

# A Review on Analytic and Holistic Approaches for Offline Handwriting Recognition

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**Abstract** - The digitalization of handwritten text is useful in many ways. It has a lot of applications especially in many government organizations like banks, post offices, archeological departments etc. But handwritten recognition is a difficult process. It faces a lot of challenges as every individual has a unique writing style. The earlier methods of handwritten recognition are tedious. But due to the advancement in deep neural networks the process has reduced its complexity compared to the former methods. Mainly there are two approaches for handwritten recognition. They are holistic and analytic approach. This paper presents a detailed review of research work carried out for handwritten recognition using these two approaches.

**Key Words:** Handwritten Recognition, Holistic approach, Analytic approach.

## 1. INTRODUCTION

The age of digitalization has resulted in a technology driven economy where digital documents have got many advantages compared to the preferred medium for content storage. It provides security, ease of access, keyword-based search, etc. Rather than storing the data on papers, it can be stored safely and can be easily accessed when the document is digitalized. Hence, most of the organizations has undergone a steady transition from paper-based to electronic records. Such transitions are beneficial for many government organizations which handle a lot of handwritten documents. Some examples are archaeological departments which process substantial historical data in the form of manuscripts, post offices, banks etc. Other applications include automatic number plate recognition, preservation of degraded documents etc. Thus the handwriting recognition system has become a hotspot area of research and the Government has also encouraged digitization of records in various departments. Therefore, handwriting recognition is of prime importance.

The aim of a handwriting recognition system is to convert human readable characters in a digitized sheet of paper and convert it into a machine editable form. It can be of two types: online or offline. In an online character recognition system, the data is captured simultaneously when the user

writes on the screen of an electronic device, which is capable of handwriting recognition. The real time transformation of characters is taking place in online mode. In an offline system, scanner captures the data after it is inscribed on the paper. Online word recognition depends on stroke direction and stroke order. Offline recognition of words uses images scanned from the handwritten documents and, therefore, it is more difficult to recognize. The recognition of handwritten text is very much difficult compared to printed text. In printed text the variation in between a character is negligible. But it is not the same in the case of handwritten texts.

There is a huge variation in handwriting. Writing style of an individual depends upon a number of factors like emotion, mood, age, health condition etc of the writer along with the variation provided by the pen used. All these factors influence writing style. Generally, offline handwritten word recognition can be approached in two ways: analytic approach and holistic approach. In the analytic approach, words are divided into characters or sub characters and then each character is identified sequentially. A lot of word recognition systems have been developed based on this approach. One of the major difficulty in this approach is to discover suitable segmentation points from the handwritten cursive words. But in holistic approach there is no need for character-segmentation. It considers the word as a whole unit. The features are derived directly from the word images in this approach, after that, it is recognized by classification methods. Holistic approach may arrive at good results even when the writing is too poor. But it has limitations like it is confined to a fixed size vocabulary.

Character recognition is one of the most interesting research areas in the pattern recognition. Various approaches [analytic and holistic] of handwritten character recognition are discussed here. It plays an important role in the advancement of an automation process. It can also improve the interface between man and machine.

## 2. METHODOLOGY

Generally handwriting recognition is divided into six phases: image acquisition, pre-processing, segmentation, feature

extraction, classification and post processing. Fig.1 illustrates the methodology.

### 1. Image Acquisition

The database is provided as scanned Image. The database is given by collecting word or character samples from different individuals in an A4 sheet sized paper. Then the paper is scanned and the word sample or character is cropped to prepare the database for the experiment. Input images for handwritten characters can also be taken by using photographs.

### 2. Preprocessing

The image has to be preprocessed to remove noise. Preprocessing normalize strokes. It also removes variations which otherwise complicate recognition and reduces the recognition rate. These distortions include the irregular size of text, missing points during pen movement collections, jitter present in text, left or right bend in handwriting and uneven distances of points from neighboring positions. The five common steps in preprocessing are size normalization and centering, interpolating missing points, smoothing, slant correction and resampling of points. In this stage background noises up to certain intensities can be identified and removed.

### 3. Segmentation

Segmentation is done to separate individual characters from the document. At first the lines are segmented using algorithms like row histogram or horizontal projection profile. The main challenges in line segmentation are skewed lines, fluctuating lines, touching lines. After line segmentation, word segmentation is performed using column histogram or vertical projection method. Finally, character segmentation is performed to extract the characters.

### 4. Feature Extraction

After separating characters' unique features of each character has to be identified for classification. Different feature extraction techniques are present. Linear Discriminant Analysis (LDA), Chain Code(CC), Scale Invariant Feature Extraction (SIFT), histogram, zoning, Principle Component Analysis (PCA), Gradient based features are some of them. These features are used to train the system for further classification.

### 5. Classification

Once the features are extracted, classification is performed. In this stage the characters are categorized and are assigned to the correct class. Most of the classifiers are distinguished based on their learning approach. Some of the learning approaches are decision based learning, probabilistic learning, function based learning and lazy learning. Function based learning is adopted by Multi-layer perceptron (MLP) and support vector machine (SVM). K-nearest neighbor (KNN) and KStar classifiers use lazy learning. Random Forest is associated with decision based learning. With the improvement in machine learning, neural networks are mostly used for classification.

### 6. Post-processing

In post processing misclassified results are corrected by applying linguistic knowledge. It is the processing of output through shape recognition. Two main tasks of post processing are output generation and error correction. The following sections presents various research works using the analytic and holistic approaches for handwritten word recognition.

## 3. HOLISTIC APPROACH

In Holistic approach, a word is considered as an indivisible unit. The features of the entire word image are considered for the recognition purpose. It is a segmentation free approach. It prevents problems like word segmentation ambiguity, variations occurring in segment shape which generally appears in analytical approach. Fig.1 illustrates the block diagram of holistic approach.

In [6] a holistic approach to recognize handwritten city names using elliptical features and MLP based classifiers are proposed. A set of 65-element elliptical features are extracted from the word image. Hypothetical ellipse is fitted on the word image. 13 global feature values are extracted from each word image. As each words differ in shapes and pixel distribution in different sub regions it is helpful to distinguish a particular handwritten word from other by computing its elliptical features. Suitable classifier was selected based on their recognition accuracy on test data set. Five well known classifiers like Support Vector Machine, Bagging, Naive Bayes, Multilayer Perceptron (MLP) and Dagging are used for testing. Best recognition accuracy was shown by MLP. They also used 3-fold cross validation method for the recognition task. Even though word images are properly classified some word samples are not classified properly because of skewness. It was also found that words belonging to different classes have almost same pixel distribution.

In [15] shape based feature descriptor known as tetragonal feature is used. In addition, Vertical pixel density histogram based feature and Elliptical feature are also used. It helps in capturing the shape or geometric nature of a handwritten word image. Both fivefold and threefold cross-validation scheme using both MLP and SVM classifiers are employed for recognition task. The system shown better recognition accuracy for most of the word classes except a few. Misclassifications occurred due to spelling disparity, complex shape and similar shaped words from different classes.

For extracting the features, gradient orientation information from each of the word images are extracted in [11]. Each word image is initially segmented hypothetically into equal number of grids. Gradient based features are extracted from each of these grids. Histogram of Oriented Gradients (HOG) feature descriptor is used as a local feature extractor here. It extracts local gradient information of an object at its preliminary stage.

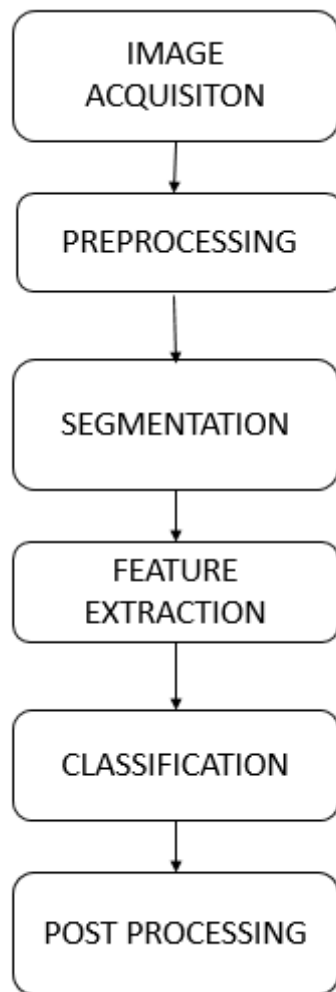


Fig. 1. Block diagram of holistic approach

Sequential Minimal Optimization (SMO) is chosen as the classifier. Even though the recognition accuracy was best in 5-fold cross validation it suffered from a number of limitations. It took more time to train the classifier as the length of feature vector was large. To overcome this, some feature dimension reduction techniques have to be employed. For misclassified words zoning scheme around the structurally similar regions can be used.

Low level features such as density, pixel ratio, area, centroid, aspect ratio, projection length and longest run are extracted from the word image in [12]. The features are extracted from entire word image or sub-images which is generated hypothetically. From each word image 89 element feature vector is extracted. The best accuracy rate was found using MLP classifier in 7-fold cross validation process.

In [10] the word image is scrambled using Arnold transform. Directional features are extracted in this system. Hough transform is used to derive directional features. The directional features depend on the stroke orientation distribution of cursive word. Arnold transform followed by Hough transform is used to estimate stroke orientation. A multi-class Support Vector Machine (SVM) is used for

classification of cursive words. Method evaluation is done using CENPARMI English legal amount word database.

An efficient multiple classifier system for Arabic handwritten words recognition was proposed in [13]. Chebyshev moments with statistical and contour based features are used for word recognition. Classification was performed using a combination of different classifiers such as Support Vector Machine, Multi-Layer Perceptron and Extreme Learning Machine.

The H-WordNet model using neural network is proposed in [16]. It consists of 5 learnable layers, four convolutional layers and one fully connected layer. The main advantage of using neural network is that, the manual feature extraction can be avoided. Dimensionality reduction and classification can also be eliminated. This model learns features automatically. This can save a lot of time. It uses back propagation algorithm. It obtains a stable system for handwritten word recognition. To train the parameters the stochastic gradient descent with momentum optimizer has been used. The model can be retrained for the recognition of word images which is written in other scripts. Approximately 0.8 million parameters are required for this model which are comparatively lower than the existing CNN models.

#### 4. ANALYTIC APPROACH

This is a segmentation based approach. The word is segmented into basic component or character set. The feature of each character is used for classification. Fig.2 illustrates block diagram of analytic approach.

In [17] statistical features are extracted. Two Indian scripts are considered. First the skew present in the handwritten words is detected and corrected. After preprocessing headline estimation is performed. Words are then segmented into meaningful pseudo-characters. Then 3 different statistical features are extracted. For classification, off-the-shelf classifiers are used and the recognition accuracy is compared to find the best combination. They also used convolutional neural network-based transfer learning architectures and compared it with the conventional ones. Seven pre-trained architectures, namely AlexNet, Resnet18, Resnet50, VGG-16, Google net, Densenet201 and VGG-19 was trained. This method was able to handle slant present in the handwritten words. It also detected the headline even though it is discontinuous.

In [7] efficient character segmentation method was proposed for Hindi language. Cursive writing of the script is also considered. Based on structural patterns, segmentation is performed. Three phases are present. In the first phase the header line is extracted. The upper strip is delineated from the remaining part. This results in middle zone and bottom zone components which is vertically separated. It could be shadow characters, touching characters, characters with lower modifier attached to it, conjuncts or a combination of these.

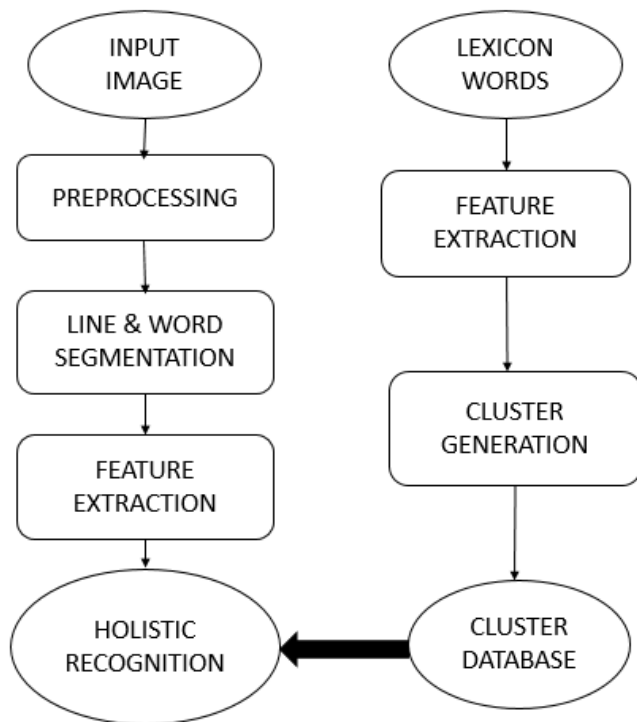


Fig. 2. Block diagram of analytic approach

In the second phase the segmentation of upper modifier is done by collecting the statistical information about intermediate individual components. In the third phase by using these statistical information, components in which further segmentation has to be performed is selected. It leads to the separation of lower modifiers from the middle zone components. This method is able to handle skewed header lines and variations in writing style.

In [8] a technique for segmentation of words and characters is proposed for Devanagari scripts. The method adopted is Pixel Plot and Trace and Re-plot and Retrace (PPTRPRT). It extracts text region from the document. Along with skew and de-skew operations, iterative processes for segmentation of lines take place. These outcomes from iterations are used in word segmentation which is pixel-space-based. After word segmentation the characters are segmented from the words. The PPTRPRT technique encompasses various dispensations to segment characters from handwritten script. It also performs various normalization steps to allow deviation in pen breadth and slant while writing.

Wavelet features are extracted in [5]. This method consists of two phases: a feature extraction stage and a classification stage. Feature extraction is done by extracting Haar wavelet transform. Support Vector Machine classifier is used for classification. The input image is converted to grayscale image. Size normalization is performed. The Haar wavelet decomposition is applied using Haar analysis filter to each character image. It yields four sub images at LL1, LH1, HL1 and HH1. The next level decomposition yields an image at LL2, LH2, HL2 and HH2. Decomposition is performed upto

third level. The extracted feature vector is then trained and tested using Support Vector Machine classifier.

In [3], the proposed algorithm recognizes characters mainly based on the lines and strokes contained in them. The OCR process consist of three stages: Pre-processing, Skeletonization and Recognition. In pre-processing, the input image is scanned and segmentation is done to separate characters. In skeletonization, digital image is transformed into a set of original components. One-pixel thick skeleton of the character is obtained. Then position analysis is done and also the count of the horizontal and vertical lines are obtained to extract the features. The features of the characters are formed by applying some functions in the skeletonized and segmented characters which calculate the number of horizontal and vertical lines. The characters are classified into different groups by using the count of horizontal and vertical lines. In recognition stage, classification is done based on their feature.

Two dissimilar classifiers are used in [9]. It is known as ensemble method where multiple classifiers are used to solve a particular problem. It can improve the performance of the system. SURF feature and curvature feature and diagonal features are extracted. Two classifiers, Support Vector Machine and neural network are used. Support Vector Machine is trained with SURF feature and curvature feature. Neural network is trained using diagonal feature.

In [4], fuzzy membership function based approach is proposed. Character images are normalized initially. Fused image is formed from the images of each character. Bounding box around character is determined by using vertical and horizontal projection of character. After cropping image to bounding box, it is resized. Thinning is performed in the next stage. Similarity score of test image is matched with fusion image. Finally, classification of characters is performed.

## 5. CONCLUSION

The two general approaches i.e., analytic and holistic approaches of handwritten word recognition system have been discussed. Many research papers based on these two approaches are reviewed in this paper. As handwritten script recognition is a challenging and emerging area, still researches are going on, to find a system with optimum solution. In literature only a few works are present which incorporate more than one language. So, for real time use, a handwritten script recognition system, which is capable of recognizing multilanguage is needed.

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