# Hand Written Telugu Character Recognition-Review

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**Abstract:** Telugu Handwritten Character Recognition System (**THCRS**) is a field of Optical Character Recognition (**OCR**) and Pattern matching. Variations in handwriting from person to person makes the translation of the handwritten text into digitized text format and recognition of the same by a machine is still a tough task and challenging in today's muchadvanced world. If user's Telugu handwriting style is not clear then the situation becomes worse when two characters are intermingled or overlapped and appears as a single character. So, converting Telugu handwritten characters in digital text format are quite difficult when compared to other languages, since Telugu characters have many curves and strokes in nature. The Telugu handwritten character extraction process is hierarchically divided into an acquisition, pre-processing, segmentation, feature extraction, classification, recognition and recognition and post-processing. The main goal of extraction is to take out the common features of patterns of handwritten characters, recognize those characters and produce the same in digital format. We have done some survey on previously developed HCR systems and explored in this paper. This paper presents a brief idea on different methods which are capable of recognizing different handwritten texts or characters taken from different individuals with great accuracy.

Keywords: Telugu characters, OCR, THCRS, Pre-Processing, Segmentation, Extraction, and Recognition.

#### **1. Introduction**

OCR is a very much interactive tool to improve the information exchange process between user and machine [1]. It can be used to convert machine printed or handwritten documents into editable text format. Major levels in an OCR System are given in Fig: 1.1



# **Recognized** OCR Systems

Recognition of handwritten char **Text** nguage is a difficult task since writing style changes from person to person. So we can follow the best approach like hierarchical-divide and conquer technique for this task, where the total recognition process is divided into sub-phases like Image acquisition, Pre-processing, Segmentation, Feature Extraction, Classification, Recognition and Post Processing. Each sub-phase can be solved individually which produces input to next phases in the sequence [2]. Handwritten character recognition (**HCR**) has many applications like in the processing of bank cheques, indexing archives, forms processing in administration, mail search, address classification system, insurance [3]. The field of handwriting recognition can be two folded like online recognition and offline recognition [4].Off-line Telugu handwriting recognition [5] is a tough task due to high variations, chanciness of human writing and number of varieties of shapes from the writing styles. Telugu script has additional goals for handwriting recognition systems as script is curvy in nature and connected components of each letter and regional differences in writing styles. Telugu is the primary language in Andhra Pradesh, Telangana and Pondicherry (Yanam) state in India. Telugu script has high complexity among all other Indian scripts, as it has largest number of vowels and consonants, Complex Composition Rule. Telugu Script is a combination of 14 Vowels, 36 nsonants, and 3Special Characters which are shown in Figure 1.2, 1.3 and 1.4 [6] [7].

بر	<sup>kh</sup>	a	<sub>gh</sub>	்
کا	அ	X	ఘ	ப
.c	చ	<sub>ch</sub>	ा	;
15		ఛ	रह	23
<sup>ih</sup> دېک	ন স্ব			
్	th	ې	dh	n
కు	Ö	کړ	C	S

ig: 1.2: List of all vowels in primary and

secondary form.

య	୪	ల	ఫ	
ప	dK .s.	ఫ	s 15	
హ	ksh	୍ରେ		

# Fig: 1.3: List of all consonants in Telugu



Fig: 1.4: List of all consonants-vowels combinations.

There are huge amount of old handwritten documents in Telugu script available. Researchers proactively have given attention towards the amazing language for OCR. On this regard, various been used by researchers based on Hidden Markov Models (HMM), Elastic methodologies have Matching, Support Vector Machines (SVM), Multilayer Perceptron (MLP), and Raspberry Pi [8]. Now a day's gadgets like small hand-held mobiles, tablets, smart watches are rapidly growing in the market. In all these types of gadgets, User Interface Screens (UIS) are designed in their local language. As of now there are many tools available to design UIS in English language but very few are available for Telugu language [9]. Many research investigations are carried out on image-based hand gesture recognition that needs the text input system [10]. Some studies specify on non-touch input methods of computer systems and some other are focused on support for the deaf and dumb people. These methods do not need keyboards, mouse devices, and body-worn devices, e.g., cyber-gloves but they need image scanning and capturing devices like cameras [11]. These methods can be commonly applied as most of the mobile gadgets have an inbuilt camera. Although, voice recognition also supports non-touch input, it has some drawbacks like being vulnerable to surroundings noise, privacy problems, and problems of mispronunciation and a voice disorder of users [12]. According to the World Health Organization (WHO), approximately three hundred and sixty million people worldwide having hearing loss and seventy million are deaf. So, some studies were also done on sign language and eye gestures [13] [14]. Digital text data can be extracted from optical scanning by OCR or intelligent word recognition (IWR) from the scanned copy of handwritten text document. Optical character recognition is the translation of handwritten or typed text into an electronic format, which can be stored, interpreted and processed by a machine. This hand written character recognition process is emerging field and part of pattern recognition too. As mentioned in Fig: 1.1 many functions are to be carried out to get right output from the text document. Each process has its own pros and cons where cons need to be fixed to step ahead for extraction process [15].

### **Categorization of Character Recognition Systems**

Character recognition (**CR**) has been growing rapidly due to the huge requirement of online and offline documents scanning and parsing, since late sixties, Categorization of CR is given in Fig: 1.5. There are number of research studies available which contain either complete or partial information regarding the character recognition. The curvy, single, multi-stroke and complex nature of characters for recognition from printed/scanned document source creates more challenges in this field of research.



Fig: 1.5 Categorization of Character Recognition Systems.

# **Character Recognition Technologies**

1. Optical word Recognition (**OWR**): Here output is typewritten text i.e. one word at a time.

2. Intelligent Character Recognition (*ICR*): It outputs the handwritten print characters or cursive/curvy text i.e. one character at a time , this generally involves machine learning (ML) techniques.

3. Intelligent Word Recognition (*IWR*): It outputs handwritten print characters or curvy text one word at a time , generally used for the languages where characters are not separated in cursive script.

All the above-mentioned types are represented in hierarchical pictorial form in Fig: 1.6.The flow control statement can be given as,

If ((*Better input image quality*) && (*Better Character Recognition Methodology*)) then

Better character recognition accuracy.

else



Fig 1.6: Different types of OCR

#### Attributes of Indian scripts

Indian languages have mainly common alphabet, though they use many forms to express it. The alphabet has vowels, consonants and a rich combination of them gives a wide range of character forms. Indian scripts are not case-sensitive. Many Indian scripts are written from left to right associatively except Urdu script which is written from right to left associatively [16]. In general, some scripts like Bengali, Hindi, and Assamese have horizontal and vertical linear features, while others like Telugu, Tamil and Malayalam have complicated curves and strokes. In India, there are eighteen official languages, namely Assamese, Bangla, Kannada, Kashmiri, Malayalam, Marathi, Oriya, Punjabi, Rajasthani, Sanskrit, English, Gujarati, Hindi, Konkani, Nepali, Tamil, Telugu and Urdu [17]. Now a couple of other languages are also added to the list.

One hundred rupees एक सौ रुपये একশ টাকা એકસી રૂપિયા ಒಂದು ನೂರು ರೂಪಾಯಿಗಳು بر مرص ال एक बिए ठिल्ल। ਇਕ ਸੌ ਰੁਪਏ நூறு ரூடாய் నూరు రూపాయలు بر ر ر

Fig: 1.7 Examples of 12 Indian scripts: Top to bottom: English, Devnagari, Bangla, Gujarati, Kannada, Kashmiri, Malayalam, Oriya, Gurumukhi (Punjabi), Tamil, Telugu, Urdu. All lines have same meaning.

Many researchers have done some studies on this emerging field of handwritten character recognition system and we have arranged all those studies below in ascending year wise.

Some previous research studies on the HCR System from the Period of 1991 to recent years Turk M and Pentland A, [18] had developed a feature extraction concept that utilized Eigenfaces for Recognition. Jacobs R A et al., [19] proposed a model for modular neural architecture which has multiple expert networks and a porting network. In class modular model one high complexity task spreads into a number of multiple subtasks and each subtask is assigned to an expert network. O.Matan et al., [20] studied and modelled segmentation concept on the basis of vertical cut which analyzed vertical projection of the picture in order to segment the ZIP codes of places or locations. Cheriet M and Suen C Y,[21] focused on pre-processing concepts as it is necessary to work out document image analysis operations prior in recognizing the text in scanned documents. Cardot H et al., [22] proposed a static signature verification system by co-operative neural network architecture (CNNA).During scanning process of the text some noise like gaps and bumps in lines, disjoint lines were found. Serra on morphological filtering where some noise removal methods [23] carried out research were discussed. Bimbo a D et al., [24] studied OCR which recognizes low-quality images by deformation of elastic templates. Chen M Y et al., [25] developed a method which recognizes offline handwritten words using a Hidden Markov Model (HMM) type stochastic network. Trier D and Jain A K, [26] focused on goal-directed evaluation of binarization methodology which is a spatial domain approach required for compression. This approach applies a concept called thresholding which minimizes the storage requirements and helps in increasing the speed of processing by converting the color (R-RED, G-GREEN, B-BLUE) or gray-scale pictures to binary by using a threshold value. Bramall P E and Higgins C A [27] derived a method that recognizes the cursive type of handwriting from scanned documents based on human reading Models. Bauer F and Wirtz B [28] designed a model based on parameter reduction and personalized parameter selection for automating signature verification process. Chen H et al., [29] proposed a piece-wise linear modulation method for handwriting character recognition. Dehghan M [30] defined a model that performs the task like signature verification using shape descriptors and multiple neural networks. Bouletreau V et al., [31] shaped a model to recognize handwriting text characters and signatures of individuals to analyze the unique nature of writing, having application in the digital forensic analysis. Kim et al., [32] found out a model for handwritten character recognition systems where the post-processing stage of the handwriting character recognition system was discussed. Coates M et al., [33] developed an automatic reading of cursive scripts using a reading method and perceptual method. Morita M et al., [34] defined a method which used mathematical morphology and weighted least squares to do corrections of handwriting baseline skew. Lee S W and Kim S Y [35] brought out a new type of cascade neural network (NN) to train the spatial dependency in connected handwritten numeral characters, which actually extended from the multilayer feed-forward neural network to improvise the discrimination and generalization power. Nishimura N et al., [36] designed a model which is for offline character recognition using HMM by multi-directional feature extraction and voting with bagging algorithm. Atul Negi et al., [37] proposed an OCR system for Telugu script. The two important features of this system are practicability and simplicity. The connected component algorithm used for segmenting words into recognizable units and the template matching used to recognize the components. Marti U V and Bunke H [38] studied the IAM-onDB an On-line English sentence database acquired from handwritten text on a whiteboard for off-line handwriting character recognition. Tomai C et al., [39] focused on transcript mapping for recognizing historic handwritten characters of document images. Bunke H [40] highlighted the state of the art in offline Roman cursive handwriting recognition where the input was an image of a numeral or a digit, a word or some text or pattern and the system produced an ASCII transcription. Deepu V et al., [41] concentrated on line Handwritten Character Recognition of the Tamil language using Principal Component Analysis (PCA). The input was a temporally ordered sequence of (x,y) pen coordinates with respect to an isolated character obtained from a digitizer. Zhixin Shi et al., [42], developed image enhancement methods for historical palm leaf images. The algorithms were based on background normalization methods for improvising grayscale images. The enhancement of color images of palm leaf was done by applying the algorithms to the component color channel images. H. Swethalakshmi et al., [43] Designed a system for recognition of online handwritten characters for Indian writing systems, represented as a sequence of strokes whose features were extracted and classified by SVM. Results have been presented after testing the system on Devanagari and Telugu scripts. Hanmandlu M and Ramana Murthy O V [44] developed a fuzzy method to recognize handwritten numeral characters. Shaw B et al., [45] proposed a method based on continuous density HMM to recognize a string. This is a feature extraction approach which uses the histogram of chain-code directions in the word image, scanned from left to right with the help of sliding window, as the feature vector. Durgesh K et al., [46] carried out a comparative study using different kernel for Data Classification using SVM. T.Sitamahalakshmi et al., [47] conducted functions performance comparison of Radial Basis Function Networks(RBFN) and Probabilistic Neural Networks for Telugu Character Recognition, presented two classification models i.e. radial basis function networks, probabilistic neural networks. The accuracy of all the classes was above 90% in both the methods. Pradeep J et al., [48] constructed a diagonal based feature extraction for handwritten alphabet recognition system using Artificial Neural Network (ANN). Chandra B V et al., [49] carried out a script independent approach to recognize Telugu and Devanagari handwritten numeral characters with probabilistic neural networks (PNN). Pirlo G and Impedovo D [50] done Fuzzy-Zoning-Based Classification to recognize Handwritten Characters. Shrivastava S and Singh M P [51] focused on the performance evaluation of feed-forward neural network with soft computing techniques to recognize handwritten English alphabet characters. Siddharth K et al., [52] suggested a zone-based feature extraction method to recognize the numerals where the densities of object pixels in each zone have been calculated. The image is partitioned into  $4 \times 4$  zones to enhance accuracy, zones are further partitioned into  $6 \times 6$  and can be extended to a dimension of  $8 \times 8$  where 116 features had been extracted. Nearest neighbour classifier had been used to classify and recognize the numerals. Dash Tand Nayak T [53] studied Non-Correlated character recognition using ANN which is an offline method and does not possess any linear relationships among the characters. The accuracy obtained in this Nayak T [54] developed an Artificial Neural Network (ANN) having method is 78%. Dash T and single output neuron which shows the tested character belongs to a particular cluster, using 'C' programming language and obtained an average accuracy of 70.32%. Patel D K et al., [55] worked on recognition of handwritten Characters using multi-resolution technique and Euclidean distance metric. Sahu V L and Kubde B, [56] developed a method using segregated English alphabets. In this method, Diagonal feature extraction scheme had been used for recognizing the offline handwritten characters. Panyam Narahari Sastry et al., [57] done Telugu Handwritten Character Recognition Using Zoning Features, the recognition accuracy was 78%. Sunitha Anne M.O.Chacko et al., [58] had done survey on Offline Handwritten Character Recognition on South Indian Scripts. Konkimalla Chandra Prakash et al., [59] developed OCR for Telugu: Database, Algorithm and designed an android application for ease of use. Ch.N.Manisha et al., [60] studied role of Offline Handwritten Character Recognition System in various Applications, Considered 7 applications for study. N Prameela et al., [61] proposed a very comprehensive and practical OCR system for Telugu language. This system is shape and font dependent that requires pre-processing and feature extraction.

#### Conclusion

It has been observed that researchers carried out different types of approaches during the last twenty plus years and suggested many ways for pre-processing, segmentation, recognition and post-processing. The studies during the recent years are based on diagonal based feature extraction, zone-based method, distribution based method, sliding window, freeman-chain-codes, and Eigenvalue. Many studies were conducted on different scripts like English, Devanagari, Bangla, Gurmukhi, Tamil, Telugu, Chinese, Japanese, Kanji, and Arabic. This paper is to generalize the survey and to brief the achievements of the previously focused work by researchers. Many studies were on limited data set or data set for some characters in Telugu language. Some have high time complexity for recognition. Finally, research on Telugu handwritten character script recognition can be moved ahead by taking high data set for a maximum number of characters and by using hybrid character recognition algorithms with best case time complexity.

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