Offline Kannada Handwritten Character Recognition Using Convolutional Neural Networks

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Convolutional Neural Networks for Kannada Handwritten Character Recognition

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***Abstract*—Handwritten characters are still far from being replaced with the digital form. The occurrence of handwritten text is abundant. With a wide scope, the problem of handwritten letter recognition using computer vision and machine learning techniques has been a well pondered upon topic. The field has undergone phenomenal development, since the emergence of machine learning techniques. This work on a major scale devises to bridge the gap between the state-of-the-art technology, of deep learning, to automate the solution to handwritten character recognition, using convolutional neural networks. Convolutional neural networks have been known to have performed extremely well, on the vintage classification problem in the field of computer vision. Using the advantages of the architecture and leveraging on the preprocessing free deep learning techniques, we present a robust, dynamic and swift method to solve the problem of handwritten character recognition, for Kannada language. We discuss the performance of the network on two different approaches with the dataset. The obtained accuracy measured upto 93.2 per cent an accuracy of 78.73 per cent for the two different types of datasets used in the work. The results obtained have been plotted and presented in the relevant sections.**

Keywords-*Convolutional Neural Network, Computer Vision, Character recognition, Deep Learning, Kannada Characters*

I. Introduction

The flow of knowledge in the field of pattern recognition has mainly taken steep turns in recent times, after the emergence of deep learning techniques.

Unlike feature identification and extraction followed by calculations, deep learning is entirely based on the data, enabling the application of the techniques as a solution to a wide array of problem statements, including handwritten character recognition.

Convolutional neural networks have become the face of deep learning due to their versatility and robustness. The technique is viable to problems which deal with the spatial arrangement of patterns, thus handwritten character recognition.

Unlike OCR and other machine learning based, feature extraction techniques, Convolutional Neural Networks, perform operations with the consideration of the strongest feature.

Also, traditional techniques that have been satisfactory with English language handwritten character recognition are not readily applicable to languages such as Kannada, due to the morphological differences between the characters of the language. This renders deep learning techniques extremely useful in solving the problem.

With noticeable contributions to the field, from various authors, the problem statement, involving international languages such as English, Chinese, Arabic, Japnese have been readily worked upon with excellent performance presentation. OCR has been constantly yielding good results but in language specific partitions of the domain.

The improvement in the availability of data and platforms, with the support of cloud-based processing technology, has turned up the quality and variety of the achievable solutions, thus, making room for-state-of-the-art technologies such as Convolutional Neural Networks.

This work aims at the application of Convolutional Neural Networks to solve the widely approached problem of Kannada handwritten character recognition.

The following sections, 2 and 3 address the related work in the direction, the later sections unfold the experimentation and result and analysis part.

II. Related Work

Handwritten character recognition has been persuaded by various authors, with significant success. The initial efforts, a historical perspective to the field is spread out by Mori et al. [7]. The authors provide a clear cut view about the status quo of the progress in the field. The work approaches the OCR technique in a historical perspective and dives deep into the template matching and structure analytics, with the provision of contrast between, commercial OCR development, and research and development on the technique. The authors provide a clear picture regarding the direction of the development in the field, with OCR as a reference point.

Further down the lane, Amin et al. [1] present their work on off-line Arabic character recognition, perceived as machine automation of human reading. The authors take a viewpoint of the complexity of Arabic characters, and the relatively lesser amount of work towards the subdomain. The authors leverage on some of the very important characteristics of writing procedure such as velocity and other temporal features. Also, the conditions such as writing space limitation have been given light by the authors in their work.

As quoted above, the complexity in recognition of Arabic characters, carries forward to, the recognition of Indian language scripts. The variations, complexities, customisations, contribute to the challenges faced in solving the problem. The origin of all Indian language being Brahmi, the similarity between the scripts of languages and the vivid distribution of the design of characters within the language, adds on to the complexity of the procedure. Unlike English, these languages have combinational characters, apart from vowels and consonants. Size, writing style variations are also to be tackled as part and parcel of the problem statement.

Thus the authors take a variational approach methodology, with the segmentation, as implicit and explicit segmentation techniques, to isolate the simple and complex characters. The introduction of Hidden Markov Models, Neural Networks have been made in the work, yielding considerable results.

Online handwriting recognition also has been majorly contributed to, and Bahlmann et al. in their work [2] have introduced, handwritten character recognition system frog on hand. The focus of this work concerns the presentation of the classification/training approach, which the authors call cluster generative statistical dynamic time warping (CSDTW). CSDTW is mentioned to be a general, scalable, HMM-based method for variable-sized, sequential data that holistically combines cluster analysis and statistical sequence modelling. It can handle general classification problems that rely on this sequential type of data, like, speech recognition, genome processing, robotics and others. The work internally uses hierarchical clustering.

Fuzzy techniques, to automate the process of handwritten letter recognition has been worked upon by Suresh et al. [17]. In this effort, the handwritten characters (numerals) are preprocessed and segmented into primitives. These primitives are measured and labelled using fuzzy logic. Strings of a character are formed from these labelled primitives. To recognize the handwritten characters, conventional string matching is performed. However, the problem in this string matching has been avoided using the membership value of the string. This result is being compared with the Modified Parser generated from the Error-free fuzzy context-free grammar.

Some works, have based themselves towards a combinatorial approach with tackling the problem statements of both handwritten and printed character recognition. Majumdar et al. in their work on Bangla character recognition [5], follow a similar approach. The work concerns automatic recognition of both printed and handwritten Bangla numerals. Such mixed numerals may appear in documents like application forms, postal mail, bank checks and others. The pixel-based features are normalized pixel density over 4 X 4 blocks in which the numeral bounding-box is partitioned. Some pixel-based and shape-based features are chosen for the purpose of recognition. A neural network approach is chosen, and the obtained results have displayed an accuracy of 97.2 per cent. Another approach to Bangla characters has been made by Naser et al. [8]. The work presents a comparative analysis of two projection based feature extraction techniques namely Radon and fan-beam. Fan-beam technique is a variation of Radon transform and usually used in tomography. An interesting accuracy of 98 per cent has been obtained for Radon feature with ANN. The authors also propose KNN performance on the features extracted.

An attempt to classify totally unconstrained handwritten Kannada characters using Fourier transform based Principle Component Analysis and Probabilistic Neural Networks is made obtaining an accuracy of 88.64 per cent by Manjunath et al. while Niranjan et al. [10] had approached the same problem of classification of unconstrained handwritten Kannada characters using FLD. A newer approach to the same problem has been the usage of ridgelet transforms, by representing monodimensional singularities in bidimensional space, is used by Naveena et al. [9].

The rise of machine learning was welcomed by the field of handwritten letter recognition also, in the context of the application range of the problem being wide. The machine learning procedure involves the extraction of features, in the data and recognising the patterns with the help of these. The feature extraction process is to avoid the outburst of parameters, as the data flow is combinatorial in almost all the models. The probability factors are considered, regarding the occurrence of the feature and the problem is fine-tuned, using the gradient descent approach, on the error function.

The focus on single language script for handwritten character recognition has been practised in abundance and a contribution in the same direction is by Pal et al. [11]. The authors present their work on the Oriya handwritten script, with curvelet feature model. Since most of the Oriya characters have a curve-like stroke, the authors use curvature feature for the recognition purpose. Finally using principal component analysis they reduce the dimensionality and this feature vector is fed to a quadratic classifier for recognition. An accuracy of 94.06 per cent has been obtained for the method.

In [3], the authors have made efforts towards the restoration of degraded Kannada handwritten paper manuscripts using both special local and global binarization techniques, by the elimination of uneven background illumination. MSE and PNSR techniques have been used to measure performance, with the benchmark results obtained by Epigraphists. Comparison of these techniques with standard techniques, such as sauvola and niblack, which demonstrate the efficacy of the proposed method is also done.

The combination of SVM with various feature extraction techniques, with KNN, has been used in many works. Rajput et al. [14] have presented Marathi handwritten numeral detection with Fourier Descriptors. Fourier Descriptors that describe the shape of Marathi handwritten numerals are used as a feature. Fourier Descriptors represent the shape of numerals, invariant to rotation, scale and translation. Three different classifiers, namely, nearest neighbourhood (NN), K-nearest neighbourhood (KNN) and Support Vector Machine (SVM) is used independently in order to recognize test numeral. The authors mention accuracies of around 97 per cent for all the techniques.

SVM based approaches, has the listing of the work by Shrivastava et al. also [16]. The work applies this technique for recognizing handwritten numerals of Devanagari Script. Since the benchmark database does not exist globally, this system is constructed database by implementing Automated Numeral Extraction and Segmentation Program (ANESP). Preprocessing is manifested in the same program which reduces most of the efforts. Moment Invariant and Affine Moment Invariant techniques are used as a feature extractor. Binary classification techniques of Support Vector Machine is implemented and the linear kernel function is used in SVM. The authors also report an accuracy of 99.4 per cent.

Further, OCR based techniques have been given importance, by authors, focusing on language-specific scripts also. The authors Jayaram et al. in [4] present the overview of OCR on the Telugu language. The authors explore various techniques, methodologies which have been used in the process of solving the problem of handwritten character recognition for Telugu script. The script is quite similar to Kannada, is also, divided into vowels and consonants. The script provides a clear depth of the technological advancements, for starting off with the research in this field. Work on Malayalam is posed by Hisham et al. in [13]. The authors tackle the similarity in the language script in Malayalam using SVD(Singular Value Decomposition) and Euclidean distance measurement. The work utilizes Active Contour based segmentation technique for character segmentation and performs a Singular Value Decomposition operation to represent the character in a low dimensional feature space. In this feature space, the recognition task is performed using the Euclidean Distance Measure. The authors also mention various pitfalls in the process.

Considerably, very fewer efforts are put into the handwritten character recognition of Kannada characters. The prominent technique overview has been provided by Shaila et al. [12]. The effort is helpful in understanding various other techniques, used in solving the posed problem of Kannada handwritten letter recognition. Some of the recent works in the field are countable.

A deep belief network-based approach is taken by the authors aforementioned, using a fast alternative feature descriptor to HOG, the distributed average of gradients. Mirabdollah et al. [6] have proposed the alternative feature vector of DAG, wherein the image is divided into blocks and windows of standard sizes, and the average of the values of pixels in each window is appended to the descriptor to obtain the feature vector. The authors Karthik et al. in [15] have grouped the vowels and consonants separately and used 400 images per character to train the deep belief network. They have claimed an average accuracy of 97.04 per cent.

III. Problem Statement

This effort is directed to solve the ”classification/recognition of handwritten Kannada characters”, by using the state-of-the-art, dynamic technique to yield reliable results. Kannada alphabet has 13 vowels and 34 consonants. The effort is focused on the identification of these characters from various sources of literature. The work is also aimed towards analysing the shortcomings in various traditional machine learning and OCR techniques, that are currently existing as the solution for the problem statement.

IV. System Architecture

The phases in the flow of data are as follows and are shown in the figure 1

1) **Data Division:** The data set is divided into two different parts, based on a standard ratio of 80:20, for testing and training.
2) **Data Preparation:** The obtained, parted dataset is further resized and converted to gray scale before the processing starts. Thus preparation is addressed.
3) **Classification:** This step involves, feature extraction, preprocessing, which is done by the network as a part of the classification process.
4) **Result Analysis:** The result analysis step involves the visualisation and inferencing out of the obtained result.

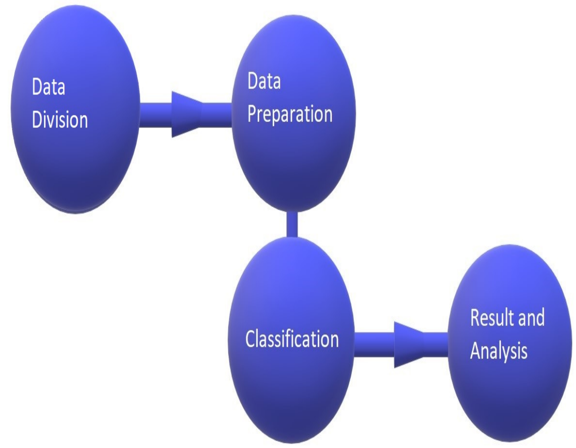

Fig. 1. System Architecture

V. Proposed Method

A. *Kannada Language*

The Kannada Alphabet or the ”Varnamale” consists of 47 characters with 13 vowels called ”Swaras” and 34 consonants called ”Vyanjanas”. Kannada as a language has a very old history and is one of the wide-spread languages in the country. It is one of the 22 official Indian languages. Unlike the character in English, the Kannada characters have very similar orientation and minor differences are seen between some characters. The strokes of the Kannada characters also vary from English ones, as in the latter, most of the letters are written with strokes above and below a horizontal line, while in the former most the letters are written with a vertical line of reference. Kannada is a Dravidian language with Sanskrit and Prakrit influence. A more definite reference to Kannada is found in ’Charition Mime’ by a scholar from Europe. With reference to the origin of Indian scripts from Bramhi script, scripts for Telugu and Kannada similar in many ways. Considering the history of Kannada there are three stages:

1) Halegannada
2) Nadugannada
3) Hosagannada

Several minor languages like Tulu, Konkani, Kodava, Sanketi and Beary also use alphabets based on Kannada script. Language Kannada has 49 alphabets or ’varnamale’ with 13 vowels or ’Swaras’, 34 consonants or ’Vyanjanas’ and 2 ’Yogavahakas’(neither vowels nor consonants) i.e ’Anusvara’ and ’Visarga’ which is common in almost all the languages across India. Consonants (vyanjanas) are combined to form digraphs (ottaksara) when there are no intervening vowels.

Kannada script was added to Unicode standard in October 1991.

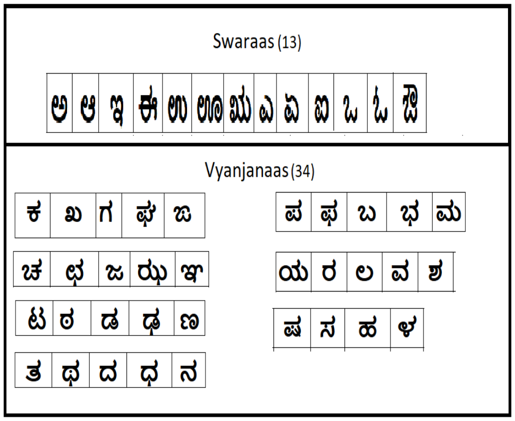

Fig. 2. Kannada Varnamale

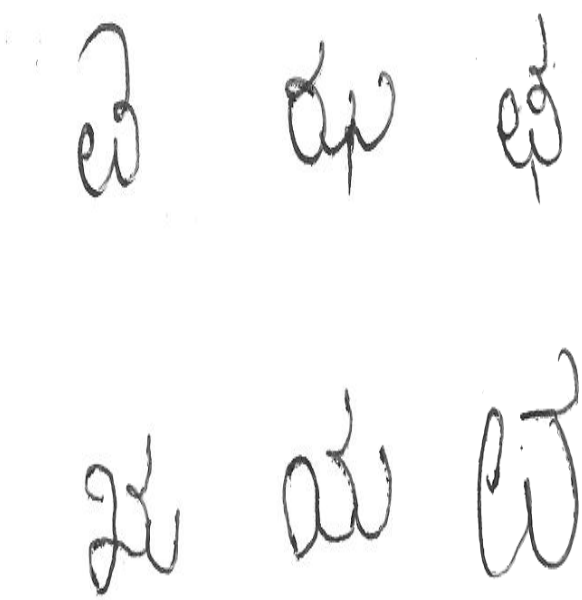

Fig. 3. Sample from the dataset

B. *Convolutional Neural Networks*

Convolution neural networks, one of the best available algorithm for building image classifiers. CNNs use a multilayer perceptron design, which requires minimal processing. For CNNs, there is no requirement of data pre-processing, reducing the great burden on data cleaning and other operations. They are capable of extracting commonly available features from the group of images supplied for learning. Based on this extracted features, an image is mapped to a specific class. They perform extensively well when supplied with a large dataset. CNNs are more data dependent and their performance is directly dependent on input data. Progressive resizing is a technique used to build effective CNNs with higher performance. The method is very helpful during training and optimization phases of the project. We can start training our network with small-sized data since it is faster. But it extracts only a few features. Later can be scaled up to the double of the size of the initial data size. It can be done by removing the first convolution layer and appending it with new layers to extract the more features from the new data set. This technique also helps in preventing the over fitting problem. Max pooling technique is used for resizing the higher order images to the size of the existing model. This helps in improving accuracy.

VI. Model

The proposed model as shown in figure 3, consists of 3 convolutional layers, with 2 max-pooling layers, which help in the reduction of the parameter overflow, due to the convolutions. The convolutional layers perform kernel convolution on the input using 3x3 kernels and the output of the repeated combinational of the max-pooling and the convolutional layer is directed to a flattening layer, connected to a dense layer. The flattening layer reduces the number of channels of data flow and the dense layer contributes in the feature pick-up, after the flattening. The output is routed to a drop-out layer which drops the output of certain nodes in the dense layer to avoid the problem exploding gradients . The output of the second dense layer is consumed to produce the output, considering the output with max probability.

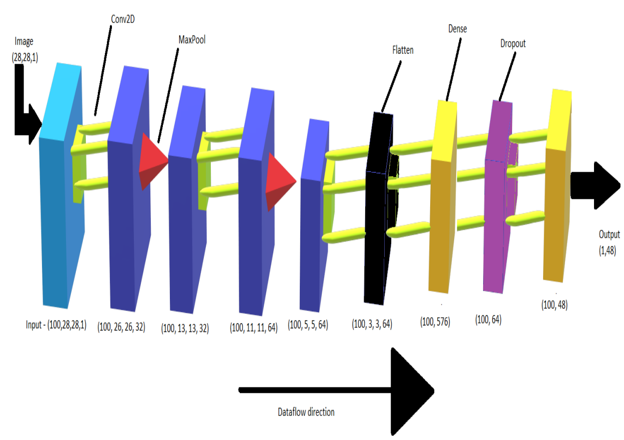

Fig. 4. Architecture diagram for the proposed model

VII. Result

A. ***Simulation Data Set***

The two data sets used in the work consists of 500 images of each Kannada character. Thus a total of 23500 images, out of which 18800 images have been used for training

TABLE I
SIMULATION DATASET RESULT COMPARISION

Dataset	Accuracy Values	Method
Consolidated Dataset	93.2 per cent	Convolutional Neural Networks
Raw Dataset	78.73 per cent	Convolutional Neural Networks
Chars 75K Dataset	60.1 per cent	HOG+SVM [18]

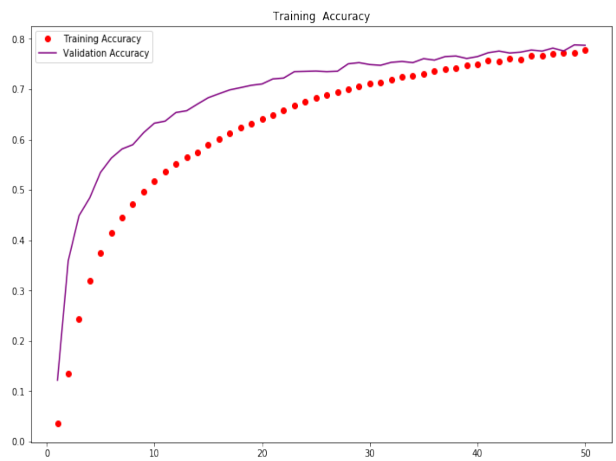

Fig. 5. Raw Dataset - Accuracy

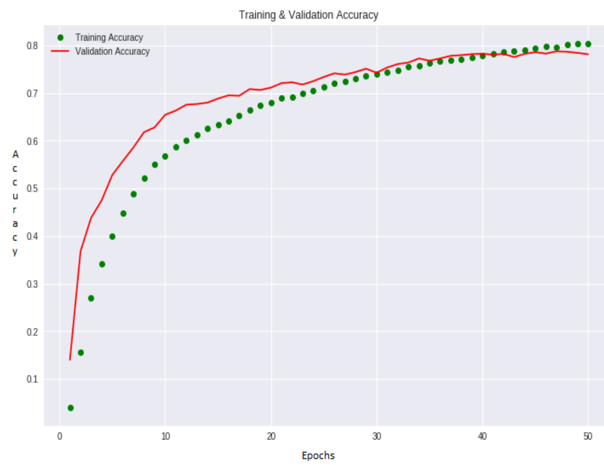

Fig. 7. Consolidated Dataset - Consonants - Accuracy

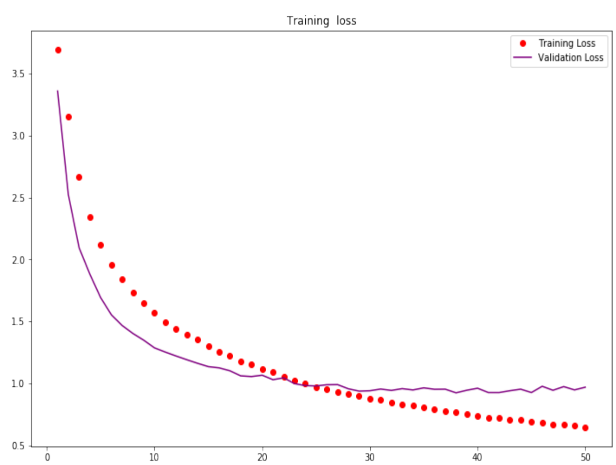

Fig. 6. Raw Dataset - Loss

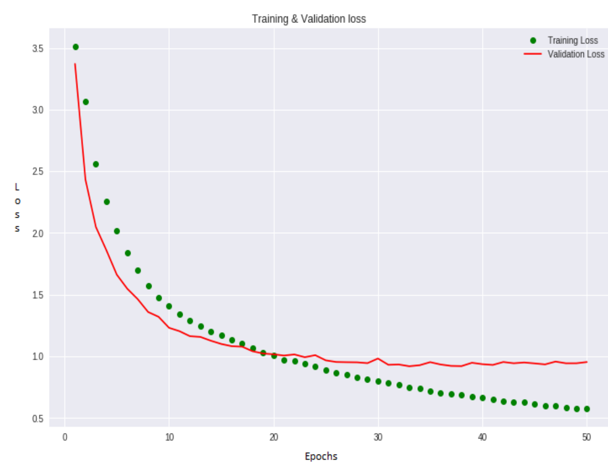

Fig. 8. Consolidated Dataset - Consonants - Loss

and the remaining 4700 for testing the network. The images were obtained from numerous writers, thus inducing variety into the dataset. The collected dataset is divided into vowels and consonants, to experiment separately. This separation has opted in the view of complex characters(”ottaksharas”) in Kannada alphabet, which consists of representations of two or more consonants, while the vowels, in combination with every consonant give a wide array of characters which make the ”gunitaaksharas”. The quality of the images in the data set varied over colours and pressure from writers. Samples are shown in figure 10

B. Simulation Results

The model was trained on 13566 images of size 28x 28 for 50 epochs and tested on 3399 images of the same size, presented an accuracy of 78.73 per cent. The presented graphs show the accuracy and loss values against 50 epochs.

Also, the seperation of consonants and vowels, bumped the accuracy up by 15 percent, due to the close similarity between the important features in the vowels and the consonants. The obtained accuracy measured upto 93.2 per cent. The values are tabulated and displayed in the graph. The training was done for a benchmark 50 epochs.

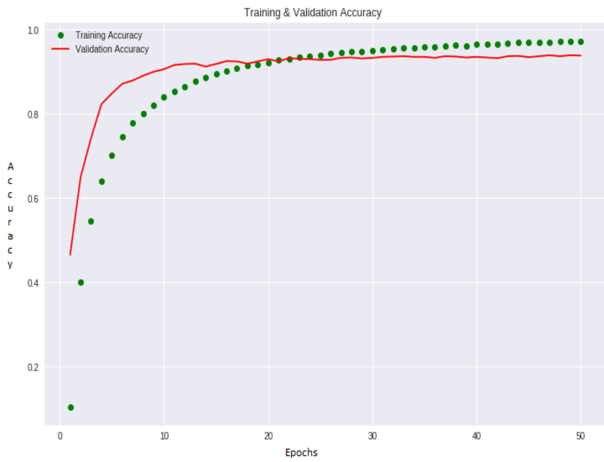

Fig. 9. Consolidated Dataset - Vowels - Accuracy

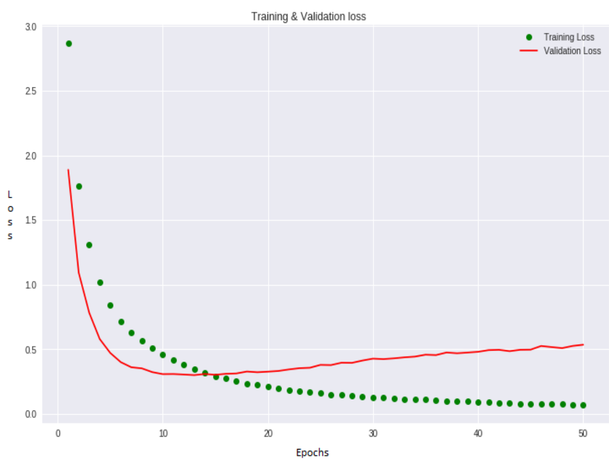

Fig. 10. Consolidated Dataset - Vowels - Loss

VIII. Conclusion

The proposed method classifies and identifies the kannada handwritten characters using deep learning method. This method gives an easy way to the user since there is no preprocessing of data. Those works are handled by the Neural network, which is brain of the deep learning model. This reduces the burden on the user making the work more promising. With capsule network the model trained with a good amount of data is able to recognise the kannada handwritten characters. The future implementations can be to recognise the words and later recognizing sentences. The next stage will be understanding the sentences and giving satisfying answers. Once the network is able to understand the sentences, model can be trained to summerise the context of the given text input or to translate the input into some other languages. The obtained accuracy measured upto 93.2 per cent an accuracy of 78.73 per cent for the two different types of datasets used in the work.

IX. Acknowledgement

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