluate mean value of the image ($P \times 1$).
   c. Perform the subtractions of the feature value along with the mean value.
   d. Calculate the Co- variance Matrix ($P \times P$).
   e. After doing calculate the $\beta$ vectors consisting of $\beta$ no of Pc score (high Eigen value).
   f. Now do the Mapping ($n \times Q$ thatn < Q.

3.4. Used Classifier for Classification

After successful implementation of above Algorithm 1 and Algorithm 2 to the handwritten character and numerals, we have obtained the key feature vector for that we would like to frame as DCT+GLCM+PCA. This key feature set of handwritten are acted as the input parameters to the classifier to report the recognition rate. Here in this section we have harnessed various classifier like Neural based Network s (NN) [24] and vector based approach (SVM)[38], Quadratic Classifier (QC)[25]. By implementing various classifiers shows the robustness of the proposed system with respect to variation of the datasets. In the neural network segment we have chosen a three layered system. Among such three layers architecture one is termed as input layer, followed up by hidden layer and at last output layer. In addition to this we have also listed the support vectors by implementing SVM algorithm to the handwritten images. Where we had drawn some decision over the hyper plane in order make the classification among the characters and chosen the cost function to give high recognition rate. Later on we have shown the Basiyan approach of classification by implementing Quadratic Classifier. This QC based approach is quite similar in approach like LDA which exhibit normal distribution among all the classes of categories.
4. Implementation of the Proposed Model

To have the above proposed model implemented successfully we have very much focused to each stage of the model. At initial stage we have done the image acquisition of handwritten character and numerals followed up by the pre-processing stage. After onward to report each unique feature of images we have applied feature extraction algorithm and also make dimension reduction to it to report the key feature. And at last we have processed the classifier over the key feature so as to note down the recognition rate by different classifier used. Here the entire steps for implementation are framed into the Algorithm 3, which is mentioned in below section and we have separated into two modules.

Algorithm 3. Steps for Offline Procedure

a. Process the handwritten image of both Character and Numeral.
b. Do the pre-processing by using Median Filter along with some morphological operations.
c. Deploy the DCT Algorithm over the images and report the approximation vector.
d. Apply the GLCM based method over the approximation vector along sub-bands of the image.
e. Report DCT+GLCM feature values.
f. After that harness the PCA over it and report the Key features.
g. Input the DCT+GLCM+PCA feature values to the classifier.

Steps for On-line Procedure

a. Load the handwritten image inputted by User
b. Process the user image to the pre-processing block.
c. Calculated the features by deploying the DCT Algorithm along with GLCM.
d. Process the PCA over the features to report the key feature vector.
e. Examine various classifiers over the input feature and predict the correct class of the handwritten image.

5. Simulation Result Analysis

In this paper we have tried to make the robust so that it can provide good recognition rate to handwritten format characters. In the simulation section all the calculation was performed under a system having windows 10, 64-bit operating system, and Intel (R) i7 - 4770 CPU @ 3.40 GHz as system specification. To make the more effective we had considered its frequency components of each character. All the handwritten character and numerals are processed over the Algorithm 1 and 2 to report the feature vector as DCT+GLCM. In addition to make the system less complex we have also performed the PCA based approach. To make the system robust we have performed the simulation at various levels of PC scores such as 30 to 60. These are further carried over to NN, SVM and QC to report the recognition rate. After maintain a proper training and testing ratio we have evaluated both the character and numerals one by one. Through NN we have obtained 97.3% for Odia handwritten Character and 97.6%, 95.6% for Odia numerals and Bangla numerals respectively. While evaluating the QC we have listed 96.3% for Odia handwritten Character and 95.6%, 94.6% for Odia numerals and Bangla numerals respectively. And finally through SVM we have obtained 98.3% for Odia handwritten Character and 99%, 98% for Odia numerals and Bangla numerals respectively. All these simulation result are depicted in below figures.

![Figure 6. Reported Recognition rate for Odia Handwritten character (NN, QC, SVM)](image-url)
Figure 7. Reported Recognition rate for Odia Handwritten Numeral (NN, QC, SVM)

Figure 8. Reported Recognition rate for Bangla Handwritten Numeral (NN, QC, SVM)

| Reference No. and Author Name | Handwritten Dataset Used | Reported Feature Extraction Techniques | Classifier Used | Recognition Rate Achieved (%) |
|-------------------------------|--------------------------|----------------------------------------|-----------------|-------------------------------|
| Pal et al. in [15]            | ISI Kolkata Handwritten Odia Characters | Curvature Feature values | Modified Quadratic Classifier | 94.6 % |
| Mishra et al. in [22]         | NIT, RKL Handwritten Odia Characters | DCT and DWT | Support Vector Machine(SVM) | 92%, 87.5 % |
| Sethy et al. in [24]          | ISI Kolkata Handwritten Odia Numerals | Binarization + DCT | BPNN | 80.2%, 90% |
| Sethy et al. in [25]          | NIT, RKL Handwritten Odia Characters | DWT+ PCA | BPNN | 94.8% |
| Bhomik et al. in [38]         | ISI Kolkata Handwritten Odia Characters | Stroke calculation along Horizontal and Vertical | Neural Network(NN) | 95.89%, 90.50% |
| we authors                    | IIT, BBS handwritten Numerals and NIT RKL Odia Characters, Bangla Numerals | DCT+GLCM+PCA | NN | 97.3%, 97.6%, 95.6% |
|                              |                          |                                        | QC | 96.3%, 95.6%, 94.6% |
Table 3. Comparison among adopted to proposed methodology

| Methodology | Accuracy |
|-------------|----------|
| SVM         | 98.3%, 99%, 98% |

6. Conclusion & Future Scope

In this paper we have focused on cosine based approach transformation which leads to calculate approximation coefficient of handwritten images. In addition to it we have concerned with statistical values as contrast, correlation, homogeneity, entropy and energy of each handwritten image and termed as GLCM feature. To make the system robust we have implemented standard Handwritten Character and Numeral Database collected from various research institutes and also pays attention to the pre-processing of handwritten images. Initially all the images matrix are make to normalized one followed up by DCT transformation. Along with that some GLCM feature is calculated and process to PCA to report the key feature. At last stage we have harnessed NN, QC and SVM Classifier over the key feature obtained and evaluated one by one. All the possible outcome are already discussed in the result analysis section and by maintaining proper training and testing ratio we have concluded as SVM classifier is the best one among all followed by NN. Subsequently we have also shown some comparison among existing model with current proposed system is depicted in table 3. Apart from these there are numerous machine driven algorithms along with feature extraction algorithm which has to test over handwritten datasets to explore high recognition rate.

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