A Proposed Framework for Recognition of Handwritten Cursive English Characters using DAG-CNN

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***Abstract*—Handwritten Character Recognition (HCR) plays an important role in Optical character Recognition (OCR) and Pattern Recognition (PR), as it has a good number of applications in various fields. HCR contributes extremely to the growth of automation and are applicable in the areas of bank cheque, medical prescriptions, tax returns etc. But handwritten characters are much more difficult to recognize than the printed characters due to difference in writing styles for different people. Both conventional approaches and deep learning techniques have been used for handwritten character recognition. Deep learning techniques such as Convolutional Neural Networks always shows better accuracy than the conventional techniques. In this paper a new deep learning techniques, namely Directed Acyclic Graph - Convolutional Neural Network (DAG-CNN) is used for handwritten character recognition.**

Keywords—Directed Acyclic Graph (DAG), deep learning, Convolutional Neural Netowrk (CNN), Rectified Linear Unit (ReLu), Handwritten Character Recognition (HCR), Optical Character Recognition (OCR)

I. INTRODUCTION

In a digitally enhanced society, we highly depend on computers to process huge volume of data. The economic and business requirements, demands a fast inputting of mountains of data into the computers. This is not efficiently achievable through manually typing the data and entering it into the computers. Hence mechanizing the manual process plays an extensive role in recognition field. Many researches and advancements came in the character recognition area, and Optical Character Recognition (OCR), has made a remark in the field of Artificial Intelligence and Machine Learning. Optical character Recognition, known as OCR is the process of reading the text from the documents, both the printed text and handwritten text and converting the text into a form that the computers can operate.

It was in the year 1870, actually character recognition has been started. During that time only two things were invented, that was retina and the sequential scanner et al. [19]. And that was a remarkable achievement of that time in the field of recognition. After that, by the time of 1950 technology was developing at a great speed and pace et al. [19]. It was during this era all the data entry and processing became computerized. And almost by the middle of 1950 OCR machines became available in the market of technology et al. [19]. Then in the year 1954, at the Readers Digest, the first OCR reading machine had implemented. Later in the year 1960 and 1970, many OCR applications was started to be used in various fields like banking, insurance, hospitals, post offices and many other industries et al.[19]. But in the early 1960s both the recognition techniques as well as computer systems were not very much powerful, so that the OCR systems make many errors while reading from a handwritten document or from a poorly printed quality. From that time onwards there were several improvements taking place in this area et al. [19].

There are several solutions for OCR in the field of machine learning and pattern recognition. OCR methods can be classified as conventional methods that is based on handcrafted-features and deep learning methods, that is Neural Network models. The conventional methods include extraction of handcrafted features and classify them accordingly. These handcrafted features cannot ensure much recognition rate or accuracy as these features are not robust. Due to the high dimension of these features, they are computationally intensive also. Hence reduces the discriminative power. The modern methods of recognition of characters uses deep learning techniques, which mainly uses the Convolutional Neural Networks and can easily solve the problem of handcrafted features. Deep learning techniques do not need to be trained using any particular features. The deep learning approaches take the input image, and provide the classification output. The major difference between deep learning and conventional methods is that deep learning automatically learns features from data, while conventional methods take handcrafted features, which mainly depends on knowledge of the programmer and is highly impossible to take the advantage of data. Deep learning can automatically learn feature representation from data, including millions of parameters. Still it is challenging to achieve hundred percentage accuracy because recognition systems are different for different languages and are worst when considering handwritten character recognition due to wide inter-personal and intra-personal variations in writing styles et al. [20].

In this paper, a cursive English handwritten character recognition using the deep neural network called Directed Acyclic Graph Convolutional Neural Network (DAG-CNN) is

proposed. The rest of the paper is organized as follows: Section 2 discusses few latest related works are done in this research area. Section 3 describes the proposed method and then list the conclusions in section 4.

II. RELATED WORKS

There are many works completed using the conventional hand- crafted feature extraction methods for Handwritten Character Recognition. A work done by J. Leena Hepzi et al. [3] used Hidden Markov Model (HMM) for recognition and K-Nearest Neighbour (KNN) for classification. In this paper the pre- processing is performed using the median filtering method. One of the disadvantage of using HMM is that, several assumptions can be made. Here it is assumed that for every observation, it does not depend on the previous state. It only depends on the current state, and it becomes difficult to handle the correlation between the continuous observations. Finally classification is completed using KNN algorithm. This method achieved an accuracy of 90%.

Pritam S Dhande et al. [4] proposed another work for recognition of medicine names from prescriptions using a conventional method. Here pre-processing is completed using various filters and morphological operations, segmentation is completed using the horizontal and vertical projection histograms. After that feature extraction is performed using the Convex Hull algorithm. Using this 125 features of each character is extracted and finally classified using Support Vector Machine (SVM) classification algorithm. This handcrafted feature method achieves only an accuracy of 85%.

Optical Character Recognition for cursive handwritting made by Nfiz Arica et al. [5] suggested an analytical approach for character recognition. Here the input image is binarized using optimal thresholding method after which segmentation is performed. In the feature extraction step a set of directional features is extracted by scanning a fixed sized window in various directions. Then to obtain the HMM parameters and parameters of the feature space HMM training is completed. This is another handcrafted feature method for recognition and only achieves an accuracy of 88.3%.

Jija Das Gupta et al. [6] proposed a offline handwritten word recognition system based on holistic approach. In this work mainly three set of features were used. 2 handcrafted features and 1 machine generated feature. The output is provided to three separate classifiers for classification. The machine generated feature is extracted using the Deep Convolutional Neural Network (DCNN). This method achieves an accuracy of 93%.

Jia Xiadong et al. [7] proposed a method for handwritten Yi character recognition. In this a density based clustering algorithm is used. This paper is mainly focused to solve two of the issues of Convolutional Neural Network. In deep learning models a large amount of data is needed to train the model. Usually a large pre-labelled data is created. Here instead of that a clustering algorithm is used to cluster the unlabelled data. Then these data are manually labelled and checked to remove errors. Then using different scales and different parameters a better neural network for recognition is constructed. The prepared dataset is then given to the Convolutional Neural Network. Softmax is used for classification. An improved accuracy is achieved than the existing Yi HCR systems.

Another work proposed by Xuchen Song et al. [8] is to recognize Chinese handwritten characters using sample set expansion and CNN. CNN, a deep learning techniques requires large amount of data to train the network inorder to achieve better accuracy. But it is difficult to obtain a large collection of Chinese characters with good quality. So the author suggested various dataset expansion techniques to scale the dataset without compromising the data quality. This system achieved an accuracy of 94.7%.

Akm Ashiquzzaman et al. [9] proposed a method for improving the the classification accuracy of handwritten Bangla compound characters. This paper suggested a method by using Deep Convolutional Neural Network (DCNN) using a greed layer-wise training approach. The two main problems occur are overfitting and vanishing gradient. These are tackled by using Dropout and Exponential Linear Unit (ELU) respectively. The proposed method achieves an accuracy of 93.68%.

A case study is completed by Bappaditya Chakraborty et al. [10] on handwritten Devanagari characters, to find out whether a deeper network provide high accuracy. Here a recognition accuracy on CNN and a hybrid CNN-BLSTM network is done for five different characters. The results showed that CNN with 5 covolutional layers and 2 fully connected layers produced a better accuracy of 95.8% than the HOG featured CNN- BLSTM architecture.

LI Pengchao et al. [11] suggested a method to improve the accuracy of recognition by reducing mis-classification. Character recognition has already achieved an accuracy rate of 0.95, but there are some mis-classifications that still occur. In this method a CNN with confidence estimation is suggested. Confidence is calculated by applying softmax function to the final layers of CNN. Then error rejection is performed by comparing this confidence with a preset threshold. The error rate was reduced to below 2%.

To improve the recognition accuracy of deep earning techniques, many models have been tried in CNN. Li Chen et al. [12] proposed a new method called relaxation CNN. The network is trained by using cascading technique. Cascading training includes pre-training, relaxation weight initialization and fine tuning. Finally The relaxation neural network is trained by global fine tuning and achieves an accuracy of 96%.

A work proposed by Ziang Yan et al. [13] develops a technique which recognizes and classifies the rare Chinese handwritten characters using a radical extraction. Radicals are the main features extracted from the characters. Global features are also extracted. A Radical Extraction Network is built and the character level classification is completed. The method provides an accuracy of 96.2%.

Tan Chiang wei et al. [14] proposed a method for the recognition of English characters using a deep neural network. The work is carried out using the inception-V3 model, which is a deep neural network with ReLu as activation function. Results showed an accuracy of 95% for recognition.

Ruyu Zang et al. [15] describes a method for recognition of handwritten Chinese character recognition using ResNet. This is performed by combining it with matric learning. Usually, output softmax function in deep network ignores the inter and intra class information. To overcome this matric learning using a centre loss module is introduced. The method gives an accuracy of 97.03%. But the complexity of the network is increased.

Quingqing Wang et al. [16] demonstrated the experimental results on recognition of similar Chinese handwritten characters

using a hierarchical CNN model. The model uses a two staged approach in which the first stage consists of the grouping of 368 similar shaped characters into 172 classes. Then for every 172 classes, separate classifiers are used to figure out the critical regions and thus recognition similar shaped characters. This method results in an accuracy of 97.6%.

Meduri Avadesh et al. [17] illustrated a method for recognizing compound Sanskrit letters. The work started by concentrating on compound letter segmentation but seems not effective. So they worked on neural network. The method seems good for digitizing old poorly maintained documents and showed an accuracy of 93%.

Xinchi Chen et al. [18] proposed an new method to include the information at word level for the Chinese word segmentation. Character based sequence labelling is completed to improve accu- racy. Using this sequence and provided vocabulary Directed Acyclic Graph (DAG) is constructed. By using a DAG-LSTM the contextual level information can be obtained. The results showed that this method have a better accuracy than the existing methods.

III. PROPOSED METHOD

Nowadays, deep learning techniques plays a vital role in character recognition. Deep learning which is considered as a subset of machine learning comes under the kingdom of Artificial Intelligence (AI). In deep learning, machines are trained by using a huge amount of data and have high flexibility. The deployment of neural networks has helped deep learning to produce enhanced results. Even by using the Convolutional Neural Network (CNN), for cursive alphabet recognition there are chances for some alphabets like 'u' to be mis-classified as 'v' and 'e' to be classified as 'l' etc. Inorder to avoid these problems and improve accuracy a new architecture called DAG ie. a network which is subdivided into several paths is applied to the basic CNN model. In DAG, features from each layer can be directly supplied to the output layer for classification.

A. System Architecture

The proposed system have various modules. The overall system architecture is shown in Fig.1. The various modules of the system are data acquisition, dataset augmentation, partitioning of training and testing data, pre-processing, model building and training, finally classifying and predicting output. In the data acquisition module various handwritten cursive alphabets are collected and dataset is created. As deep learning techniques need large amount of training data, the dataset is augmented to increase the training samples. Various augmen- tation techniques used are scaling, rotation, transformation etc. After that, the dataset is divided into training and testing set. Next pre-processing operations such as noise removal, skew detection and elimination etc. are performed on the dataset to improve the quality of the data. After these basic steps the neural network model will be build and trained. Then this trained neural network is used for classification of the handwritten cursive alphabets.

B. DAG Network

Directed Acyclic Graph (DAG) is a multi-scale Convolutional Neural Network which can be subdivided into several

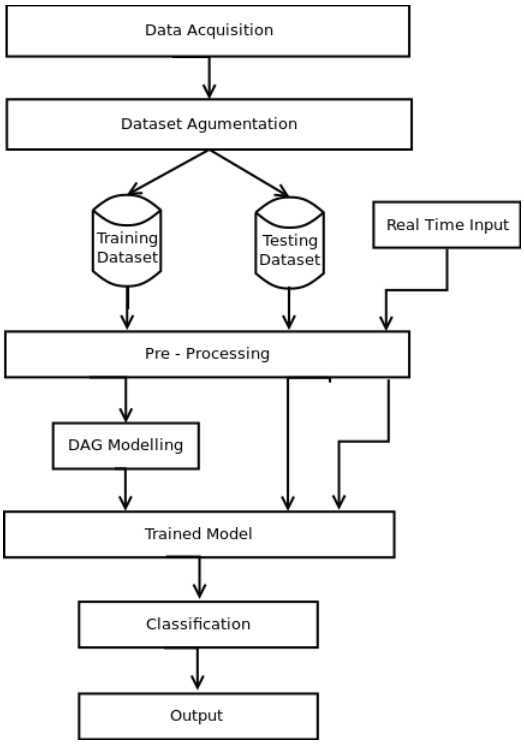

Fig. 1. System Architecture

paths. A basic convolutional neural network has a linear structure in which the output of each convolutional layer is connected to next convolutional layer. Only output of the last convolutional layer will be directly connected to the output layer for classification. So as the network goes deeper the accuracy will get reduced. This happens due to vanishing of gradient. Deep neural networks solve this problem by using skip connections. The basic CNN architecture is as shown in Fig.2 and the DAG-CNN architecture is as shown in Fig.3.

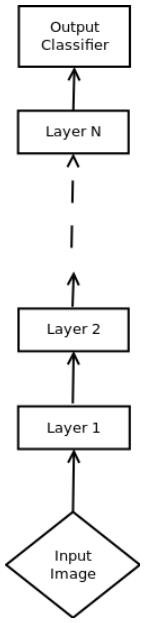

Fig. 2. Basic CNN

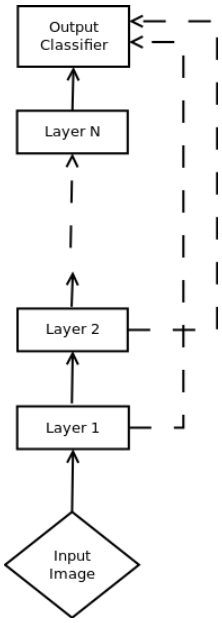

Fig. 3. DAG-CNN

DAG is no more linear in structure but is connected as a directed acyclic graph. And has a unique characteristic due to this architecture. It can have multiple inputs and outputs. This multiple connection to each layers allows every layer to be connected to the final classifier layer directly by using skip connections. So that all the low, mid and high level features can contribute to enhance the performance of the network. At the same time, since we are taking features from every layer, total number of feature will be very high. This will create a problem of over fitting. Inorder to avoid that the optimal layers which enhances performance must be selected. This can be achieved using a greedy forward selection strategy. In various real time applications basic CNN will be greatly affected by noise, for such case a more robust network is required. DAG is a suitable solution as it incorporates the features from every layer. One of the advantage is that all the features will be already processed by some layers and are available for free. After extracting all the features and before feeding it into the classifier some other operations need to be performed. All the extracted features at each convolutional layer will be given to an addition block. Here an element wise addition of features across the layers will take place. After that normal average pooling operation will be done. From there the output will be given to softmax module for classification and accuracy prediction.

IV. CONCLUSION

Handwritten Character Recognition plays an important role in optical character recognition and pattern recognition. It greatly contributes to automation of many things like medical prescriptions, tax returns etc. Earlier handcrafted feature methods were used for character recognition, which are inefficient and requires much effort and time. One of the best alternative for conventional handcrafted features was to use deep learning techniques for character recognition. All the features used here are machine generated features and produces much efficiency and accuracy to the result. The various deep learning techniques used are convolutional neural network, deep belief network auto encoders etc. The Convolutional Neural Network produces a better accuracy, but it is a linear model where only the last layer will only be directly considered for classification. So inorder to use the low, middle and high level features for classification we use multi-scaled CNN called Directed Acyclic Graph Convolutional Neural Network (DAG-CNN).

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