

A Survey on Recognition of Offline Handwritten Words

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Abstract - Handwritten Word Recognition (HWR) is one of the attractive and challenging research areas in the field of pattern recognition. Pattern recognition is a type of machine learning it focus on recognizing the pattern and regularities in the data. HWR is challenging task as there is no constraint on human handwritten style, size, variation in angle and shape of the letters. As opposed to the character recognition in which each character in each word is recognized, in HWR each word is treated as individual entity and recognizes the word from the overall shape. HWR are used in document verification, forensic science, historical manuscript etc. This paper survey of the major works on offline handwritten word recognition with the various filters, classifiers along with their corresponding performance. Major works done in English, Arabic, Hindi and other scripts are addressed in this paper.

Keywords: HWR; filters; classifiers

I. INTRODUCTION

Handwritten Word Recognition (HWR) is the conversion of handwritten text on the image into computer readable format. Document image processing involves handwriting recognition and HWR can be classified into two methods, namely offline and online recognition, based on the format of the handwriting inputs [1].

In offline word recognition only handwritten text scanned image is an input to HWR system. Online word recognition will give the temporal information such as position and velocity of the pen along its trajectory to the HWR system.

Mainly there are two approaches identified in HWR namely segmentation approach and segmentation-free approach. In segmentation approach requires that each word has to be segmented into characters and in segmentation-free approach involve the recognition of the whole word. Line and word segmentation is used in segmentation-free approach to create an index based on word matching [2,3].

This paper convey about the offline handwritten word recognition system that involved with 6 steps shown in fig 1.

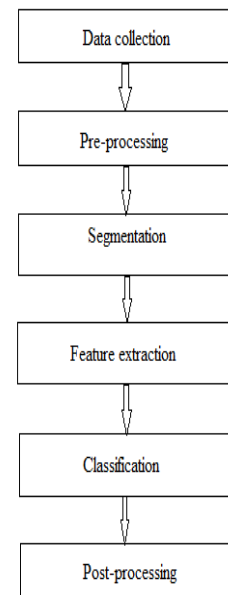


Fig1. Major steps of HWR system

A. Data collection

Handwritten documents are collected from different writers irrespective of age groups. The collected documents are scanned through scanner like HP scanjet G2410 to obtain digitized image. There are many databases available in internet like IAM Historical Handwriting Database, IFN/ENIT, IRONOFF etc.

B. Pre-processing

Scanned document is stored as a binary image in the format JPEG, GIF, TIF etc and that is an input to pre-processing. The pre-processing applied to the scanned document to reduce noise in the image using filters like Median filter, Morphological filter, Gaussian filter etc. Many operations are applied in pre-processing for normalization, slant correction, stroke thickness normalization, baseline detection, contour smoothing etc.

C. Segmentation

Segmentation is used in order to separate text from graphs, images and lines. In segmentation based approach, the word is separated into character for recognition. In segmentation free approach whole word is consider for recognition without separate the word into character.

D. Feature Extraction

Feature extraction is finding the set of parameters that define the shape of a word. There are many features considered namely Structural features, Statistical features, Selected features, Density features, Contour features etc.

E. Classification

The classification is the process of identifying each word and assigning it to the correct word class by using classifiers like Neural networks, Hidden Markov Model (HMM), Support Vector Machine (SVM), Nearest Neighbor Classifier etc based on extracted features.

F. Post-processing

In post-processing one can improve handwriting recognition rate by relying on contextual post-processing or lexical post-processing, using which recognition rate can be increased by resolving ambiguities [4].

II. REVIEW

- Yousri Kessentini et al. proposed approach for multi-script handwritten word recognition. This approach used multi-stream HMM and to combine two low level feature streams namely density based features and contour based features extracted from two different sliding window widths and upper and lower contours respectively. They use IFN/ENIT benchmark database for Arabic script and IRONOFF database for Latin script. This approach achieved 86.2% and 81.2% recognition efficiency in IFN/ENIT for contour and density features respectively, 91.6% and 90% recognition efficiency in IRONOFF-196 for contour and density features respectively [5].
- Douglas J. Kennard et al. proposed a wordwarping for offline handwriting recognition. To compute 2-D geometric warps they used automatic image morphing and that align the strokes of each word image with the strokes of word images of training examples. On two own datasets got 88.77% and 89.33% recognition accuracy. These are increases of 7.89% and 17.16% than the 1-D DP approach [6].
- Anuja Naik, M S Patel proposed a method that performs preprocessing steps like skew and slant correction. To find skew of a word the least black pixel in every column are determined, the input image is rotated as per rotation angle to remove skew. Next slant is estimated by finding contour of threshold image and chain of connected pixels representing edges of stroke. Orientation of those edges close to the vertical is considered as slant. Upper black pixels and Lower black pixels are used to determine Upper and Lower baselines respectively. In Skeletonization, Input image is first smoothed by convolution with a Gaussian filter to remove noise. Next iterative erosive, thinning algorithm is applied to reduce width of strokes to width of a pixel. They used structural features for feature extraction and Euclidean distance method is applied for classification that produces single matching word having minimum difference value [7].
- Soulef Nemouchi et al. presented a Arabic word recognition application to handwritten Algerian city names for that they used by classifier combination. Feature extraction and classification phases are focused here. In this system, they retained three feature sets and four classifiers used namely K Nearest Neighbor algorithm (KNN), Fuzzy C-Means algorithm (FCM), K-Means algorithm and Probabilistic Neural Network (PNN). Simple vote and weighted sum methods are combined for classifiers results and they got 80% of recognition efficiency [8].
- Ahlam Maqqor et al. presented offline handwritten Arabic word recognition used by multi-stream HMM approach. Two methods are used to extract a set of simple statistical features. From a window which is sliding long that text line right to left and the approach Vertical Horizontal 2-dimensional (VH2D). Thresholding or binarization, normalization, filtering, smoothing and skew detection operations are applied to text image to extract the word feature simplify. Multi-stream approach is used and that involved multi-classifiers, multi-model approach, multi-band approach and multi-stream formalism. Hidden Markov Model used for recognition and they achieved recognition rate of 78.2% for sliding window, 76.6% for VH2D and 83.8% for combination of both [9].
- Youssouf Chherawala, Partha Pratim Roy and Mohamed Cheriet proposed feature design for offline Arabic handwriting recognition. They evaluate the automatically learned features performance and that is compared with handcrafted features. The recognition model is based on the connectionist temporal classification (CTC) neural networks and long short-term memory (LSTM). HMM model is used as classifier for this method. Multidimensional LSTM network is able to automatically learn features from the input document image. The IFN/ENIT database used as benchmark for Arabic word recognition [10].
- Silky Bansal, Munish Kumar, and Mamta Garg proposed a approach for recognize handwritten city name written in Gurumukhi script for postal automation. Used holistic approach in which they considered the whole word. For recognizing words they used a tree-diagonal feature extraction technique in which a tree structure comprises of zoning and diagonal feature extraction technique used with SVM and k-NN classifiers. They had collected 18,000 samples of handwritten city names in Gurumukhi script from 60 different writers. Maximum recognition accuracy of 90.8% achieved with SVM classifier [11].
- Anne-Laure Bianne-Bernard et al. proposed HMM modeling with dynamic and contextual information for HWR. For modeling the contextual units, a state-typing process based on decision tree clustering is introduced here. Then applied this modeling to the recognition of handwritten words and experiments are conducted on three publicly available databases that are Rimes, IAM, and OpenHart [12].

- Ankush Acharyya et .al proposed HWR holistic approach using MLP based classifier. The holistic approach in handwritten word recognition treats the word as a single, indivisible entity and attempts to recognize words from their overall shape. Neural network based classifier used to classify word images belonged to different classes. CMATERdb1.2.1 dataset used in this approach. The best-case and average-case performances of the technique for data set are 89.9% and 83.24% respectively [13].
- B Gatos et .al proposed efficient off-Line cursive handwriting word recognition. This approach is combination of two different modes of word image normalization and robust hybrid feature extraction. The pre-processing is used in order to correct word skew, word slant and normalize the stroke thickness. Two types of features are combined in a hybrid fashion. The first one divided the word image into a set of zones and calculated the density of the each zone. In the second type of features, calculated the area that is formed from the projections of the upper and lower profile of the word. They used IAM database and got 80.76% recognition rate [14].

TABLE 1: Brief description on survey.

Authors	Script	Filters	Classifiers or Classification Method	Features	Database	Accuracy
Yousri Kessentini et .al	Multi-script	-	HMM	Density and Contour Features	IFN/ENIT and IRONFF	average 83.7% for IFN/ENIT and average 90.8% for IRONOFF-196
Douglas J. Kennard et .al	English	-	2D-Warping and Distance Map	-	Own Dataset	88.77%
Anuja Naik, M S Patel	English	Gaussian Filters	Euclidean Distance	Structural Features	Own Dataset	-
Soulef Nemouchi et .al	Arabic	-	FCM ,K-mean, KNN and PNN	Global Structural Features	Own Dataset	80%
Ahlam Maqqor et .al	Arabic	Median Filters	Sliding Window and VH2D approach	Statistical Features	Own Dataset	83.8%
Youssef Chherawala et .al	Arabic	-	HMM	Distribution, Concavity, Visual-descriptor-based and Automatically learned features	IFN/ENIT	89.1% for MDLSTM
Silky Bansal et .al	Gurumukhi	-	SVM and KNN	-	Own Dataset	90.8%
Anne-Laure Bianne-Bernard et .al	Latin and Arabic	-	HMM and Nural Network	Geometric features	Rimes, IAM, and OpenHart	-
Ankush Acharyya et .al	English	-	MLP	Holistic features	CMATERdb1.2.1	Average of 83%
B Gatos et .al	English	-	Minimum Distance Classifier and SVM	Hybrid features	IAM	80.76%

III. APPLICATIONS

There has been significant growth in the application of off-line handwriting recognition during last decade.

- Signature Verification
- Forensic Science
- Bank Check Recognition
- Handwritten Address Interpretation
- Historical Manuscript conversion etc

IV. CONCLUSION

Handwritten word recognition is challenging task and it requires higher level of accuracy. Most of the techniques used for HWR are script dependent and holistic approach is avoid the challenges of character segmentation. Which are the features extracted those are used in classification and classifiers are used for word matching based on extracted features. Some authors used combination of classifiers in classification method. Most of the work done in this area achieved more than 80% of accuracy but still an efficient HWR for the recognition of handwritten words does not exist. Applications of HWR are extent and used in many fields.

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