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Optimized convolutional neural network deep learning for Arabian handwritten text recognition

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ABSTRACT

In general, the term handwritten character recognition (HCR) refers to the process of recognizing handwritten characters in any form, whereas handwritten text recognition (HTR) refers to the process of reading scanned document images that include text lines and converting those text lines into editable text. The identification of recurring structures and configurations in data is the primary focus of the field of machine learning known as pattern recognition. Optical character recognition, often known as OCR, is a challenging issue to solve when it comes to the field of pattern recognition. This article presents machine learning enabled framework for accurate identification of Arabian handwriting. This framework has provisions for image processing, image segmentation, feature extraction and classification of handwritten images. Images are enhanced using contrast limited adaptive histogram equalization (CLAHE) algorithm. Image segmentation is performed by k-means algorithm. Classification is performed using convolutional neural network (CNN) VGG 16 and support vector machine (SVM) algorithm. Classification accuracy of CNN VGG 16 is 99.33%.

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1. INTRODUCTION

The automatic segmentation and recognition of text on photographs of previously printed papers and books has made it possible for a broad variety of applications to become a reality. As a consequence of this, a wide range of uses have been made available. Academics are interested in the topic of off-line handwriting segmentation and recognition due to the high degree of ambiguity and complexity present in the types of picture documents being discussed as well as the requirement of optical character recognition (OCR) in many applications, most notably in office automation. Writing that is cursive by hand is the most difficult for OCR

software to segment and recognize. Far little research has been done on the difficult problem of separating out individual words and phrases in Arabic literature. Because it was essential to process tones from Arabic books and papers that had been produced in the past, the area of Arabic script handwriting presents its own unique set of technical challenges, which have only very recently been overcome. In order to make the most of this theory, offline handwritten Arabic documents need to be split and recognized in a more effective way [1].

The identification of recurring structures and configurations in data is the primary focus of the field of machine learning known as pattern recognition. What we're talking about here is the process of assigning important characteristics to incoming data in order to categories it as objects or classes. OCR is a challenging issue to solve when it comes to the field of pattern recognition. Due to the vast number of fields in which it may potentially be used, including business, research, and academia, there is a lot of controversy around this topic. "Optical character recognition" describes the process of transforming scanned images of printed, typed, or handwritten materials into text that can be read by a machine [2].

OCR makes it feasible to search for information in a document using a number of different strategies, which was previously impossible. This strategy saves a large amount of time when contrasted with the traditional practice of searching through paper-based documents. For instance, the text that is generated by OCR can be used to enter data from paper records, recognize postal codes and extract addresses from documents that have been mailed, or it can be used in automated evaluation systems, voice recognition, author identification, and other applications that process text.

The handwritten text recognition (HTR) may be further split into specified boxes, separated by space, run on discretely written or cursive writing, or mixed mode writing [3]. This depends on how the text is produced. In general, the term handwritten character recognition (HCR) refers to the process of recognizing handwritten characters in any form, whereas HTR refers to the process of reading scanned document images that include text lines and converting those text lines into editable text [4]. The block diagram of HTR is shown in Figure 1.

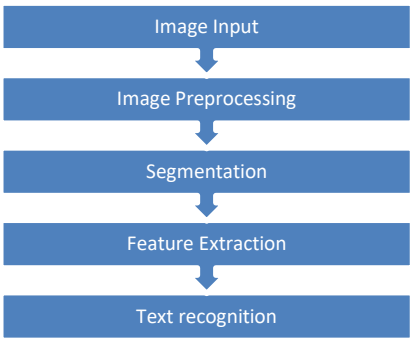

Figure 1. Block diagram of HTR

During the preprocessing step, a variety of activities are carried out with the intention of enhancing the document so that it may be used during the segmentation phase, which comes after it. Character thinning that is reliant on the input method may be accomplished using a number of different processes, including grayscale conversion, noise reduction, binarization, skew detection and correction, text cutting, morphological process improvement, and a variety of other procedures. These processes may also involve the following operations, depending on the mode of input: converting the document image to grayscale; deleting undesired pixel values; rendering the content in the foreground as text and background; and binarizing the document [5].

It is required to do preprocessing in order to minimize the quantity of data that is included in the scanned picture and to decrease the amount of noise that is contained in the scanned image. The HTR system includes a segmentation step that is considered to be very important. The fundamental objective of HTR segmentation is to divide an image of a document into a series of interconnected pieces that are similar according to one or more criteria.

The process for segmentation was determined with the help of the overall recognition approach. The two basic categories are the holistic and the analytical approaches. When using a holistic approach, a word is the smallest unit of segmentation output that may be achieved. A character is the smallest output unit for

segmentation that may be produced by an analytical approach. It is essential to be able to extract feature information from the segmented lowest units of a letter or word and recognize that information.

A feature is a characteristic or primitive of an item that helps in the description of the thing in a meaningful manner, hence assisting in the identification and object distinction of the thing. Features may also be thought of as aspects of an item. In the process of feature extraction, helpful information, such as features, are extracted or created from a segmented unit (such as a character) in order to assist in the task of character identification. This is done so that characters may be recognized more easily [6].

Feature vectors and feature sets are both names for the same thing: a collection of extracted features that may be used to assist in character identification using classification algorithms. The qualities are selected in such a way that they may be categorized according to their character class using the fewest amount of components as is humanly practical, with the goal of optimizing the recognition process. Because the value of the features has an impact on the procedure of recognition, attending to this phase is essential [7]. The compiled set of extracted characteristics is one of the things that are sent into the recognition process. In the past, the feature set of a character was what was utilized to place that character into a certain category inside the recognition or classification engine.

When it comes to character categorization, researchers use a wide number of methodologies, each of which is determined by the problem that they are attempting to answer and the strategy that they are using. Classification methods for character recognition include structured and rule-based approaches, statistical techniques, and neural networks. If you have a large quantity of data on the variations of handwritten characters, you may want to consider using a neural network because of its ability to adapt and learn from consistent qualities over time.

This section presents optimized feature selection and image processing based statistical machine learning for Arabian HTR. Images are enhanced using contrast limited adaptive histogram equalization (CLAHE) algorithm. Image segmentation is performed by k-means algorithm. Useful features are selected using the particle swarm optimization (PSO) algorithm. Then classification of images is performed by support vector machine (SVM), artificial neural network (ANN), and K-nearest neighbour (KNN) algorithm.

2. LITERATURE SURVEY

According to the research presented in the paper authored by Bannigidad and Gudada [8], a KNN and SVM-based classification algorithm was used to develop a technique for the categorization of ancient handwritten documents written in Kannada and the determination of the family to which they belonged. According to the findings of the study, the SVM classifier investigated on HOG features performed more accurately than the KNN classifier.

In a recent study on Bengali character recognition [9], the histogram of oriented gradients (HOG) and colour histogram feature extraction methods were recommended as effective techniques. In order to accurately represent individual digits, HOG properties are extracted from a picture and recorded in vector format. The final product is created with the help of SVM. A 98.05% accuracy rate may be achieved with this dataset.

Due to the cursive nature of Arabic writing, language recognition may be challenging. Characters written in Arabic are identified offline using zoning features and the neural network classifier when they are printed out [10]. Each letter has been segmented into three vertical and horizontal zones of size 33 in order to bring attention to the aspects of the curve that are most significant. By using this zoning technique, we were able to achieve a success rate of 96.14%.

According to Dongre and Mankar [11] saw the development of an algorithm for the identification of Devanagari numbers and characters. To display them, the structural and geometric characteristics of the Devanagari numbers and letters are utilized. Each image is broken up into nine different areas or zones, and from each region or zone, a total of eight structural characteristics and nine global properties are extracted. In the end, 81 distinguishing features extracted from the image were chosen to best convey its essence. A multilayer perceptron neural network (MLP-NN) is used in order to accomplish the classification.

The article "Extracting characteristics from photographs" by Kumar and Bhatia [12] examined a variety of methods for doing this task, as well as which approach is most suited for certain categories of scenarios. Character recognition relies heavily on various image processing techniques, particularly those pertaining to the extraction of features. Feature extraction is the process of defining the shape information that is offered in a pattern in order to facilitate the process of pattern classification. The authors discuss a variety of properties, including zoning, moments, HOG, projection histograms, and Fourier descriptors, in length. This book also discusses the many characteristics and types of features, as well as the utility and significance of such characteristics and features. This research, which focuses on the extraction of features, discusses a broad variety of different techniques to feature extraction.

Yadav and Purwar [13] recommended employing a number of different classifiers for the purpose of automating the identification of handwritten solitary Hindi letters. In this investigation, the HOG and the profile projection histogram are the two types of characteristics that are analyzed and described. Using these qualities, the output of a variety of classifiers has been evaluated for accuracy. The results that the quadratic SVM algorithm produces are superior. It is advisable to utilize more than one kind of character due to the possibility that different classifiers would provide different results for the same set of features. Among the many classifiers that are used, SVM, ensemble subspace discriminant, and bagged trees are some examples. Using the five distinct classifiers discussed above, HOG and projection profile histograms have been analyzed in order to identify offline Hindi characters.

In this study, Ansari and Sutar [14] investigated a variety of different strategies for the extraction of features. They developed an effective extraction strategy with the assistance of the comparative study that they carried out. The HCR that is accessed online has a broad variety of potential applications in the actual world. As a direct consequence of this, the dependability and overall quality of such systems have to be very high. In this article, the relevance of feature extraction as a technique is discussed in detail. In HCR, the system constantly requires a high level of accuracy within a relatively short amount of time. This work aims to examine and offer a new strategy for feature extraction, which is a vital step in HCR. Its mission is to investigate and supply this innovative approach.

Shelke and Apte [15] came up with an innovative fuzzy logic approach in order to recognize handwritten Devanagari characters that were not limited. At first, the dataset is segmented into smaller subsets, each of which has a lower number of samples. In order to pre-classify the characters, fuzzy logic is used. The next step is feature extraction, during which we will start working with our characters. Character recognition falls back on feed forward neural networks as a fallback option (NN). The process of classifying things in this way involves a lot of different phases. It uses fuzzy logic, whereas phase two makes use of extra structural aspects such as end points and enclosed space. The former is based on the latter. The recognition of a character's vertical bar and the exact location of that bar is part of the process of fuzzy classification. Depending on the density of the pixels, information is supplied into a neural network that uses feed forward back propagation. According to the authors' observations, the fuzzy classification was much more effective than the crisp classification in improving recognition. Additionally, the recognition accuracy is improved since it reduces the amount of pressure placed on the processes of feature extraction and identification.

Pal *et al.* [16] employed a total of 12 distinct classifiers and gave four distinct groups of criteria in order to determine whether handwritten Devanagari letters belonged to which script. Curvature and gradient information are utilized to generate feature sets by using pre-processed images as the source material. These feature sets are used as input by the classifiers. Classifiers such as projection distance, mirror image learning, Euclidean distance, linear discriminant function, modified projection distance, KNN, and SVM are just some of the many that may be utilized in the classification process. Other classifiers include Euclidean distance, linear discriminant function, modified projection distance, and linear discriminant function.

Kamble and Hegadi [17] investigate a brand new technique for the extraction of features that is known as rectangle histogram oriented gradient (R-HOG). R-HOG estimates the gradient's biggest difference in intensity in a teeny-tiny zone located somewhere within the range of each pixel by using a Sobel filter. When applied, the Sobel filter gathers information on the gradient in both the horizontal and the vertical planes. The examinations make use of the Marathi alphabet and its characters.

On the other hand, compound characters in Devanagari are made up of both vowel and consonant letters combined together. More than 8% of all sentences written in the Devanagari script are made up of compound characters. A hybrid method is presented in a paper for the purpose of recognizing handwritten Devanagari compound characters [18]. The authors proposed a rotation-invariant rule-based thinning strategy as a means of distinguishing between handwritten Devanagari compound letters. In addition, they presented a fuzzy-neural hybrid approach. By preserving the form of the character in all directions, a symmetrical reduction in thickness may be brought about along the centre line. By maintaining the same formed and thinned nature, the speed of the training may be accelerated. The recognition is accomplished with the help of a fuzzy rule-based neural network, which is then trained on the ideal weights.

3. METHOD

This section presents a machine learning based framework for accurate identification of Arabian handwriting. This framework has provisions for image processing, image segmentation, feature extraction and classification of handwritten images. Images are enhanced using CLAHE algorithm. Image segmentation is performed by k-means algorithm. Classification is performed using convolutional neural network (CNN) VGG 16 and SVM algorithm. It is shown in Figure 2.

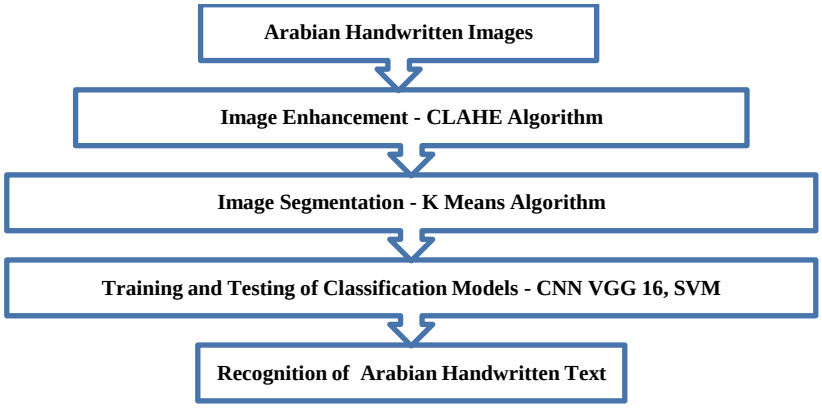

Figure 2. Arabian HTR using optimized machine learning techniques

The background extraction process, which is an essential part of picture identification, has to be adaptable enough to take into account the particulars of each image. When using CLAHE, it is only feasible to construct a histogram for pixels that are immediately next to the pixel that is presently being analysed. The amount of contrast that may be altered is restricted by CLAHE, which does this by putting a maximum, sometimes known as a "clip level," on the height of the local histogram. As a direct consequence of this, the maximum contrast improvement factor will be decreased. As a result, there will be less noise in the background of the image today [19].

In this research, regional segmentation is utilized to divide the region of interest (ROI) into a number of different pieces, each of which may include possibly unique patterns and textures. The local mean is used as the clustering pattern for the k-means algorithm, and each observation is assigned to one of the k clusters that it generates. The total number of groups from which data may be collected is denoted by the letter k when used in this context, which is why the word "k" is employed. Euclidean square distances make it possible to instantly evaluate how near two data points are to one another. When deciding how to label the elements included in a data collection, it is usual practice to make use of a set of k preset categories as a starting point. A similarity metric is used in order to cluster the data points [20].

In order to construct a straightforward CNN, you are going to need a convolutional layer, a pooling layer, and an output layer. In very unusual circumstances, the pooling layer may not be applied. VGG 16 pre trained CNN is used [21]. It is shown in Figure 3. This particular design is optimal for the classification of handwritten image files. an input layer, a pooling layer, a normalizing layer, a convolutional layer, and a fully connected hidden layer are all included, in addition to an output layer. It is possible for certain neurons in one layer to connect with neurons in the next layer, which makes it easier to scale up to higher resolutions. By pooling or sub sampling the data, it is possible to reduce the number of input dimensions. Within the CNN model, the input image is segmented into a number of very small sections known as "receptive fields." A mathematical process known as convolution is used to the input layer in order to create a model that replicates the output of the layer that comes after it. A visual prompt is used almost exclusively to offer a response.

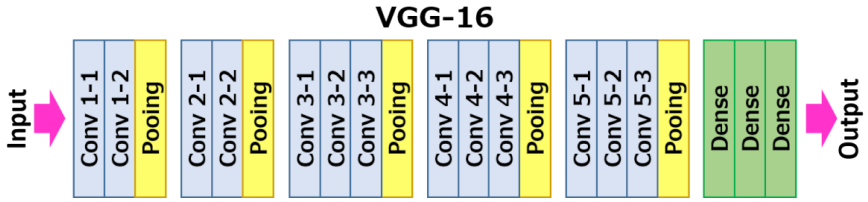

Figure 3. CNN VGG 16 layers

The data is loaded and stored at the input layer of the architecture. This layer is responsible for defining the dimensions of the input image as well as the number of channels that hold the RGB data. The hidden layers are the essential component of any CNN that has been thoughtfully developed. In order to carry

out the process of feature extraction, they make use of a collection of convolution, pooling, and activation functions. During this stage, the characteristics of the handwritten digits are determined [22].

A convolutional layer will be the first layer that is layered on top of the picture that was used as input. With the use of this technique, features may be retrieved from an image. When a m filter is applied to the n n neurons that are found in the input layer, the output that is produced is a n m 1 matrix. This is accomplished by the use of the activation function of the neural network, which is in and of itself a non-linear function. The majority of the inputs for the convolutional layer come from the receptive field, stride, dilation, and padding operations. A pooling layer is placed in between two convolutional layers in a neural network in order to reduce the amount of complexity caused by the computation. By using pooling, just the data that are required to go to the next level are sent, while the other data are left behind. The pooling layer also offers a hand in the fields of feature selection and overfitting, which are two more areas. The activity of pooling is carried out individually. The function of the system is to produce a single output value from several input photographs that have been tiled in such a way as to prevent any two adjacent regions from overlapping one another. The two types of pooling that are used the most often are the maximum pooling and the average pooling. The max-pooling procedure is often considered as a beneficial instrument in modern settings due to the fact that it collects the highest values from each of the divisions while simultaneously preserving the greatest amount of data. As a consequence, generalization is enhanced, and convergence occurs more rapidly [23].

Activation functions are used in CNN architecture, just as they are in classic neural network design, in order to produce non-linearity. The sigmoid function, rectified linear unit (ReLu), and SoftMax are a few examples of well-known activation functions that find widespread usage in the context of deep learning applications. Because of the information loss that occurs in the input data while using the sigmoid activation function, it has been shown that the CNN model might be rendered less accurate as a result.

The final layer of a CNN is known as the classification layer. It is mostly used as a classifier and operates as a feedforward network with all of its links intact. There is a connection between every neuron in the layer below and every neuron in the completely connected levels. It is up to this layer to figure out which classes are expected to be present in the incoming picture. When making the identification, you will need to take into account all of the qualities that you learned in the preceding rounds. There is a one-to-one relationship between the number of classes present in the input dataset and the number of classes present in the output dataset. The SoftMax activation function is used by the classification layer in order to perform the task of classifying the input image attributes that were generated by the layer that came before it into various classes according to the data that was used for training [24].

A bigger family of generalized linear classifiers was the inspiration for the development of the SVM. SVM are dependent on the hypothesis space of linear functions in order to learn new information. Learning algorithms are put into action in the process of training the multi-dimensional feature spaces. While all evaluations are carried out in the same space, the hyper plane separation that is produced by the kernel function is localized by the SVM in some feature space. The primary objective is to establish the hyper plane as the dividing line between the two groups. In order to demonstrate how better nonlinear clustering is, it makes use of a kernel approach. Despite having access to just a tiny portion of the total available training data, it surpasses other competing classifiers in terms of accuracy.

The decision planes and decision boundaries provide the basis for the support structure that is the SVM. Using the choice plane, it is possible to differentiate between groups of objects that have fundamentally different perspectives on the world, and the lines that separate the decision plane from the ground are referred to as decision boundaries. The decision plane also goes by the name of the hyper plane, which is still another term for it. The decision function for the given training set may be obtained once the convex optimization has been assessed. In order to determine where the dividing line is for making a decision [25].

The structural risk reduction approach is used inside the data space by the SVM. The fact that this strategy relies only on boundary data points to get the final answer is a highly remarkable and original feature of the method. Defined here is the buffer that sits between the splitting hyper plane and the data points that are closest to it. These points are referred to as support vectors by their names. This machine gives the potential to find the solution to issues that cannot be linearly partitioned by virtue of the fact that it is capable of conducting the non-linear transformation.

4. RESULTS AND DISCUSSION

In this experimental work, images are collected from Hijja data set [26]. Total 400 images were selected randomly form these data sets. 300 images were used for the training of model and remaining 100 images are used for the testing of models. Images are enhanced using CLAHE algorithm. Image

segmentation is performed by k-means algorithm. Classification is performed using CNN VGG 16 and SVM algorithm.

$$Accuracy = (TP + TN) / (TP + TN + FP + FN)$$

$$Sensitivity = TP/(TP + FN)$$

$$Specificity = TN/(TN + FP)$$

where, TP is true positive, TN is true negative, FP is false positive, and FN is false negative.

Results are shown in Figure 4. Classification accuracy of proposed CNN VGG 16 for Arabian HTR is 99.3%. Images are enhanced using CLAHE algorithm. Image segmentation is performed by k-means algorithm. This image enhancement and image segmentation helps in improving the accuracy of image classification and recognition. Accuracy of SVM is 95.6%. Sensitivity of proposed CNN VGG 16 is 99% and it is 5% higher than the sensitivity achieved by SVM. Specificity of CNN VGG 16 is 98% and it is similar to the specificity achieved by SVM. Proposed CNN VGG 16 technique for Arabian handwriting recognition is performing better in terms of accuracy and sensitivity in comparison to SVM technique.

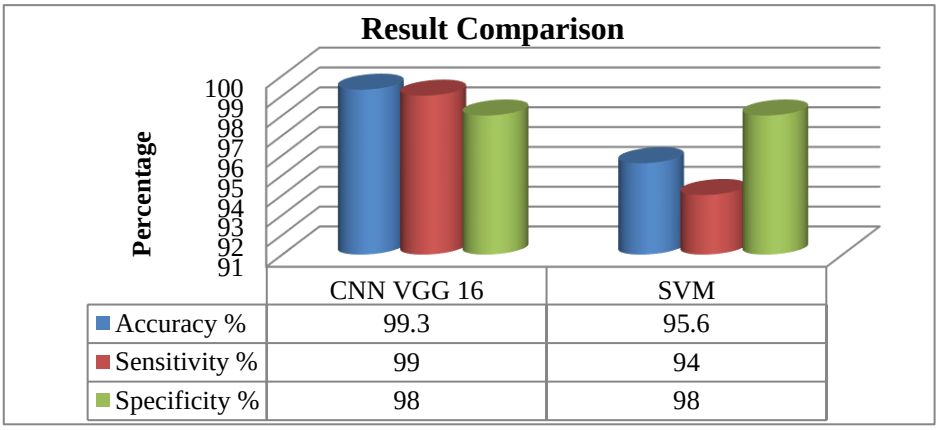

Figure 4. Accuracy of classifiers for Arabian HTR

5. CONCLUSION

HCR refers to the process of recognizing handwritten characters in any form, whereas HTR refers to the process of reading scanned document images that include text lines and converting those text lines into editable text. In general, the term HCR refers to the process of recognizing handwritten characters. In the subject of machine learning known as pattern recognition, the major focus is on the discovery of recurrent patterns and configurations in the data. In this context, "the process of assigning key features to incoming data in order to categories it as objects or classes" is what we mean when we talk about what we're talking about. When it comes to the subject of pattern recognition, one of the most difficult problems to address is OCR, which is more commonly referred to as OCR. paper proposes a methodology for the accurate recognition of Arabian handwriting that is facilitated by cloud computing. Provisions have been made within this framework for the processing of photos, the segmentation of images, the extraction of features, and the categorization of handwritten images. The CLAHE algorithm is used to improve the quality of the images. The k-means method is used to do the segmentation of the image. The classification is carried out with the help of the CNN VGG 16 and SVM algorithm. The accuracy of the CNN VGG 16 classification system is 99.33%.

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