



The Performance of Online Telugu Character Recognition using Multilayer Feed forward Neural Network (MFNNs)

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Abstract—Feature extraction plays vital role in online hand written character recognition. Local Features captured through co-ordinate system approach plays significant role in modeling and determining the online telugu character recognition. In this paper, we have instigated the performance of various features using Artificial Neural Networks (ANNs). ANN model is tested with various combination such as (x, y) co-ordinates, pen-up pen-down, $(\Delta x, \Delta y)$ - $(\Delta^2 x, \Delta^2 y)$. Finally it is observed that amalgamation of $(\Delta^2 x, \Delta^2 y)$ with other features have given better modeling performance. The modeling performance against the number of epochs is evaluated for 14 Telugu vowels. 98 % of recognition accuracy is obtained for 14 Telugu characters. The database used for the study is HP-online Telugu database.

I. INTRODUCTION

Though languages like English can be or given as an input to the computers to execute as commands or process the data. It is not the same for quite a few languages like Telugu, Chinese, Hindi and other Indian or Japanese languages. Because these languages involve lot of stroke variations from writer to writer. But, rather than giving input via keyboard or voice, it is advisable to give it via handwritten samples (like parchments of paper or electronic pens). For instance, entering data into the database from the hand-filled Railway-reservation applications is a tedious task and can be automated. Moreover, properly trained systems will be capable of recognizing the hand-written text better than that of the human.

And this handwriting recognition is plays a crucial role in the human computer interaction model. Efforts have already been made to build system in both online and offline fields for achieving various aims, like recognizing numeric characters, language recognitions like Assamese[1], Thai[2] and Arabic [3].

Unlike English, the basic characters in Telugu script consist of 16 vowels and 36 consonants. The characters in telugu script are a combination of these basic characters and their modifiers which gives rise to about 18,000 unique characters. All these unique characters in telugu can be represented as a combination of a manageable set of 235 strokes. Also the character strokes, other the first stroke taken as main stroke, can be divided, based on the position of the stroke, into three - top stroke, bottom stroke and baseline stroke. As a preliminary attempt, we use character based

recognition for on-line handwriting recognition of Telugu which is a very popular south Indian language, in which much research has not yet done.

Telugu language found in the South Indian states of Andhra Pradesh and Telangana as well as several other neighboring states. Subset Telugu symbols given in the following figure 1.

In Telugu script, many of the characters resemble one another in structure. Further, many users write two or more characters in a similar way which can be difficult to classify correctly. In Telugu some of the confusing pairs are there. An SVM based stroke recognition method used in [1] for Telugu characters. Based on proximity analysis, the recognized strokes are mapped onto

characters using information of stroke combinations for the script. Each stroke is represented as preprocessed (x, y) coordinates. The data sample size 37817 was collected from 92 users using the SuperpenTM, a product of UC Logic. The observed recognition accuracy is 83%. Importance of annotation of online handwritten data illustrated in [5]. Modular approach for recognition of strokes proposed in [6]. Based on the relative position of strokes in the character, the strokes are categorized into baseline, bottom, top strokes. The recognition model SVM was used for each category separately. The recognition accuracy is high for each stage, when compared to combined classifier. Elastic matching technique, DTW used in [7]. The features used are local features: x-y features, Tangent Angle (TA) and Shape Context (SC) features, Generalized Shape Context (GSC) feature and the fourth set containing (x, y) coordinates, normalized first and second derivatives and curvature features. The observed results are 90% with the combination of all the seven above mentioned features, over the collected using Acacad Digital Notepad. A data collection procedure using ACECAD Digimemo illustrated in [7].

The combination time-domain and frequency domain features proposed, which enhances performance rather than applying individual features. Hanmandlu and Murthy [8] proposed a Fuzzy model based recognition for the Hindi hand-written numerals and have observed a accuracy of 92.67% . Bhattacharaya et al [9] modeled a Multi-Layer Perceptron (MLP) neural network based classification approach to recognize the handwritten Devnagari numerals and have obtained 91.28% accuracy. They have taken a multi-resolution features based on wavelet transform into account for their proposed model. Bajaj et al [10] deployed three different kinds of features namely, density, moment and descriptive components for the classification of Devnagari Numerals. They posited a design with multi-classifier connection for increasing the reliability and they have obtained an accuracy of 89.6%. In the Shanthi et al. [11] pixel densities over different zones of the image were used as features for the SVM classifier and their recognition rate was found to be 82.04% on a handwritten Tamil character database. In K. Mohana Lakshmi et al. [12] recognition rate on Telugu character dataset using HOG features and Bayesian classification was found to be 87.5%. Jawahar *et.al.*, [20] work shows a bilingual Hindi-Telugu OCR for documents containing Hindi and Telugu text. The used Principal Component analysis as a base and support vector regression as subsequent. Any accuracy of 96.7% was reported by over an independent test set. Rakesh and Trevor [13] used convolutional neural networks for the Telugu OCR. For the training data, they used 50 fonts in four styles each image of size 48x48. Although their model was fascinating they have not considered all the output of CNN. Handwritten digit recognition by neural networks with single layer ANN[13]

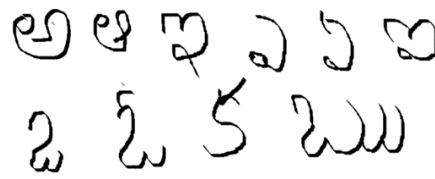


Figure 1: Sample Telugu Characters

II. METHEDOLOGY

As shown in the figure 2, Preprocessed HP database is collected. Local features such as (xy), pen up, pen down, $\Delta x, \Delta y$, $\Delta^2 x, \Delta^2 y$ are extracted from the given samples. Multilayer Feed forward Neural Network is used for modeling. Finally it is tested with the modeling.

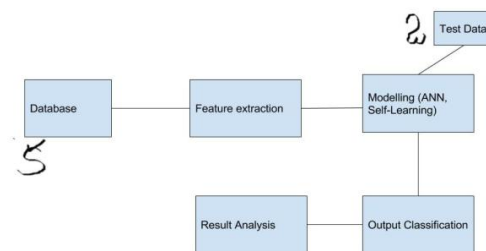


Figure 2: Methodology used for Character Recognition

A. Pre-Processing

In online mode, the handwritten pattern is captured as a series of (x, y) coordinates. Figure 3, represents the unprocessed character. The preprocessing stage performs size normalization, smoothing, interpolation of missing points, removes duplicate points, and resampling of the captured coordinates. Figure 4, represents the character after applying the preprocessing.

B. Size Normalization

Generally, handwritten patterns have large variations in size, probably due to the amount of space provided for writing each example or the individual preferences of the writers. It is necessary to normalize these variations before feature extraction and modeling. In the present work, size normalization is

performed by scaling each pattern both horizontally and vertically.

The size normalization is performed as follows:

$$x_i = \frac{(x_i^1 - x_{\min}^1) \cdot (x_{\max} - x_{\min})}{x_{\max}^1 - x_{\min}^1} \quad (1)$$

$$y_i = \frac{(y_i^1 - y_{\min}^1) \cdot (y_{\max} - y_{\min})}{y_{\max}^1 - y_{\min}^1} \quad (2)$$

Where (x_i^1, y_i^1) denotes the original point, (x_i, y_i) is the corresponding point after normalization, $x_{\min} = \min(x_i^1)$, $y_{\min} = \min(y_i^1)$, $x_{\max} = \max(x_i^1)$, $y_{\max} = \max(y_i^1)$ and W and H are the width and height of the normalized character, respectively

C. Smoothing

Smoothing removes any noise captured during data collection. The amount of noise depends on the capturing device used and the speed of writer. In this work, smoothing is performed by moving average filter of size three. Each pattern is smoothed in both x and y directions separately.

D. Removal of Duplicate Points

To remove redundant information from the raw data, the duplicate points are removed

E. Resampling

The captured coordinate sequence implicitly contains the writing speed of the writer. This speed varies from writer to writer. This variation is removed by sampling the coordinate sequence spatially. To resample a numeral example, first, the cumulative distance is calculated along trajectory of a numeral example. Missing points are interpolated by using calculated cumulative distance. The interpolation of points is repeated until the distance between any two points is less than one. Finally, the coordinates in resampled coordinate sequence are equidistant. During resampling the first point and end point of each numeral example are preserved because these points contain vital information.

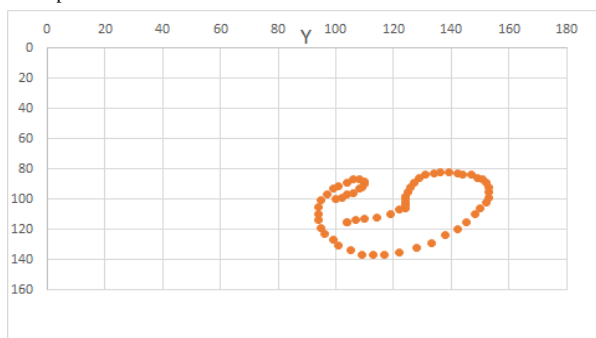


Figure 3: Illustration of Unprocessed character

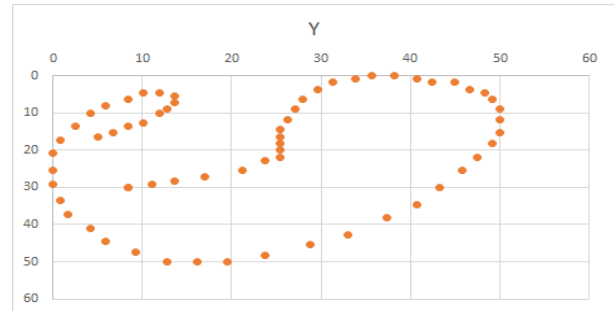


Figure 4: Character after Preprocessing

III. FEATURES USED FOR CHARACTER RECOGNITION

In a research area related to pattern recognition Benchmarking database is very important. In Telugu the dataset available is Hp-Labs data in UNIPEN format[4]. The data were collected using AcecadDigimemo electronic clipboard devices using the Digimemo-DCT application. Literature survey shows very less research done using HP-Labs dataset and researchers used their own databases for evaluating their techniques. If the standard database used, it will be good to compare various techniques proposed by the researchers. To increase accuracy some preprocessing techniques can also be applied over this dataset. This dataset contains nearly 270 samples for each of 166 Telugu "characters" written by native Telugu writers. The data are collected using AcecadDigimemo electronic clipboard devices using the Digimemo-DCT application. These 166 symbols are collected from 146 users in two trials. Among these collected 45,219 samples, 33,897 samples are used for training and remaining are used for testing.

A. (X,Y) Co-ordinates

(X, Y) co-ordinates are used for character recognition purpose. HP Dataset provides x,y co-ordinates for all the telugu characters. Figure 2 depicts some of the sample telugu characters and Figure 5 gives (x,y) co-ordinates of a telugu character.

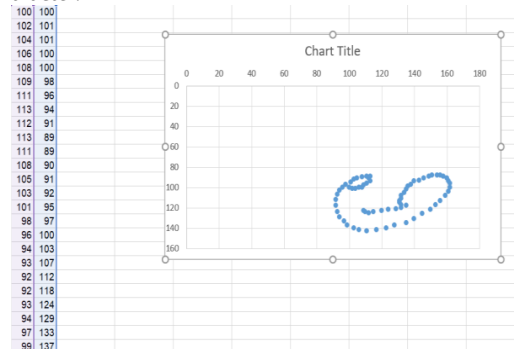


Figure 5 : (x,y) co-ordinates representation

B. $\langle x, \Delta y \rangle$ and Co-ordinates

From the given HP Dataset $\langle x, \Delta y \rangle$ co-ordinates are extracted from the (X,Y) co-ordinates with the following mechanism as mentioned in Figure 4.

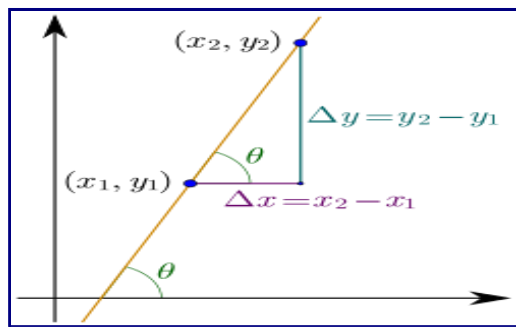
Figure 6: $\langle x, \Delta y \rangle$ co-ordinates of a Telugu character

Figure 6 represents the extraction of $\langle x, \Delta y \rangle$ from the telugu character. Similarly $\langle x^2, \Delta^2 y \rangle$ co-ordinates are extracted from the given database as mention below.

I. FIRST ORDER DERIVATIVE:

$$x'(j) = \frac{\sum_{i=1}^2 (x(j+1) - x(j-i)) \cdot i}{2 \sum_{i=1}^2 i^2} \quad (3)$$

$$y'(j) = \frac{\sum_{i=1}^2 (y(j+1) - y(j-i)) \cdot i}{2 \sum_{i=1}^2 i^2} \quad (4)$$

II. SECOND ORDER DERIVATIVE

$$x''(j) = \frac{\sum_{i=1}^2 i(x'(j+i) - x'(j-i))}{2 \sum_{i=1}^2 i^2}$$

$$y''(j) = \frac{\sum_{i=1}^2 i(y'(j+i) - y'(j-i))}{2 \sum_{i=1}^2 i^2}$$

III. EXPERIMENTAL RESULTS AND DISCUSSION

Here in this process, we have used Artificial Neural Networks (ANNs). First features are extracted from both

vowels (14 characters) from 80 users are used for training. Each user has provided with two sample of each character, The extracted features are trained with ANN by considering four hidden layers as depicted in Figure 7.

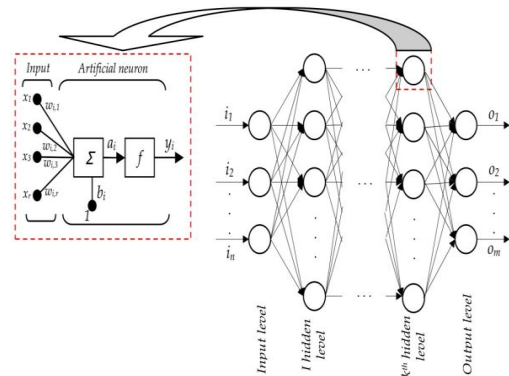


Figure 7: Multilayer Neural Network for Telugu Character Training.

A. Experimental Setup

Tensor flow is used on Windows 10 with I7 HQ processor clock speed of 3.5Ghz, 12 GB of RAM and 2GB Nvidia GTX 950M GPU.

B. Database used for the Study

HP online Telugu dataset is used for the study. This dataset contains approx 270 samples of each of 166 Telugu "characters" written by native Telugu writers. The data was collected using Acecad Digimemo electronic clipboard devices using the Digimemo-DCT application[4].

C. Model Optimization

ANN model with four layers have been used for modeling of 14 characters. In this model optimization $\{x=338, y=338, \text{pen-ups}=338, \text{pen-downs}=338, \Delta x=338, \Delta y=338, \Delta \Delta x=338, \Delta \Delta y=338\}$ number of features are considered for modeling.

First it (x,y) co-ordinates are considered.

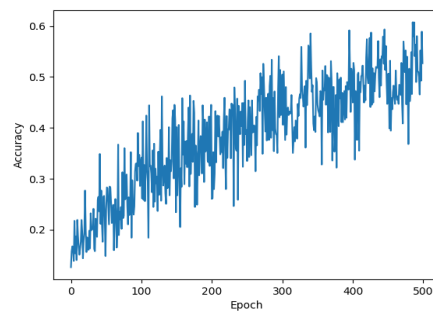


Figure 8: Accuracy of the ANN Model with respect to (x,y) co-ordinates for 14 telugu characters

From the Figure 8 it is observed that the accuracy of the system is 60.23% for 500 epochs. This is very low. In order to overcome this disadvantages pen-up and pen-down features are also amalgamated to (x,y) co-ordinates.

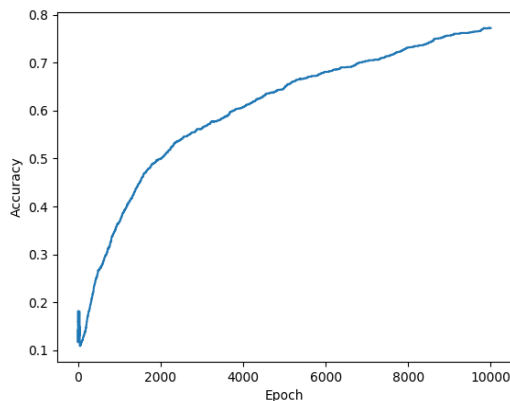


Figure 9: Accuracy of the ANN Model with respect to (x,y) , pen up and pen-down co-ordinates for 14 telugu characters

After considering both (x, y) and pen-up and pen-down co-ordinates, it is observed that the accuracy of the system has been enhanced to 77.18% for 10000 epochs as depicted in Figure 9.

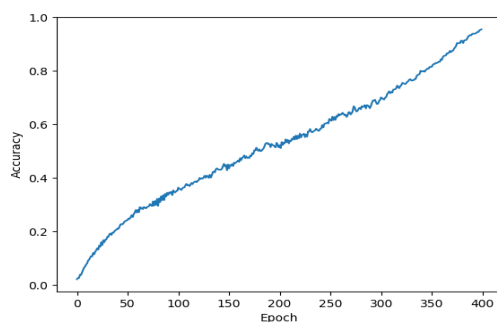


Figure 10: Accuracy of the ANN Model with respect to (x,y) , pen up , pen-down and $\langle x, \Delta y \rangle$ co-ordinates and for 14 telugu characters.

Based on these results obtained and as shown in figure 10, it is clearly established that the system accuracy increased abnormally to 88.24 % by considering (x,y) , pen up , pen-down and $\langle x, \Delta y \rangle$ co-ordinates for 14 characters.

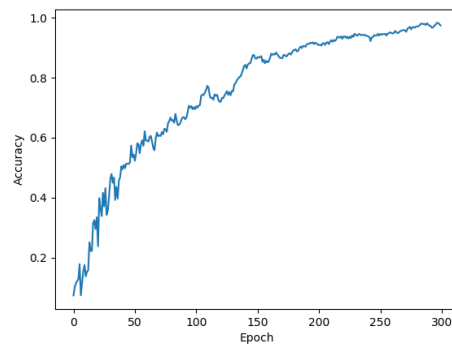


Figure 11: Accuracy of the ANN Model with respect to (x,y) , pen up , pen-down , $\langle x, \Delta y \rangle$, $\langle x^2, \Delta^2 y \rangle$ co-ordinates and for 14 telugu characters

Finally for all the above features amalgamation, 97.18 % modeling performance is obtained for 300 epochs for 14 Telugu characters.

ANN model is trained with 160 samples of each character and tested with 60 samples. The performance of the model is assessed for 14 characters by considering all the co-ordinates. As shown in the Table 1, it is clearly observed that the recognition rate is 98 %.

Table 1: Confusion matrix for 14 characters

Class	అ	ఆ	ఇ	ఈ	ఉ	ఊ	ఋ	ౠ	ఎ	ఏ	ఐ	ఒ	ఓ	ఔ
అ	90	5	-	-	-	-	-	-	23	-	27	-	-	-
ఆ	53	943	-	-	-	-	-	-	-	-	04	-	-	-
ఇ	-	-	943	-	-	-	-	-	-	-	-	06	51	-
ఈ	-	-	-	911	34	55	-	-	-	1	-	-	-	-
ఉ	-	-	-	29	91	61	-	-	-	-	-	-	-	-
ఊ	-	-	-	47	55	90	-	-	-	-	-	-	-	-
ఋ	-	-	-	-	-	-	96	4	-	-	-	-	-	-
ౠ	-	-	-	-	-	-	2	98	-	-	-	-	-	-
ఎ	-	-	-	-	-	-	-	-	86	136	-	-	04	-
ఏ	-	-	-	-	-	-	-	-	94	886	-	-	2	-
ఐ	-	-	-	-	-	-	-	-	15	35	95	-	-	-
ఒ	-	-	-	-	-	-	-	-	-	-	-	972	28	-
ఓ	-	-	-	-	-	-	-	-	-	-	-	13	98	07
ఔ	-	-	-	-	-	-	-	-	-	-	-	03	27	97

IV. CONCLUSION

In this paper we have explored various feature sets for telugu character modeling using Artificial Neural Networks (ANNs). We have modeled ANN using various feature sets such as (x,y), pen-up and pen-down, $\langle x, \Delta y \rangle$, $\langle x^2, \Delta^2 y \rangle$ co-ordinates by considering 14 Telugu character. For (x,y) co-ordinates modeling of ANN is not that promising. Whereas for the combination of (x,y), pen-up and pen-down co-

ordinates promising results are obtained. For (x, y) , pen-up, pen-down and $\Delta x, \Delta y$ significant improvement of 88.24 % is achieved for 400 epochs. Finally 95.18 % performance is obtained for 300 epochs for 14 Telugu characters. We have tested this for 14 Telugu vowels and it is observed that 98 % recognition accuracy is achieved. From the results it is established that the combination of all the local feature parameters such as (x, y) , pen up, pen down, $\Delta x, \Delta y, \Delta^2 x, \Delta^2 y$ the modeling performance as well as recognition accuracy has been enhanced.

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