



## Hand-Written Text Recognition Methods: Review Study

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### ABSTRACT

The great and rapid development of information technology, Artificial Intelligent, and its daily uses in all areas of our life, requires keeping up with distinguished software tools especially those used in data entry. The handwritten text is an important example to speed up the process of using any software. Researchers around the world provided many techniques to convert handwritten text into an understandable form for the computer system. This paper provides a study about used methods and approaches for Handwritten Text Recognition (HTR), and general overview of the properties of HTR approaches, and the advantages and disadvantages of each one.

## 1. INTRODUCTION

Computer vision is a very important field of Artificial Intelligence (AI) that enables smart software systems to extract significant information from images, and other graphical data forms such as texts, personal photo, fingerprint, health information about the patient, or about geographical terrain, est. For example the deep neural networks can be used even for auscultation in physiological diseases [1]. All types and models of Artificial Neural Network (ANN) can be used sufficiently for image processing and related applications. But the handwritten text in the images is still a challenge for computer vision software systems. One of the most important computer vision issues is how an image can be classified and recognized, especially if it contains a handwritten text (HWT), because the HWT is different from one person to another, and the language factor also has affecting on the recognition process [2]. The HWT can be recognized offline or online, the offline method extracts text from the image and converts it into digital form or ASCII code; the online method converts text written by computer user using special devices. Nowadays there are many number of methods (traditional and modern) used to implement handwritten text recognition (HWTR), where traditional methods focus on segmentation of each character, the other one focus on detecting and recognizing all text characters in one segmented part using (ML) machine-learning algorithms. In this research study we are trying to explain these methods and show the properties of each one.

The HTR Challenges [3]: Ambiguity and big variability in handwriting from one person to another one, inconsistency in handwriting style, decreasing source document quality over the time, often the text is written on a line that is not strictly straight, difficulty of collecting and preparing high quality dataset, handwritten text can have changeable rotation, and the separation and recognition of the handwritten text letters is complicated especially for some language such Arabic.

In the following sections, the section 2 provides a motivation and research significant, the related works and literature review will be provided as the third section, the

section four will discuss the different approaches used for handwritten recognition, and section five will provide discussion and advantages and disadvantages of the methods listed in section 4, finally the conclusion of this research will be discussed in the last section.

## 2. MOTIVATION

It is not new to anyone when we say that data entry for computer systems is a very important, tiring, and time-consuming matter, and these days with the development of new input technologies that depend on touch screens and digital devices. The matter of recognizing handwritten text becomes very important. Hence the need for special intelligent software systems used for Handwritten Text Recognition which will automatically detect and extract texts and convert characters into human-readable form. In this research, we provide a review study of HWT recognition approaches required for AI developers to help them in their works to produce quality AI software systems.

## 3. LITERATURE REVIEW

In the era of advancements in Artificial intelligence and through the last twenty years, significant and very significant progress has been made in the process of detecting and recognizing handwritten text. The research related to HWTR using Deep Learning methods with TensorFlow software [4] focuses on transcription using scanned documents with handwritten text as an input to a neural network (NN). The training images with a text were taken from IAM dataset, the used NN was combined of three parts which are (CNN) Convolutional Neural Network, (RNN) Recurrent Neural Networks, and (CTC) Connectionist Temporal Classification, this research is dealing with one method that obtained more than 90% of accuracy.

The authors of review of techniques used to offline handwritten character recognition using NN [5] presented a comprehensive evaluation of various methods used in offline handwritten text and character recognition such as: pre-processing, image acquisition, segmentations, Classification, features extraction and recognition, it concluded that the accuracy of text recognition is depending on the kind of and nature of the input data (images) to be read and also by its goodness and quality. The researchers of “Handwritten Text Recognition and Digital Text Conversion” [6]: This work uses Neural Network to recognize text existing in the processed image as segmented word, it applied the IAM dataset for training phase. 75% of the words (previously used in training) were recognized correctly.

In the review work of HWR [7], the authors provided a very good conclusion about methods used to detect, extract and recognize handwritten text existing in different types of documents such as images, or video files, they actually discussed a lot of methods used for hand written text recognition such as: Line and Word Segmentation, Incremental and Semi Incremental Recognition Method, Part-Based Method, Slope and Slant Correction Method and many other.

One more comparative and analysis review study of part-based handwritten (PBHW) character recognition [8] introduces comparative performance and analyzing study experimentally for three types of PBHW character recognition methods which are class distance, single and multiple voting. As a result of this study the single voting achieved the lowest accuracy and the highest degree of accuracy was for the class distance.

A review study for English language recognition methods [9] was provided as significant work in handwritten text recognition, separated characters' styles give high accuracy but whole word recognition is not very high and it can be affected by the writing methods depending on the writer's style. For Arabic language witch is more complicated comparing to English, because there are no letter separation and the recognition process must go through word segmentation and word recognition in general, in this context the study [10] provides a good deep learning solution with 100% of accuracy (depending on their database used for training) using morphological gradient, and Multilayers Neuron Network.

#### 4. TYPES OF HANDWRITTEN TEXT RECOGNITION APPROACHES

##### 4.1 Convolutional Neural Network recognition

Artificial Neural Networks have many types such as Radial basis function, Feed-forward, Kohonen Self Organizing, Convolutional, Long Short Term (LSTM), Recurrent, and Modular [11]; all of these types were developed to process different types of problems. For example one of the most known types of ANN in deep learning called Recurrent (RNN), one of the specific RNN architecture is LSTM, it is used for processing sequential data to be able to generate output and identify temporal patterns. The research called “Effective offline handwritten text recognition model based on a sequence-to-sequence approach with CNN–RNN networks” [12] uses both CNN and RNN to recognize hybrid hand text recognition using the sequence-to-sequence approach (Seq-2-Seq), this recognition model extracts features from

handwritten text image, and use them as input for Seq2Seq model then pass the output to RNN and LSTM for achieving the graphical properties and features representing the characters existing in the text image. One more research “AHWR-Net: offline handwritten Amharic word recognition using convolutional recurrent neural network” [13] is focusing on the same methodology.

The researchers of “Handwritten Text Recognition and Conversion Using Convolutional Neural Network (CNN) Based Deep Learning Model” [14] used the handwritten text as a input picture, then converted it into digital text. Also they used CNN to studied classified properties and features of related entities collecting from many samples of the input image. The LSTM of this research was used as extension of RNN, and CTC used to process the text in different positions in the input image. Good results were achieved by this research using text images containing more than 100,000 words written by 600 different writers. In the research “Fast writer adaptation with style extractor network for handwritten text recognition” [15] very important proposal was discussed, it is focused on using deep learning method to process writing text style depending on text writer adaptation.

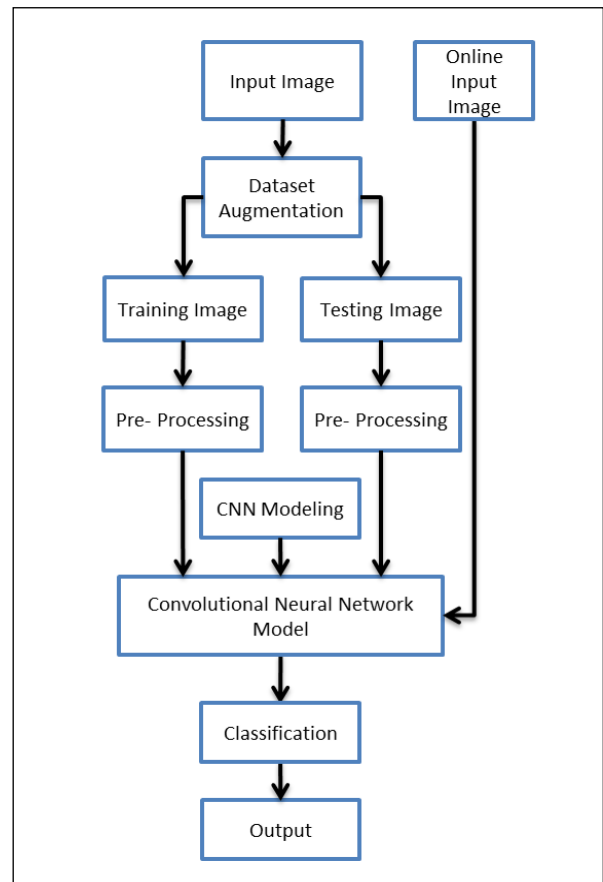


Figure 1. The CNN general structure

Generally, RNN, and LSTM types have a limitation, it can deal with one-dimensional data only, and it cannot process data from image directly. The multi-dimensional RNN can solve this limitation. Using deep-learning approach gives better accuracy, but it needs more samples for training, and it takes much time in training process [16, 7].

An important advantage of this approach: it is not depending on lexical segmentation and feature extraction manually; also can be used for recognition multiple languages

[17]). The CNN model is the most widely used model for HWTR, the input image should be pre-processed before entering to the CNN, through the following steps: crop or wrap the image in order to discard unimportant parts that do not contain important information, resize images to one size for all images [7, 18]. CNN excels compared to other ANN because it works very successfully with image and speech recognition, it consists of three main layers (Convolutional, Pooling, and Fully-connected). Figure 1 shows the general structure for CNN approach method [19].

#### 4.2 Semi incremental recognition approach

The incremental approach for handwritten text recognition can be used with busy and lazy recognition [16]. The Incremental learning algorithm can learn and achieve new additional knowledge and information using new dataset, and no need to access the used dataset in training phase; Acquired knowledge base will be preserved, and ability to accommodate new classes using new data [20].

Incremental learning process as shown in Figure 2 consists of following steps: 1) receiving stroke, 2) updating geometric features, 3) recognize the symbols according to the input stroke, 4) Update CYK table, Finally get the recognition output [21, 20]. By comparing Incremental method (IM) with semi-incremental (SIM) we found that SIM increases rate of recognition [22]. The main goal of SIM development is to make possible processing as much as possible while the user is typing [23], the main algorithm describing this method is shown in Figure 3 [23], it's a general method for semi-incremental recognition.

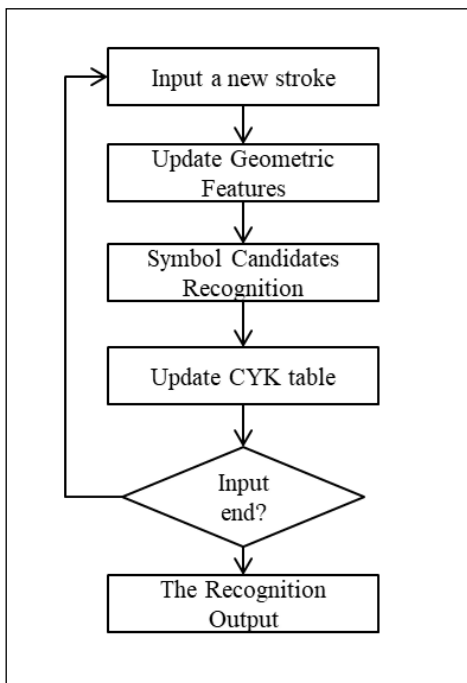


Figure 2. Incremental recognition flow

#### 4.3 Part based recognition approach

Generally, this method of recognition is organized in two steps, training and recognition steps [24]. It can be described in terms of the following properties: representation a single image using multiple key points; it is overlooked when it used to evaluate global features similarity, this issue will lead to

increasing resistance to variations of object display, and the similarity in the image depends on whether or not the image will be as a basic point, if the same then the image will be considered to be in the same class as Key point.” It has three sub methods: Single, Multiple Voting, and Class Distance [8]. The Part-Based benefits: possibility to recognize characters with ambiguity of their structure, because it does not depend on the global structure. It is applicable to recognize cursive scripts component character (that is make segmentation easier), and also It is applicable for scenery images containing characters, the characters can be detected and recognized. Part Based Recognition has three sub methods: Single, Multiple Voting, and Class Distance.

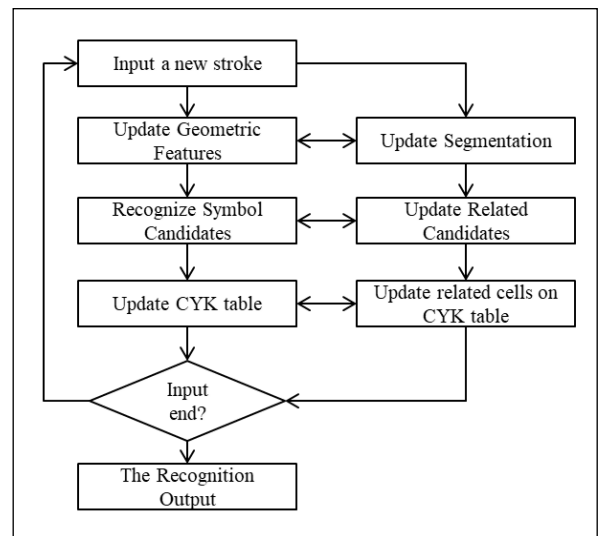


Figure 3. Semi-incremental recognition flow [23]

#### 4.4 Line and word segmentation recognition approach

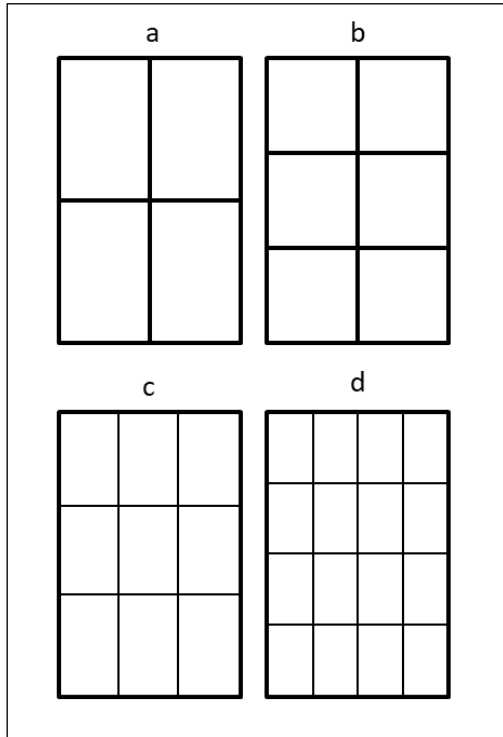
The segmentation the segmentation is not easy handwritten text recognition problem, because each person has own handwritten form, and writing slope factor is playing important role in recognition process in general, in this approach, text in the image can segmented based on line, word and character [25]. This method includes three steps of processing (pre, post, and Hough transform mapping) [26]. For an example the works provided by " Line and word segmentation of handwritten text document by mid-point detection and gap trailing" [27] and "Line and Word Segmentation of handwritten text documents written in Gurmukhi Script using midpoint detection technique" [28] present the word segmentation and text line existing in limited (unconstrained) handwritten pages using Horizontal Projection Histogram method to find out the middle points and gaps between text lines. A novel method for handwritten text line segmentation [29] was proposed as counting formulation, this method counts how many text lines from the beginning of the text at each pixel position. This solution provides direct prediction per-pixel text line number for a input image document using deep NN.

#### 4.5 Zoning recognition

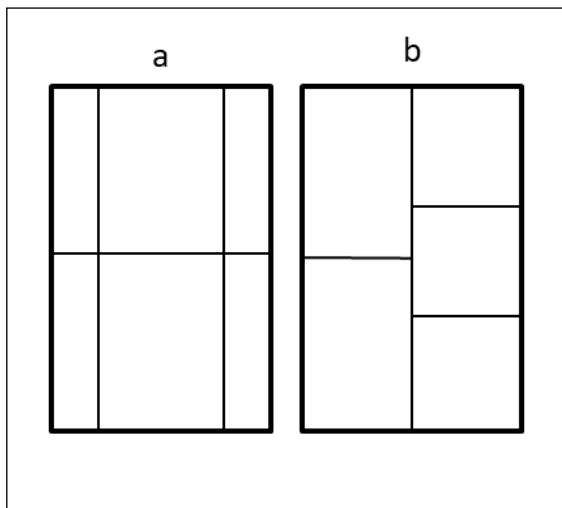
Zoning Recognition is one of the important pattern recognition methods, where the pattern image is split into a number of zones providing regional information; this method is very successfully for handwritten character recognition, it

can be implemented in two forms (static, and dynamic) [30, 31]:

- **Static Zoning:** in this method, the zones will be distributed uniformly, and of the same size, the accuracy will be higher by increasing the number of zones [31], as shown in Figure 4.
- **Dynamic Zoning:** The size of zones in this type is not the same, and the image is divided into non-uniform zones, as shown in Figure 5.



**Figure 4.** Static zoning



**Figure 5.** Dynamic zoning

#### 4.6 Ensemble recognition approach

This approach uses a new machine learning classifier called Ensemble Method; it is used to automatically generate multiple classifiers based on one class base [32]. The classifier of this method selects the best level of recognition as a feature; it improves the performance of prediction used in static-

learning techniques [33]. This method was used for Non-English languages such as Arabic and others, for example handwritten text in Bagala language was processed in the research work “Convolutional neural network-based ensemble methods to recognize Bangla handwritten character” [34], it achieved a good result by using classifiers of language characters and using CNN and shallow machine learning, and five of ensemble methods. Another work was implemented in “Ensemble methods for handwritten text line recognition systems” [35] for offline detecting of handwritten text by classifier and ensembles.

Generally, there are different types of ensemble methods [36], the methods are: Bagging is an abbreviation formed from the initial letters of other words and pronounced as a word, it was the first proposed method for ensemble approach. The second one is AdaBoost or Boosting is the most famous method, it has been used in many application domains, the third one is Random subspace method (RSM), in this method, for testing and training purposes, the RSM uses its individual classifiers to randomly select a fixed size subset of features from the main set of all properties and features.

#### 4.7 Slope and slant correction recognition approach

The writing style variation is affecting on recognition process, this method helps developers to avoid this issue, and the better slope correction increases the accuracy of handwritten recognition, and simplifies the process of segmentation [7, 37]. Using Slope Correction method the word can be evaluated using the baseline slope. There is no contribution of ascenders and descenders to the initial formulation; they will be thrown out as much as is achievable [7]. To enhance the basic slope it had been corrected by applying word rotation around the angle of inclination (slope). The baseline still used to estimate the word slope [38].

#### 4.8 Vertical attention network approach

The Vertical Attention Network (VAN) presented by research [39] uses a VAN which is free architecture “end-to-end encoder-decoder segmentation-free using hybrid attention” [39]. To avoid using any adaptation, it provides encoders to be able to recognize text in lines or paragraphs, these types of CN encoders are capable to process variant input images with different sizes, VAN discovers the end of the processed text paragraph, this issue leads to end of the recognition procedure itself.

The line segmentation method allows recognition of complex layouts including slightly willing strains. Further, it does no longer want pre-training and could without problems be used for entire web page textual content recognition. In contrast to widespread-step architectures, the Vertical interest network may be trained without label of line segmentation. In this case the VAN model will give better result of Character Error Rate comparing to the step model for prediction in short period of time and a simpler structure.

### 5. DISCUSSION AND RESULTS

All methods and approaches discussed in the above sections are important for text recognition including the handwritten text, but some of them is good fast for particular case, and might be slow and in other cases. The following table (Table

1) shows the main differences, advantages, and disadvantages of all discussed methods and approaches.

**Table 1.** Summary of reviewed hand-written detection and recognition approaches

#	Approach	Description
1	Convolutional Neural Network Recognition	Using CNN the image will be recognized depending on the network training process, this approach is widely used in computer vision and recognition, but it needs a very long time and many samples for training to get high accuracy.
2	Incremental and Semi Incremental Recognition	This method takes the prior segments and last strokes into consideration to complete the recognition process; it does not take a long waiting time. On the other side, it is a little bit complicated by comparing to the pure-incremental method, and cannot work by itself only; it needs to be accompanied by other types. Incremental always has a problem with the segmentation.
3	Part Based Recognition	Possibility to recognize characters with ambiguity of their structure, because of the non-dependency of the global structure. Also It applicable to recognize cursive scripts component character, and also It is applicable for scenery images containing characters.
4	Line And Word Segmentation Recognition	This approach is very powerful for printed text documents, but it cannot be used for pattern detection.
5	Zoning Recognition	It gives very high accuracy level in general, but this level will be decreased if the number of zones in the image is small.
6	Ensemble Recognition	It gives very high accuracy level also, but this level will be affected by the components of line segmentation.
7	Slope And Slant Correction Recognition	This approach is good for printed documents with high accuracy and simple segmentation, the accuracy for handwritten text is not high.
8	Vertical Attention Network Approach	VAN provides encoders to be able to recognize text in lines or paragraphs, these types of CN encoders are capable to process variant input images with different sizes, VAN discovers the end of the processed text paragraph, this issue leads to end of the recognition procedure itself

Using CNN the image will be recognized depending on the network training process, this approach is widely used in computer vision and recognition, but it needs a very long time and many samples for training to get high accuracy. The Incremental and Semi Incremental Recognition method takes the prior segments and last strokes into consideration to complete the recognition process; it does not take a long waiting time. On the other side, it is a little bit complicated by comparing to the pure- incremental method, and cannot work by itself only; it needs to be accompanied by other types. Incremental always has a problem with the segmentation. Using the Part Based Recognition, there is a high possibility to recognize characters with ambiguity of their structure, because of the non-dependency of the global structure. Also It applicable to recognize cursive scripts component character, and also It is applicable for scenery images containing characters. The Line and Word Segmentation Recognition approach is very powerful for printed text documents, but it cannot be used for pattern detection. Zoning Recognition gives very high accuracy level in general, but this level will be decreased if the number of zones in the image is small. Ensemble Recognition gives very high accuracy level also, but

this level will be affected by the components of line segmentation. Slope and Slant Correction Recognition approach is good for printed documents with high accuracy and simple segmentation, the accuracy for handwritten text is not high. VAN provides encoders to be able to recognize text in lines or paragraphs, these types of CN encoders are capable to process variant input images with different sizes, VAN discovers the end of the processed text paragraph, this issue leads to end of the recognition procedure itself.

## 6. CONCLUSIONS

The computer vision and its applications is very important field of Artificial Intelligent (AI) in general, the image processing and text extraction, and text recognition is used everywhere in AI Applications. The purpose of this work is to provide discussion and detailed information about all methods and approaches used for handwritten text recognition (HWTR), this process can be affected by many conditions and restrictions, because of that each method can good in some condition and not very good in another conditions; the accuracy of text detection and recognition is better if the recognition system uses CNN. The Slope and Slant Correction Recognition approach is good for printed documents with high accuracy and simple segmentation, the accuracy for handwritten text is not high, one more thing about Line and Word Segmentation Recognition, also is good and powerful for printed text, but it cannot be used for pattern detection.

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## NOMENCLATURE

AI	Artificial Intelligence
ANN	Artificial Neural Networks
CN	Convolutional Network
CNN	Convolutional Neural Network
CTC	Connectionist Temporal Classification
HTR	Handwritten Text Recognition
HWT	handwritten text
LSTM	Long Short- Term Memory
ML	Machine-Learning
NN	Neural Network
PBHW	Part- Based Handwritten
RNN	Recurrent Neural Networks
VAN	Vertical Attention Network