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ORIGINAL RESEARCH

Cognitive Reading and Character Recognition in Image Processing Techniques

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Abstract
The trend of researches in cognitive reading has become so popular in programming area in the field of computer science from late 1990s when scientists and researchers show more interests in computational approaches are complex in nature to derive from a known algorithm of solution. For instance, in the research areas of biology, medicine and human management sciences there are various problems where we need cognitive reading to deliver a complex and in-exact solution when there is no polynomial time to arrive at an exact solution. This article explains some of the methods in cognitive reading in image processing for character recognition and briefly discusses the steps involved in the process of character recognition in image processing.

Keywords Cognitive reading · Neural network · Image processing · Character recognition

Introduction

Text interpretation in an OCR system is done using cognitive process of simulating human reading which involves conversion of printed symbols into formation of characters or words or sentences. AI researchers have worked in identifying how human interpretation of document reading is done and how the segmented characters or words or sentences or paragraphs in the text script are done and tried to implement such interpretation process in an OCR system.

Typically, such researchers are working in shaping a better character recognition system by addressing questions like:

- How a word recognition is done by holistic shape-based character recognition.
- How words in multiple languages are read by human brain.
- How language identification and character recognition are achieved for any given document in any degraded input.

Many studies were done in building a cognitive reading system which tries to address one or all of the questions listed above and builds a system for simulating human interpretation with higher accuracy as possible.

These handwritten character recognition systems are using optical recognition methods but a complete recognition system to handle correct segmentation or format of text or offline character recognition. Such a researches have worked on different methods to be applied for online or offline character recognition system.

Online handwritten recognition principally has different problems than offline handwritten recognition. In an online recognition system, user input is used to correct the interpretation then and there as feedback is quite possible in such systems. In the other side, offline character recognition system relies on efficient training mechanism which provides higher recognition accuracy.

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Offline Character Recognition

This kind of system handles conversion of scanned image into text or letter codes and is used in any applications like mail sorting system or bank cheque processing system. This method uses static representation of handwritten characters as strokes or segmented letter codes, and such interpretation is difficult in processing as different human-written characters have different styles.

These kinds of systems are classified into the form of OCR or ICR. Intelligent character recognition (ICR) is a modern engine, and it uses different patterns of recognition for different types of text representation like printed or handwritten character recognition.

As of today, OCR engines are focusing on printed characters and ICR is handling handwritten characters in a most efficient way. Most of the ICR systems are handling multi-language inputs in an efficient way as compared to OCR handling printed characters.

In a multi-language character recognition, the most important task is to identify the language and interpreting characters from the identified language character sets to complete the document recognition which helps in application of such systems in many industries like script recognition in ancient scribblings in libraries or cheque processing system in banks or document processing in a land registration process. Palm script or stone carvings reading is also important application of these systems where it simplifies the process of recognition.

The important goal of such a recognition system is to get higher confidence in recognition accuracy which is nearer to acceptable threshold as expected by user or to reduce noise or manual correction in order to achieve higher recognition percentage.

From cognitive theories of computing, two primary strengths of the human brain are:

1. Massive interconnection of various data stored in brain.
2. Parallel processing architecture.

Neural network is based on such theories of the human brain and intelligence and hence forms an alternative computational approach called artificial neural network (ANN).

Challenges in handwritten character recognition

In a handwritten character recognition system, the major challenge is mimicking a neural network system into an artificial system to enable the system to think and decide based on the analysis it has done which is a simulation of human brain.

For example, the brain function of a child will not be matching to the decision system of supercomputer as the child can recognize its parent despite make-up change or haircuts. It is always a difficult task for a computer to perform such a recognition even if we train multiple times.

A user can enable more permutation and combination of the system to increase the accuracy of recognition. This is one the key reason that even after 30 years of dynamic and deep research in artificial intelligence field, computers fall short of the expectations of intelligence we have of them. Like this, there are many problems to be addressed by artificial intelligence like speech and image recognition, robotics, vision and combinatorial optimization, which is quite challenging and different from conventional computational methods.

Another challenge in ANN in simulating human brain is that it has to process based on intuition or deeper insight into the problem based on historical approach of solving problem. In other words, ANN is somewhat like a trained monkey which is trained to take right decision based on empirical reasoning without explicit verbalization of the problem.

Please note that the monkey has its own mind and decision-making power or native neural networks and is also capable of solving tasks on its own with more complex solution than any task one might train the monkey to do, but it is not in the scope of simulating the natural system.

Related works

There are many researches done for offline character recognition using various neural network-based solutions, and some of them are specific to a language (e.g. Devanagari, Urdu, Arabic) and some of them are specific to handwritten character recognition, but none of these researches provide a unified solution for multi-language-based character recognition and none of them provide a solution which is cost-effective in terms of training and accuracy in recognition rate.

When the input quality decreases, the recognition ratio also proportionately decreases and reliability of such system decreases in effect of this. Hence, a single algorithm does not satisfy to address recognition system at all situations based on different degradation of inputs and combination of multiple algorithms in terms of skew correction, noise reduction, segment processing or processing stroke-based recognition is considered to be more efficient in getting higher recognition accuracy.

First-order processing of a front-end system is the basic step in such processing and the next level of processing engages judgement of recognition of character and it entitles modification of recognition to get higher accuracy. These

offline handwritten recognitions are widely implemented in identifying text in different industry, whereas online recognition process uses user input in a given touch surface like licence processing which uses movement of writing device (such as digital pen or finger or stylus) and uses continuous stroke-based interpretation of character or word when entered into the system.

In such methods, user can edit the input or output to train the system in order to correct the misinterpretation of characters and get higher recognition percentage. On the other side, offline recognition system identifies characters or word from a given image and training duration can be increased as much to get higher recognition ratio.

Literature Review

Filip and Wallberg [1] proposes a method [2] of automatic script recognition and orientation which detects characters after pre-processing steps like noise reduction or skew correction.

The system does not have inbuilt knowledge of language when input is fed and hence user has to manually choose the language to be used for recognition, and the character sets of the selected language are used for pattern matching. When more than one script language is used [3], orientation detection helps to identify the language and then based on orientation and angle of character features are formed to recognize the scanned document [4].

When the scanned document image is wrongly oriented and given as input, the processing steps which follow the interpretation fail to provide correct result and cognitive reading of such wrong input is not efficient to correct the orientation [5].

For any handwritten document where text orientation varies heavily for different users by using cognition reading strategy in wrong orientation should be recognized properly by automatically correcting the orientation [6]. Based on such a technique, higher accuracy ratio of about 95% is achieved [7] in experimental evaluation.

Goyal and Dutta [8] propose a method of character recognition in which OCR-based method is developed for a given script or language in interpreting each character provided as a graphical representation of strokes of a given language set or a group of languages [9].

In common, a script is based on a single language or sometimes it can use more than one language. For example, Arabic script written in Asia [11] or Africa [12] uses several languages like Persian, Arabic, Pashto or Urdu language script. A typical OCR system recognizes characters from any language with higher precision of recognition.

But there is higher difficulty in finding a single OCR system which can identify characters from a given script of any language. Any OCR system has typically set of languages that it can work efficiently or brute-force solution [13] is possible to build a training set of any language to improve the OCR system in recognizing characters.

Such a manual training process is a time-consuming work, and getting higher accuracy is directly proportional to higher time for training [14], and there are boundary limits associated with such process in that a generic solution is not possible for different languages or training for one language cannot be used for another language. Hence, training for each language-based character set is more important for such a system in order to process any language script [15].

But these kinds of hybrid evaluation lead to classification errors [16] as there is an increased number of classification classes for different language sets. Also, it depends on structural properties of writing styles and it differs from one script language to another. There exists one more solution [17] which combines character- or word-level text classifiers formed for different languages or scripts, and getting respective classifier is the pre-task in getting particular character of a language. This kind of pre-task requires prior knowledge in knowing appropriate classifier, and hence, automatic script recognition-based methods [18] are engaged in a typical cognitive recognition system which handles classifiers efficiently.

Joseph et al. [19] evaluated various popular character recognition techniques, viz. optical character recognition (OCR) that has processing functionality to convert any form of image automatically like written text [20] or printed text or even handwritten texts [20] which is mapped to a form which can be electronically analysed and organized into computer readable segmented image collection.

They are transformed from optically scanned image to binarized format which can be used to create suitable form of image pattern and can be used to analyse later [21]. There are numerous feature recognition techniques available in practice which can be used to examine and to recognize characters based on captured/predetermined patterns stored in data store or historical record or trained data [22].

But all these techniques when carefully experimented have high dependency on standard fonts in case of printed text or intensive training to capture many combinations of data sets for handwritten characters. Also due to text formation in handwritten text, there is noise in recognition (reduced accuracy) due to a change in size like reduction, magnification or rotation (transformation of source image), different lighting conditions (display condition), resolution limitation (device capability), perspective distortions (device fault), arbitrary orientation (manual error) and also poor quality of characters due to non-uniform illumination

conditions during image acquisition (which can be considered as manual mistakes).

Hence, it is a high demand in IT industry for a system for character recognition and a unified method to achieve the same seamlessly and automatically.

Borgo et al. [23] explain real-time application of these techniques by doing research study and practical application of offline character recognition methods in various industrial applications. Here is the example where handwriting recognition techniques can prove to be solution for enhancing banking which satisfy the visually challenged person and may prove to be the best banking solution.

In order to build loyalty and drive profitability, banks need to offer a non-stop interactive banking environment. To achieve this, banks need to increase their business agility by anticipating customer needs and offer an engaging user experience. The automatic processing of bank cheques involves extraction and recognition of handwritten or user-entered information from different data fields on the cheque such as courtesy amount, legal amount, date, payee and signature. Hence, automatic bank cheque processing systems are needed not only to counter the growing cheque fraud menace but also to improve productivity and allow for advanced customer services. In next-generation banking system, automatic cheque processing system is used to improve customer satisfaction and early identification of skilled forgery by doing efficient validation techniques in such system.

Automated Cheque Processing System

The suggested handwritten character recognition system by Bai Jinfeng et al. (2014) applied as a banking technique employed in the modern banking system proves to be efficient time-saving system.

The automated validation system using such artificial intelligence mechanism minimizes the forgeries and proves to be cost-effective system to the bank. Manual efforts spent in validation of cheques can be reduced and also improve the performance of the bank by dedicating the valuable time for other business activities involved in banking.

ATMs enhanced with handwriting recognition technique for customer validation can prove to be effective user-friendly technique for visually challenged person. ATM accepts the cheque and processes the cheque using automatic cheque processing system to validate the amount, date, cheque number and signature.

Chacko and Dhanya [24] have published different research papers on automatic recognition of handwritten characters and one such key application is handwritten dates present on bank cheques which are also very important in application environments where cheques will not be processed prior to the dates shown. In countries like India, a cheque cannot be processed after 6 months of the date written on it.

Some of the cheque recognition systems are based on ink-based character recognition, and training the system with various handwritten formats is important for the accuracy in recognition (Fig. 1).

Verification of the hand-printed signature present on a paper cheque is the most important challenge as the signature carries the authenticity of the cheque.

Table 1 shows the comparison of various character recognition algorithms in terms of method used for recognition and accuracy percentage in recognition.

Problem Formulation

Handwritten character recognition does not produce accurate results in most of the artificial intelligence system unless they are trained more for repetitive handwritten styles, used for closed handwritten character languages and manual corrections allowed.

The approach proposed here uses a unique combination of feature extraction for self-reading, thus reducing the cost/time for training the system/neural network, noise reduction to generalize the pattern of strokes of common characters into an uniform pattern and genetic algorithm to self-heal the system in terms of training, storing character sets for different languages and processing multiple-language recognition.

Though these are common approaches in character recognition, the proposed system uses a unique combination of these methods with custom algorithmic changes. There are various techniques involved for such offline handwritten character recognition which is briefly discussed below.

Feature Extraction

In pattern recognition, feature extraction is one the key term used and such feature can be characterized by steps of process to differentiate one type of object from another in a more meaningful and concise manner than is represented in the raw structure. So, it is always an important task in the pre-definition stage to define meaningful features which

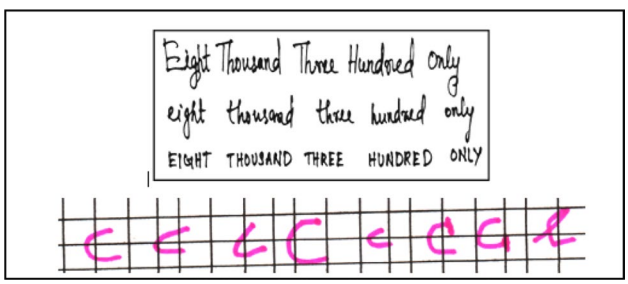


Fig. 1 Different styles of handwritten character writing

Table 1 Performance comparision for various Character recognition algorithm

System proposed by	Method of recognition/algorithm used	Accuracy in %
Mukarambi et al. [25]	Feature extraction, SVM classifier	83.02
Kumar et al. [16]	k-NN classifiers and parabola curve fitting-based features	84.17
Bai et al. [3]	Feature extraction, stroke-based recognition	85.44
Favata et al.	GSC classifier	86.62
Kumar et al. [16]	k-NN classifiers and power curve fitting-based features	90.06
Liu et al. [26]	Normalization and Feature extraction	92.18
Kumar et al. [16]	SVM and parabola curve fitting-based features	94.29
Liu et al. [26]	MQDF, NPC, DFE, DLQDF	95.77
Al-Marakeby et al.	AOCR, QDF-based Zernike moments	96.19
Kumar et al. [16]	SVM and power curve fitting-based features	97.14
Venkat Rao et al.	OCR as well as HCR using matrix matching and feature extraction	94.62
Jagtap and Kulkarni [27]	Edge detection, feed-forward back-propagation	82.50
Elleuch et al. [10]	Dropout technique, SVM classifier	97.98
Saharan and Malhotra [28]	Binarization, median filter, salt-&-pepper noise removal	72.30
Kumar [29]	Multi-layer feed-forward, diagonal-based feature extraction	89.05

helps to develop a processing engine called a good recognizer, as it is well known that a common or generalized solution is not feasible.

In most of the cases, these features are usually defined based on the experience and/or intuition of the system designer. Depending on the type of problems given, there are numerous ways and a lot of variety of such features can be defined in extracting methods and ways of representation. In practical cases, it is not unusual where a problem involving hundreds and thousands combination of features.

Noise Reduction

In an offline character recognition system, noise reduction would be based on language in which character is written. For example, Hindi characters will have specific strokes where noise reduction is based on strokes used, Telugu language is based on shapes and curve notation which can be used for noise reduction.

In mixed-language content, it is always challenging to do noise reduction as there would be more than one language representation. In a mixed-language handwritten content scenario, this gets complicated for languages with similar scripts or strokes. For example, if the user assumes Hebrew document as Latin document and finds a Latin translator, the outcome of the translation would be wrong.

And since, in the case of offline interpretation, the user does not provide immediate feedback, there opportunity to correct such misinterpretation is impossible. Image recognition is based on a technique where recording and matching of image characteristics such as size, segmented groups (strokes) and character interpretation are carried out. Both recording of an image and its subsequent matching with other images will be carried out through a series of stages of processing. There are six major such stages of processing as explained in the following.

The purpose of such processing step is to convert an image's graphic form into a binarized format which can be accessible and retrievable from a conventional and easy to process group of attribute (indexed store) and at the same time maintains relationship among the segmented group which helps to retain all information necessary to describe the image's characteristics.

The six stages involved in the processing of image in this work are

1. Image creation.
2. Image markup or reduction.
3. Segment group storage.
4. Searching for segment group.
5. Matching first stroke.
6. Character interpretation.

Hybrid Recognition

Since mixed language recognition for handwritten character is always complex and requires multiple iteration of training, using a Hybrid recognition technique would provide better accuracy due to its variant in processing technique. Application of artificial neural networks (ANNs) in image analysis

is done for various script evaluation and they prove to be efficient for isolated characters or numerals like bank cheque processing system or coded answer sheets of an examination.

When a recognition system uses a combination of ANN and HMM also termed as hybrid recognition approach, getting better results in script recognition is achieved, and researchers have evaluated many such hybrid evaluation systems using combination of ANN and HMM to address two key issues, viz.

1. How a recognition system handles structures of characters in identifying character or words and how ANN is engaged in such a paradigm like multi-layer perceptron or radial-based system or TDNN method.
2. How to train the system to get higher recognition ratio for any given script.

There are many hybrid systems designed in the past which was evaluated under various experimental tests using either geometric technique or probability density function in engaging classifiers in recognition.

Many of these hybrid systems use ANN-based classifiers to get observation probabilities of character to be recognized for HMM model. They require combined training mechanism for both ANN and HMM and use complex neural network-based classification architecture in storing and recognizing characters like time-delay neural network (TDNN) or space displacement neural network (SDNN).

Segmentation

Many character recognition methods use segmentation-based approaches where a word is segmented to characters, and each character is further segmented into strokes or segmented character, and this is used for identifying the character. But a low-resolution scanned image is problematic in recognition for both printed and handwritten documents, and such a input affects character recognition accuracy in recognition.

There are many modern techniques proposed by different researchers in getting higher accuracy in various kinds of degradation of document recognition. Few of these methods use word-level recognition without segmenting characters, and few others use character-level recognition with segmented strokes of a character.

These kinds of system are called holistic word recognition approach, and they do not process characters directly and use global features like T-junctions or d-loop/b-loop or strokes or ascenders or descenders of word recognition. The main drawback of such word-level recognition is limited to small set of vocabularies.

There is another strategy involved in hybrid recognition methods, and it uses recognition-based segmentation approach. The scanned document is divided into overlapping pieces, and processing these pieces is using hypotheses graph to classify characters of one or more languages using dynamic programming-based procedures.

Pre-processing

This is one of the basic or foremost steps of any character recognition process where it removes noise and skew variation and normalizes the characters of the scanned image. In the proposed work of this article, pre-processing is done to normalize height, weight and colour of text line images in order to get higher accuracy in pattern matching.

This kind of pre-processing is done by rescaling the image in vertical and horizontal overlapping pieces as shown in Fig. 2 by adjusting height and width of all isolated characters in the scanned image in order to get new image having equal height and width of characters.

This figure shows step-by-step pre-processing in getting image normalization. Self-training the system in order to automatically handle the image normalization is proposed in this system in order to improve the processing efficiency in character recognition. This is done by pre-determining the text/character position, size and weight (font weightage like width, bold, italics etc.,) and preparing a classified stroke-based character recognition.

Stroke Recognition

From classical definition, stroke-based recognition is a key area in neural-based pattern recognition system which is a branch of artificial intelligence, and concerns the construction and study of systems that can learn from data. To simplify its kind of computer intelligence, a system of algorithms recognizes a pattern over and over and actually learns from it, just like humans through experiences. Like a

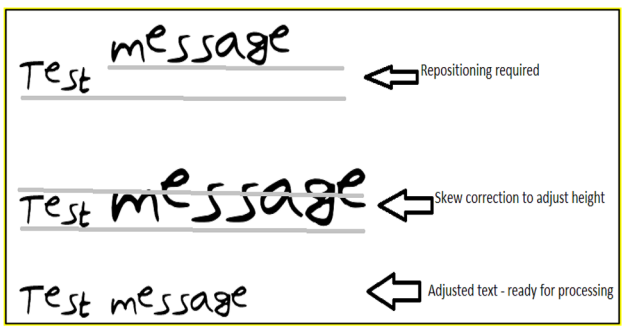


Fig. 2 Pre-processing

system learns to identify e-mail messages as spam or non-spam message.

The main idea of such pattern recognition system lies in representation and generalization. Representation of data instances and functions evaluated on these instances are part of all machine learning systems. Generalization is the property that the system will perform well on unseen data instances; the conditions under which this can be guaranteed are a key object of study in the subfield of computational learning theory (Fig. 3).

There are various types of pattern recognition system that has its own key advantages and disadvantages. To build an easy categorization, user can largely base them on the way of adoption while making a system "learn". Pattern recognition algorithms can be organized into taxonomy based on the desired outcome of the algorithm or the type of input available during training the machine.

Human interpretation of document reading from different fonts or style is more precise even there is the presence of noise or clutter. This kind of recognition accuracy needs to be attributed to different cognitive process and reading techniques. Various researches are carried out in the field of cognitive psychology in presenting various theories and methods explaining the cognitive process involved in such recognition strategy.

Cognitive Reading Algorithms

Cognitive reading algorithms are search heuristic and optimization technique, which is used to generate useful solution for optimization and search problems. It has typically five parts.

1. The first stage is to represent character to be recognized where the representation is called a chromosome or genotype is used, which is a set of parameters to define the novel solution of this work.
2. The second stage contains a group of character sets (representing each solution unit or chromosome unit), e.g. first stroke to identify character.
3. The third stage contains a fitness function for pattern matching.
4. The fourth stage executes a selection function for character identification.
5. The last stage does a crossover for group of selected solution.

Algorithm for cognitive reading comprises two important stages, viz. initialize to prepare data set for evaluation and evaluate to carry out interpretation. Though self-training is an important step in a character recognition system to build the knowledge base, it is not an easy step to design as the variance in stroke group and the character group to

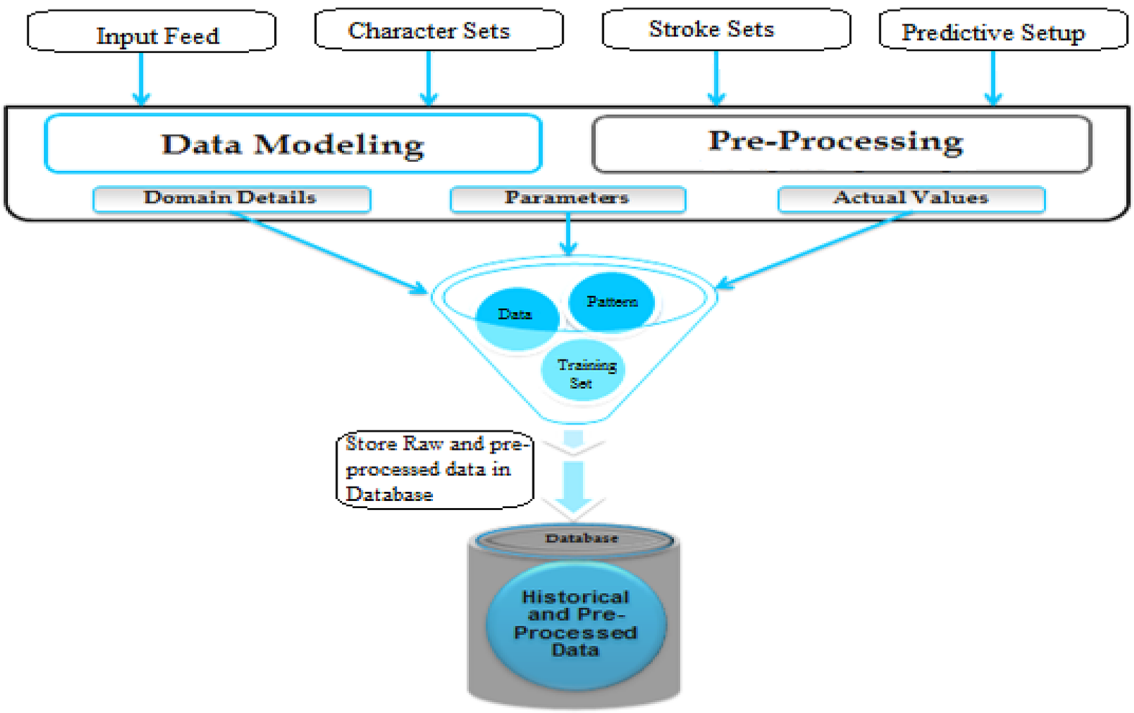


Fig. 3 Pattern recognition system

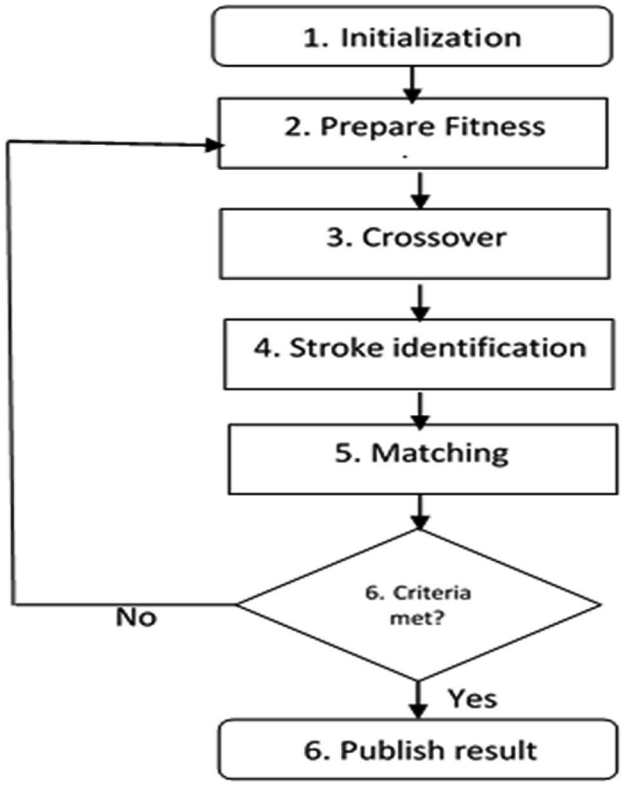


Fig. 4 Processing steps in cognitive recognition

be mapped with different languages has a lot of combinations of results. Hence, it is important to understand the challenges addressed by self-training system.

Figure 4 shows a simple processing steps involved in a typical cognitive-based recognition algorithm where training is handled automatically. Also, listed below the algorithmic steps involved to explain how edge detection and segmented reading is done during recognition process.

```
0) Get set of strokes from a character in a InputTraverseList
1) Loop through list of strokes and take a single stroke
1.1) Fix the stroke position from current position as (x,y).
1.2) OutputTraverseList= InputTraverseList + current position (x,y).
1.3) If stroke matches a stroke at position (x-1, y-1) then
        Do validate if the position is not in InputTraverseList.
        Call Function Edgedetection(x-1, y-1, OutputTraverseList);
  end if
2) If stroke matches a stroke at position at (x-1, y) then
        Do validate if the stroke position is not in InputTraverseList.
        Call Function Edgedetection(x-1, y, OutputTraverseList);
  end if
3) If current stroke matches with a selected stroke at identified position (x-1,y) then
        Do validate if the current stroke is not in InputTraverseList
        Call Function Edgedetection(x-1, y+1,OutputTraverseList);
   end if
4) return;
```

The *InputTraverseList* built from this algorithm is the knowledge base which uses genetic algorithm techniques that are very useful in finding the suitable in most critical paths improving training efficiency and building the training set.

The primary challenge associated with an offline handwritten recognition system is that the text cannot be modified or edited or re-entered by user and re-processing is the only option in order to improve the recognition ratio. User feedback is got for correction of the output after character interpretation in case of a wrong recognition of a selected input character or word.

Hence, accumulating these error corrections is done in such a system when interpreting offline character recognition by getting user inputs as needed. It is desirable to improve the efficiency of recognition algorithm engaged in an offline recognition system and get a better result by improving the training sets of the system by correcting the error ratio in recognition.

The next challenge in offline recognition system is that there are various styles of handwritten patterns of same characters by different users, and hence, normalizing the input such as shape and size correction, noise reduction is important steps in pre-processing stage in order to correctly recognize the characters.

This challenge grows high when multiple language recognition is done for a given input document. For example, a character in a given language looks similar to a character in another language, and it need not to be same in both language and hence identification of the correct language in order to identify the correct characters which is important in an offline recognition system.

These kinds of problems arise when handling handwritten characters as against printed characters. Some of these learning types used in this system are:

Specific inference–Learning through memorization where an input character is segmented and the strokes are arranged in its own order and associated with a character as a key-value pair in the indexed map stored in KB.

Inductive Inference–Learning through instruction/operationalization where manual input is provided to correct the character segments to improvise the learning.

Abductive Inference–Learning through induction (from sample training) where a sample character is trained and the variance of the same character is automapped with adjacent cell representation of one or more associated strokes.

Analogical Inference–Learning through analogy where the character stroke is repeatedly learned and stroke group is created until the accuracy level is increased to a desired level for a given character set.

Technical Implementation of the proposed model

Heuristic learning in learning a character stroke is based on two ideas, viz.

1. mathematical algorithms and
2. automation of process.

The idea behind this is to automate the building of analytic model that uses algorithms to "learn" from data in an iterative fashion on its own. This helps in reducing the cost and time for training the system. This process pertains to gaining knowledge or some desired results by intelligence rather than following some pre-established formulas or training patterns. This way user can achieve more combinational results with less time and without dedicated training process.

The implementation of this proposed algorithm is done in Java language using java.awt API on a windows environment using Spring Tool Suite (STS) IDE as development environment and tested with different scanned images of handwritten text in different degraded stages. The test results are evaluated on recognition accuracy on individual characters and the complete text as an average, thus getting higher level of confidence in terms of percentage for the complete experimental evaluation of script recognition. The test program requires at least 64 MB RAM and 1 GB storage (to have the IDE) with 2.1 Ghz processor speed in order to execute and achieve results with good processing rate. Screenshot showing the evaluation of individual characters from a single line of text and the statistical evaluation of individual characters are shown in Figs. 5 and 6.

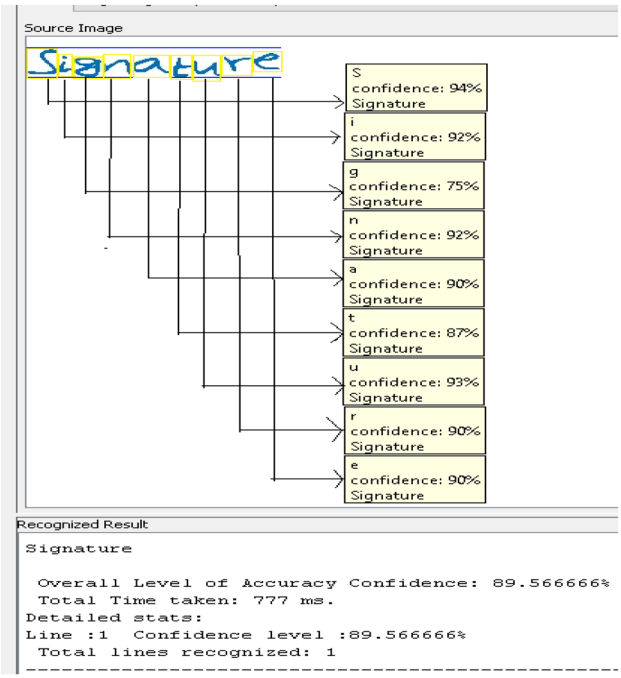


Fig. 5 Sample screenshot showing character recognition

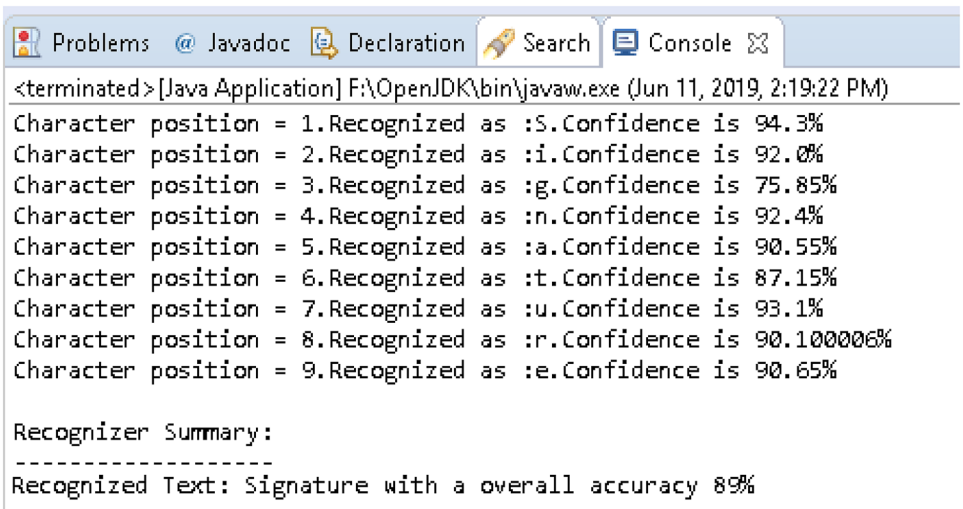
Neural Network in Hybrid Recognition

Application of artificial neural network (ANN)-based system is used in many document image analyses and recognition processes, and a good recognition system relies on accuracy of detection. Most successful applications of ANNs are limited in the process of isolated word sequence or characters or numerals (e.g. vehicle number plate recognition) (Fig. 7).

A combination of ANN and HMM is effectively used in different texts or speech recognition problems in the past, and they are referred as combined hybrid recognition system.

In developing a hybrid system based on HMM and ANN, two designs or architecture problems are addressed such as:

Fig. 6 Console output showing character recognition statistics



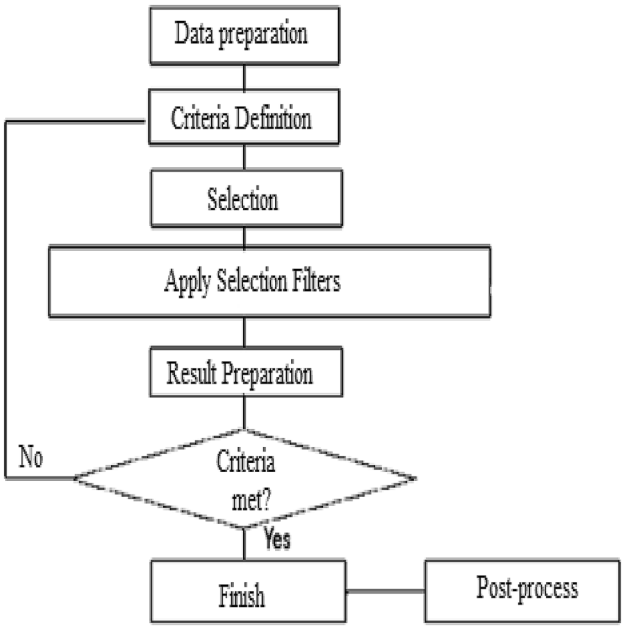


Fig. 7 Flow of process in the proposed system

1. How a discrete or continuous structure of HMM at character or word level gets selected and uses what kind of paradigm (e.g. multi-layer perceptron or radial basis or TDNN) to be used.
2. How to train these modules to get higher recognition.

Hence, it is important for a hybrid recognition system to apply relevant selection filters in order to meet the criteria of recognition for a given document input in order to process the script recognition for segmenting and for output generation.

Here, the earlier stage of the processing starts with defining the criteria of recognition to which the pattern matching is evaluated in order to achieve the required result of processing the input document.

Conclusion

Many hybrid HMM- or ANN-based systems have been evolved in the past and use different structures or templates of processing. Many of these hybrid systems use ANN to augment the model of HMM based on approximation of density function or a neural vector-based quantizer. These systems combine training criteria in order to use complex neural network architecture like time-delay neural network a.k.a TDNNs or space displacement neural network or otherwise SDNNs. The key challenge in a hybrid recognition system is to handle multiple-language-based script recognition and getting higher recognition ratio in lesser training or preprocessing stages.

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Compliance with ethicalstandard

Conflict of Interest The authors declare that they have no conflict of interest.

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