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OHKWR: Offline Handwritten Kannada Words Recognition using SVM Classifier with CNN

Ramesh G, Sandeep Kumar N, Champa H. N

Abstract*: *In field of handwriting recognition, Robust algorithms for recognition and character segmentation are presented for multilingual Indian archive images of Devanagari and Latin scripts. These report basically suffer from their format organizations, low print and local skews quality and contain intermixed messages (machine-printed and manually written). In order to overcome these drawbacks, a character segmentation algorithm is proposed for kannada handwriting recognition. In this work, in initial steps we are obtained the segmentation paths by using the characters of structural property and also the graph distance theory whereas overlapped and connected character are separated. Finally, we are calculated results by using the SVM classifier. In proposed recognition of character, they are three new geometrical shapes based on new features such as center pixel of character is obtained by first and second feature and third feature is calculation purpose we are used in neighborhood information of text pixels. Benchmarking results represent that proposed algorithms have best work identified with other contemporary methodologies, where best recognition rates and segmentation are obtained.

Keywords: Convolutional Neural Network, Computer Vision, character recognition, Word recognition, SVM classifier.

I. INTRODUCTION

Computer Vision is said to be fast-growing and technically emerging field of computer science that is making its own path into different domains. Developing a generic and efficient recognition system for handwritten text is an important challenge in the field of Computer vision that meets the interest of a wide range of applications. Reading sign boards, translation of different scripts, banks, legislative bodies, offices, areas of literature, assistance to blind, archaeological applications are the main areas of handwriting recognition application. By using the handwriting recognition method huge number of achive can be efficiently carried out. One such application is identifying the scripts of various languages. Recognizing the scripts of South Indian languages is very difficult and involves a lot of effort in account due to its compound characters and large character set among the Indian languages. Therefore, there is a good scope of research and tremendous demand for optical character and word recognition system development that includes handwritten documents. To identify the text in handwritten or typed papers, the technique of OCR (Optical character recognition) is used. The need for OCR system development also raises the prevalence of web and multimedia techniques. There are several attempts that have taken place to build an efficient OCR system to identify handwritten characters from Kannada script. The design of an effective and stable OCR system requires a lot of efforts and several steps to be followed. The OCR system included the steps of pre-processing, extraction and classification functions. These steps must be taken care in a predetermined manner in order to achieve the result. Preprocessing is the procedure where the raw image is transformed into an appropriate processed image. This processed image will be used as an input for extracting the features from the image. In the preprocessing cycle, suitable methods are used to methodologically scrutinize the raw image given as an input. The most critical process in the OCR system development is the extraction of the element. The Convolution Neural Network and Support Vector Machine classifier is used to recognize Kannada handwritten words.

In image processing, a digital image is being collected from a determinate number of fundamental elements in which each individual element has an assessment. The elements are technically referred to as picture elements or image elements or pixels. The image which is digitized can then be displayed on a high-resolution monitor. For the image to be displayed, it needs to be stored in a buffer memory with rapid-access. The most critical process in OCR system development is the extraction of the element. The convolution neural network and support vector machine classifier is used to recognize Kannada handwritten words. The fourth major language of south India is kannada language. Its spoken by around 50 million people in Karnataka, Andhra Pradesh, Tamilnadu and Maharastra. A low quality process of segmentation results in mis-recognition or faulty segmentation. Because of the existence of conjunct consonant characters. Pre-processing consist of removing noise, identifying skews, recognizing regions, thicking, thinning and binarizing. Segmentation process involves two steps: segmentation of the word and segmentation of the character.

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* Correspondence Author
Ramesh. G,*, Department of Computer Science and Engineering, University Visvesvaraya College of Engineering, Bangalore, India. E-mail: rameshmg6308@gmail.com
Sandeep Kumar N, Department of Computer Science and Engineering, University Visvesvaraya College of Engineering, Bangalore, India. E-mail: sandeepredefined@gmail.com
Champa H. N, Department of Computer Science and Engineering, University Visvesvaraya College of Engineering, Bangalore, India. E-mail: champahn@yahoo.co.in

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Word segmentation is the process where only words are extracted from the pre-processed image. Since we know that from one word to another there is a gap, for word segmentation, we use concept of vertical projection profile [4]. Character segmentation is the method in which we remove only characters from word segmentation.

Segmentation of characters being an important aspect in the identification of character, the process of character segmentation various experts has worked easily. In English language the character set quantity is 26, while Kannada character set consonant, vowel consolidation is 35x16= 560. The number of vowel and consonant mixes that can be imagined is 35x35x16= 19600. The bend shape of the 19600 Kannada character mix makes the recognition system more and more complex.

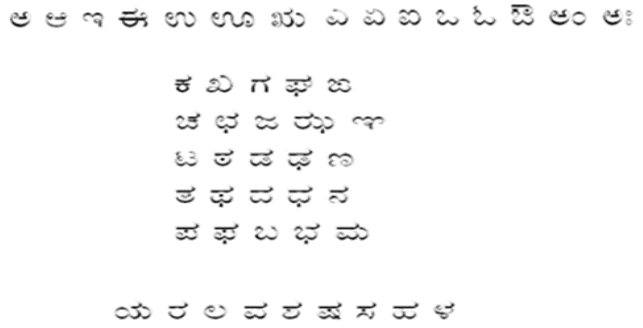

Figure. 1: Kannada Character set

Kannada is one among all the 22 official languages of India. Kannada is recognized at 33rd place in the list of extensively spoken languages entire the world. The state Karnataka Kannada is extensively spoken and used as the official language. In modern Kannada or the Hosagannada they are 49 base characters with 10 numerals. Sample of these handwritten numerals are shown in Figure 1. We can see numerous structural features in the character set of this language. One of the difficult understanding with the Kannada character recognition is the recognition of the characters which are comparable fit as a shape. These comparable characters are having little varieties among them and they assume a significant job in the recognition accuracy. Due to its structured unpredictability, Kannada content is complex when compared with Latin-based languages. Furthermore, Kannada language has 49 letters, as shown in the Figure 1, All 49 letters are further divided into 3-groups, Vowels, Visarga (15), Consonants (34) and modifier glyphs (Half-letter). 15 vowels are used to modify the 34 base consonants, making a total of (34* 15) + 34=544 characters, however, modifiers are used. This gives an aggregate of (544*34) +15=18511 characters, examples of modifiers appeared in the Figure 2.

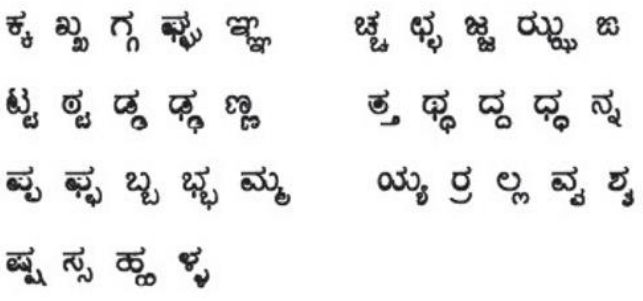

Figure 2. Kannada Consonant conjuncts (vattakshara)

Organization: The rest of the paper is organized as follows, Initially, we discuss the Related works on in Section II. Problem Statement and Objectives are discussed in Section III. Proposed System are discussed in Section IV. Section V discusses the Feature Extraction. Classification is explained in section VI. Implementation is examined in Section VII. Section VIII contains Results. Conclusions in Section IX.

II. LITERATURE SURVEY

R.S. Kunte *et al.,* [2] were the first persons to report research on handwritten recognition of Kannada Online. Kunte used a wavelet function in 2000 and also identified MILE LAB's efforts to manually write and create the 100,000-word dataset for each Kannada and Tamil to establish an online character recognition system. The segmentation of character is a most important pre-processing step in all OCR systems for recognition of characters. Segmentation of character has been a well-researched area over the previous decade and its main point has been to bring the optical character recognition (OCR) calculations to individual characters. Yungang Zhang *et al.,* [3] have presented the character segmentation estimate, using Hough adjustment for a License plate character segmentation. For the segmentation and identification tasks of character recognition, researchers have made several different approaches. In case of segmentation, only less number of researchers have used Artificial Neural Networks [ANN]. Blumenstein1 *et al.,* [7] has presented a new smart technique for segmentation that can be used together with a neural network classifier and a very simple lexicon to identify difficult handwritten words. Prasad Mahadeva *et al.,* [8] have used KNN's main component analysis classifier and reported an average 81 percentage of recognition rate. Ramakrishan *et al.,* [9] have used Support Vector Machine as a classifier for the recognition of characters using dataset that is provided by MILE Lab and recorded 56% accuracy of preliminary segmentation (PS) output and accuracy of 62% Attention Feed-Based Segmentation (AFS) output. Niranjan Jhosi et al., [10] was presented demonstrated the correlation of elastic matching schemes and the adaptive time distance warping test for Tamil characters based on online handwriting recognition. S. Karthik *et al.,* [21] have introduced another methodology depending on deep learning technique with the distributed average of gradients feature is introduced for the recognition of manually written characters of Kannada which brought about 97.04% accuracy. Ramesh *et al.,* [22] has proposed the Deep learning technique, ANN's have also been used claiming a considerable increase in results, Disadvantages of CNN which are solved with the use of Capsule Networks. Magnificent outcomes have been acquired as far as accuracies. Further new methods, for example, CNN have been reported for to be recognized to Kannada numerals. Ramesh *et al.,* [23] have presented the work on a significant scale devises and the state-of-the-art technology, deep learning, for transcribed character recognition, using the convolutional neural Network.

CNN have been known to have performed quite well, on the vintage grouping issue in the field of computer vision. The execution of the network on two unique methodologies with the dataset. The acquired accuracy.

III. PROBLEM STATEMENT AND OBJECTIVES

The problem considered in the proposed work is to recognize kannada handwritten words.

The objectives considered are:

1. To achieve better accuracy in training and validation.
2. To achieve better specificity of words and characters.
3. To maintain higher precision ratio.
4. To increase higher sensitivity while recognizing characters.
5. To obtain highest segmentation and recognition rates.

IV. PROPOSED SYSTEM

This section describes the proposed Kannada word and character recognition technique of unconstrained handwritten words. Initially, the connected component is used to analyze the CCA and Vertical Projection Profile (VPP) algorithm for detecting all the components in a word image. Scanner digitizes this collected data collection on a 300-dpi flatbed HP scanner which typically yields low noise and good report image quality. These pictures were manually cropped and stored as gray frames. Image binarization is performed using the global thresholding method of Otsu and is stored in the format of bmp files. The digitized images typically contain noise in the digitization of the actual input due to inaccuracies and erratic hand movements. The noises present in the images are eliminated by using median filter. All the above procedures are briefly explained in following subsections and Figure 3.

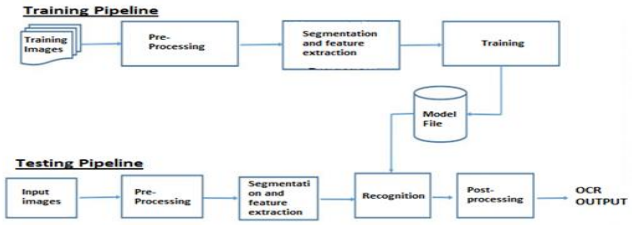

Figure 3: Proposed System Architecture of Handwritten Kannada Word Recognition

A. Pre-Processing

Pre-processing is the method to convert the data image to a picture that is better suited for extracting features. As pre-processing methods slant correction, binarization, skew detection and noise reduction and morphological operations are used. The methods for preprocessing are explained below. Skew detection of images and correction: Fourier transform [15] is used to perform this operation.

1) Binarization

This process is basically used to convert all the gray scale images into binary images through a method of global Otsu threshold approach. Otsu's thresholding strategy includes iterating through all the possible threshold values and computing a measure of spread for the pixel levels each side of the edge, for example the pixels that either fall in background or foreground. The point is to discover the threshold value where the total of foreground and background spreads is at its less.

2) Noise removal

This step is performed to remove the noise with the technique called Median filtering. This technique reduces maximum background noise from the image.

3) Normalization

The technique for changing the images that are of irregular measured images to standard-sized images is called normalization. This method is utilized to dispose of variety between characters between groups. Before to the procedure of normalization, all the additional blank areas in the image are evacuated. In conclusion, the given information image is normalization to a standard 32x32 resolution.

4) Thinning

This operation of thinning is performed by removing the binary-valued image regions to lines approximating the region's skeletons to make the image crisper. The images that are preprocessed are ready for use in further phases of extraction and classification of features.

V. SEGMENTATION

Segmentation is a strategy used to segment the image into many segments. A two-level segmentation is carried out using the method of the vertical projection profile and the bounding box. The method of the projection profile is also called projection or vertical projection. The two segmentations are discussed below, such as word segmentation and character segmentation.

A. Word Segmentation

Segmentation is the step where it analyses the distance from one word to another. In word segmentation technique, a text line has taken as an input. After a content line is separated, it is checked vertically. On the off chance that in one vertical output two or less dark pixels are encountered, at that point the is indicated by 0, else the output is signified by the number of dark pixels. In this way a vertical projection profile is built. Figure 4 displays the Kannada script vertical projection.

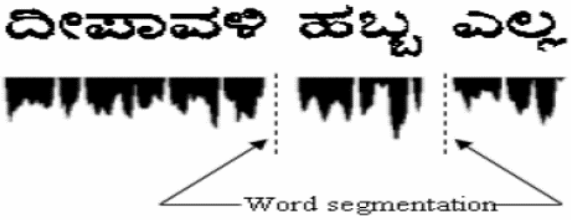

Figure 4: Vertical projection of words

B. Character Segmentation

The word segmentation contributes to word separation and separate sub-pictures are generated we extract just characters from word. Character segmentation is very difficult step of OCR system as it extricates meaningful areas for analysis. This method breaks down the image into classifiable units called character.

Segmentation is very poor division process leads miss recognition or dismissal segmentation process completed simply after the preprocessing of the image.

Wherever a character is segmented, a bounding box technique is applied for the segmented character to demonstrate the segmentation of characters. The representation of bounding box technique for character segmentation is showed in Figure 5.

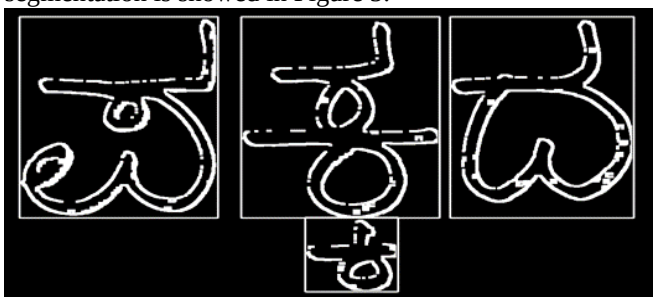

Figure 5: Character segmentation represented in bounding box.

VI. FEATURE EXTRACTION

The feature extraction is the issue of extracting from raw information, the data which is generally significant for order purposes, in the sense of limiting the inside class design pattern while improving the between-class design pattern. great highlights must fulfill the accompanying requirements: First, intra-class variance must be little. Furthermore, the inter class partition ought to be enormous. So as to recognize numerous varieties of a similar character, includes that are invariant top certain transformations on the character should be utilized. At that point, based on data contained in the element vector [10], the model recognition system characterizes that word from the populace. In feature extraction by extracting they are global transformation and structural features. In structural features are depend on geometrical and topological properties of the character, such as branches, joints, curve, end point, aspect ratio, loop, line, crossing point, are obtained. Wavelet transform are utilized transformation features.

A. Structural features

The preprocessed image is partitioned into four quadrants Q1, Q2, Q3 and Q4 as appeared in figure 6. From every quadrant, a set of five features, for example, corner detection, relationship, quadrant thickness, perspective proportion is separated. This procedure is connected for all the four quadrants. In this manner, 20 features are gotten from the four quadrants. One more features, for example, width feature is removed from the image as whole. Thus, 21 feature are acquired as structural features and put away as 'vector 1'.

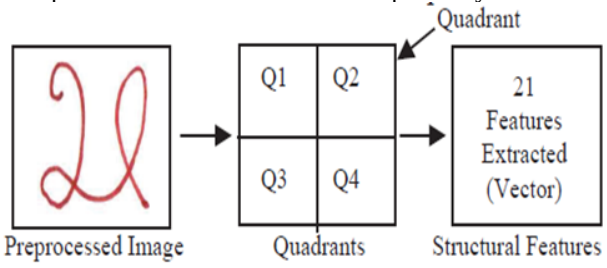

Figure 6: Structural Features Extraction

B. Wavelet Transform

Worldwide highlights are separated utilizing Wavelet transform. Wavelets are numerical functions that cut up information into various recurrence segments and analyze every part with a goal coordinated to its scale. Wavelet transform are confined in both real and Fourier space contrasted with Fourier transform. The wavelet changes are utilized to break down the image at various frequencies with various goals. Multi resolution analysis, break down the sign at various frequencies with various resolutions, to separate the signal into a lot of signals, so on are a portion of wavelets.

C. Combined Features

A lot of 21 features are getting as structural feature and put away in 'vector 1'. A numerous of 128 features are getting as worldwide feature utilizing Wavelet transform and put away in 'vector 2'. At last, the 'vector 1' and 'vector 2' are joined to frame a solitary list of capabilities (149 highlights). These features set are utilized in the arrangement stage to perceive the manually written in Kannada numerals.

VII. CLASSIFICATION

Despite choosing suitable features, to understand a solid character recognizer, it is crucial to choose a fair classifier. The use of SVM with a straight bit as the classifier in the tests to plan and check the function vectors. Separate SVM models were designated for each Kannada character class using feature vectors obtained from 64,811 tests (approx. 500 examples for each class). In addition, insights into the perspective ratios (width to tallness ratio) of the examples of each group used and calculated during segmentation with the goal of testing.

A. Convolution Neural Network (CNN

Convolutional Neural Network (CNN) is a standard class of artificial feed-forward neural networks which are very commonly implemented in areas like computer vision, for issues such as object or a character recognition. CNN's distinction from a network of "flat" multilayer perceptron's (MLP) is its use of convolutionary pooling layers, and non linearity like ReLU, tanh, sigmoid for example, the convolution layer (referred to as CONV) where it has filters of 5 * 5 * 1 (5 pixels for both width and also height, and 1 for the images which are in grayscale). The major work of the CONV layer of CNN is to "slide" input image through its width and height dimensions, calculating the width and height product of the input image region and the parameters of learning the weight properties. This will in effect generate an activation map of 2-dimensional consisting of filter responses at certain regions. As described in Figure 7, the net shows a typical architecture of Convolutional Neural Network for handwritten word recognition. This consists of a multi-layer array. The user input is initially combined with a several different set of filters (C hidden layers) to get the feature map values. Next, to decrease the dimensions and size of the input data (S hidden layers) of the feature map's spatial resolution, a sub-sampling layer pursues each convolution layer. Convolutionary layers are the alternate way of sub-sampling layers and they further extract features to obtain discriminating properties or information from the user provided raw images.

Finally, output layer and two fully connected layers (FCL) followed those layers.

Every layer that is currently in process takes the output of the previous layer as the source.

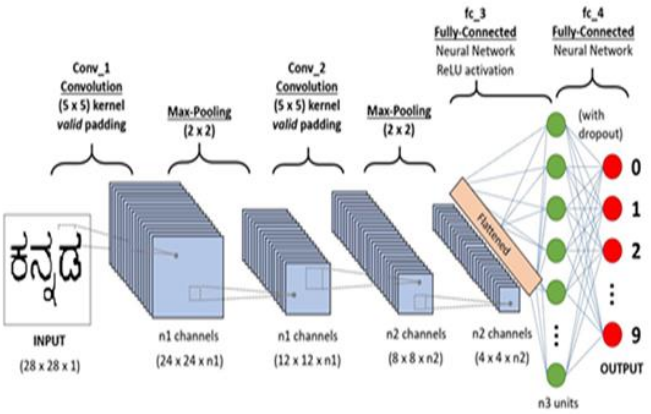

Figure 7: CNN architecture consisting of layers for featured maps applied for recognition of kannada words and characters.

Here implementing a base CNN model with the following architecture:

Step 1: INPUT: 32 × 32 × 1

Step 2: CONV5: 5 × 5 size, 32 filters, 1 stride

Step 3: ReLU: max (0, hθ (x))

Step 4: POOL: 2 × 2 size, 1 stride

Step 5: CONV5: 5 × 5 size, 64 filters, 1 stride

Step 6: ReLU: max (0, hθ (x))

Step 7: POOL: 2 × 2 size, 1 stride

Step 8: FC: 1024 Hidden Neurons

Step 9: DROPOUT: p = 0.5

Step 10: FC: 10 Output Classes

Eventually, the trigger function is applied to implement to compute non-linearities. Without this, the template can know just linear mapping. The widely utilized trigger feature of present generation is the ReLU function [8]. Which is widely implemented over sigmoid and tanh because it has been observed that it accelerates the process of converging stochastic gradient descent relative to the other two functions [11]. In comparison, compared to the comprehensive computation needed by tanh and sigmoid, ReLU is implemented simply by thresholding matrix values at zero, in Figure 8,9.

The L2-SVM is introduced at the 10th level for CNN instead of the traditional softmax method with the cross-entropy feature (for computational loss). In other terms, the output will be converted into the following case and will be checked by $\{-1, +1\}$. The parameters of weight are then taught using Adam optimizer [10].

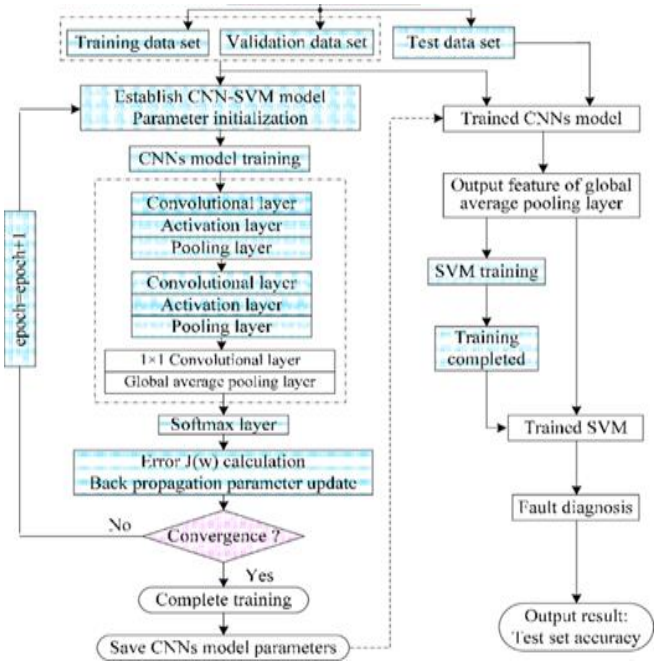

Figure 8: Architecture of CNN Training and Testing using SVM.

Implementation of a base CNN model with the following architecture:

```
convnet = input_data(shape =[None, IMG_SIZE, IMG_SIZE, 1], name ='input')

convnet = conv_2d(convnet, 32, 5, activation ='relu')
convnet = max_pool_2d(convnet, 5)

convnet = conv_2d(convnet, 64, 5, activation ='relu')
convnet = max_pool_2d(convnet, 5)

convnet = conv_2d(convnet, 128, 5, activation ='relu')
convnet = max_pool_2d(convnet, 5)

convnet = conv_2d(convnet, 64, 5, activation ='relu')
convnet = max_pool_2d(convnet, 5)

convnet = conv_2d(convnet, 32, 5, activation ='relu')
convnet = max_pool_2d(convnet, 5)

convnet = fully_connected(convnet, 1024, activation ='relu')
convnet = dropout(convnet, 0.8)

convnet = fully_connected(convnet, 2, activation ='softmax')
convnet = regression(convnet, optimizer ='adam', learning_rate = LR,
    loss ='categorical_crossentropy', name ='targets')

model = tflearn.DNN(convnet, tensorboard_dir ='log')
```

B. SVM Classifier

Support Vector Machine is a powerful discriminating classifier prasented by Vapnik[15] and Cortes [16]. It is very commonly used for various pattern recognition / classification activities with good results [17]. It is known to be the state of the art method for the resolution of non-linear or linear problems of classification in Figure 10, [15], due to its parsimony, mobility, global optimum character and statistical potential.

Structural risk minimization is basis of their formulation rather than empirical risk minimization, which is used in artificial neural networks [15]. SVM is essentially used to evaluate an optimal hyperplane separation (equation 1) or judgment.

$$f(x) = WT\ \Phi\ (x) + b \quad (1)$$

Where W ϵ Rn , b ϵ R and Φ(x) is a feature map. Because the linearly inseparable property of feature space, transformation by correctly mapping the user provided input data (xi, yi) into a larger dimensional feature space by using a nonlinear operator (x). As a consequence, the optimal hyperplane can be described as :

$$f(x) = \text{sgn}(\Sigma\ yi\alpha i\ K(xi , x) + b) \quad (2)$$

Where K (xi, x) = exp (-γ|| xi – x || 2) The kernel form based on the radial base function (RBF) and sgn is the sign variable. Another classifier template named the RBF kernel SVM is applied to remove the last output layers of the CNN software to conduct the Arabic handwritten text classification.

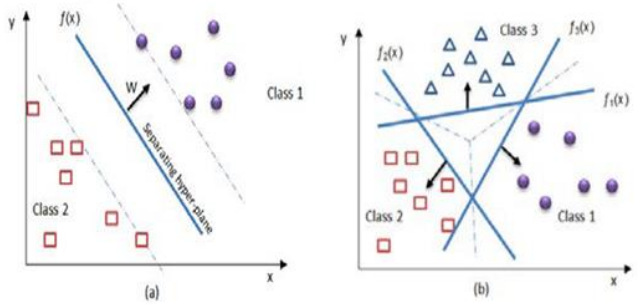

Figure 10: Support Vector Machine principle; (a) hyper-plane of two-class example, (b) one-versus-all method

Input: X: Training set. δ: Threshold. **Output:** X_R: $X_R \subset X$ s.t. $|X_R| \ll |X|$. **Begin** Train a decision tree $\mathcal{T}$; // X_R Begins empty $X_R \leftarrow NULL$
For each leaf $\mathcal{L}_i$ of $\mathcal{T}$ **do**
  for each opposite class neighbor $\mathcal{L}_j$ **do**
  if entropy of $\mathcal{L}_j$ is low **then**
  //Select closest examples
    Use $\mathcal{L}_i$ and $\mathcal{L}_j$ to build X^+;
    Compute ω (Eq. (12));
    Add $x_i \in \mathcal{L}_j$ to X_R according to (12);
    end for
  else
  //Add all the elements in $\mathcal{L}_j$ to X_R.
    $X_R \leftarrow X_R \cup \mathcal{L}_j$;
  end if **end for return** X_R **End**

Figure 11: SVM pseudocode

- **Input:** set of (input, output) preparing pair tests; call the information test features x1, x2… xn, and the output result y. Commonly, there can be various of input feature xi.
- **Output:** set of weights w (or wi), one for each feature, whose straight predicts the estimation of y.
- **Important Difference:** The strategy utilized of enhancement of maximing the edge ('road width') to decrease the quantity of weights that are nonzero to only a not many that relate to the important features. This is significant as that 'matter' choosing the isolating line, these nonzero loads relate to the help vectors.

VIII. IMPLEMENTATION

Recognition of handwritten words and character is the important subject in OCR implementation and also in the field of pattern recognition. All the kannada scripts that contains handwritten content are distinct, because of its varying font size and style. These handwritten documents are created without restrictions on paper, pen, flow of ink, color of ink, size, etc. For testing, the data set was generated as there is no data set which is standard. It is considered to be neatly typed documents containing Kannada script. For the purpose of research, a minimum of 50 handwritten documents were considered. The proposed template is built on the Windows 10 platform using Python and Django. Figure 12 shows the samples of handwritten documents containing Kannada script collected from different writers which are written in their own handwriting having various age groups. All the images that were gathered the filtered with a resolution of 300dpi.

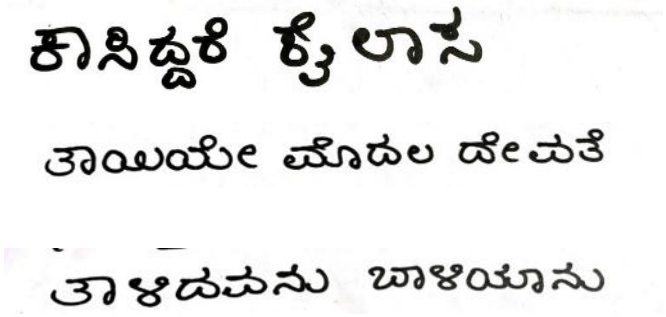

Figure 12. Handwritten custom kannada dataset.

Table 1 shows the accuracy achieved for segmentation phase. Word segmentation is achieved with an average accuracy of 97.5 percent. But accuracy cannot be calculated at character level because the number of segmented characters is greater than the total number of characters, which is 300 the total number of characters available in 50 documents and 700 the number of segmented characters. The explanation for this is that the Kannada script consonant modifiers are combined with one of the characters to form compound characters, and these compound characters often occur quietly in this language. Segmentation of such compound characters is complicated and the treatment of compound characters requires a different perspective.

IX. RESULTS

As all the parameters are considered in calculating accuracy of handwritten word and character recognition we also consider the training and validation of both Accuracy and loss. The only difference between them is the accuracy is a measure of actual correct recognition of words and characters and loss is the measure of incorrect recognition, while we train our neural network correct data should be provided, so that the neural network can understand similar type of inputs very easily with high efficiency. As in the proposed method the accuracy of each input is above 85% and the left out is considered as loss. Figure 13 shows the accuracy graph for the training and validation and Figure 14 shows the loss for training and validation.

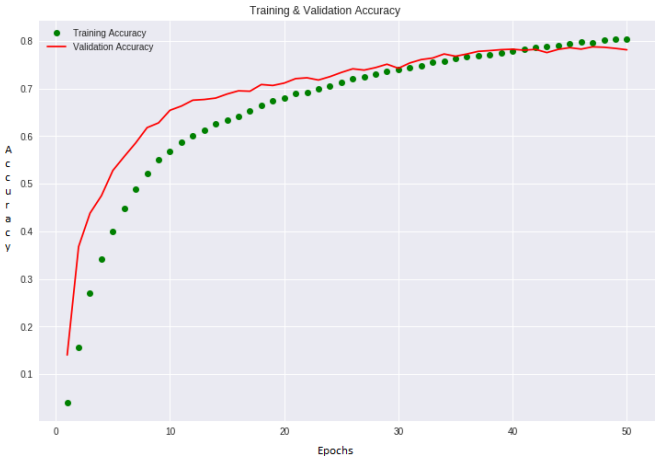

Figure 13: Training vs Validation Accuracy in CNN

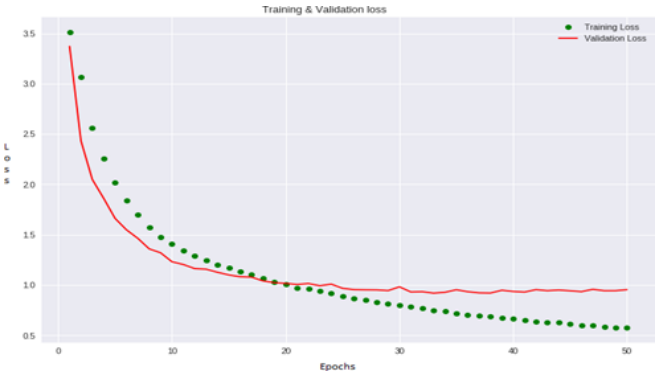

Figure 14. Training vs Validation Loss in CNN

➢ **Accuracy:** This is the shortest indicator of performance. Figure 15 shows the accuracy for each and every characters of both the word thalidavanu and baaliyaanu, when we calculate the overall accuracy of both words we have achieved 98%.

Accuracy = (TP+TN) / (TP + TN + FP + FN) (3)

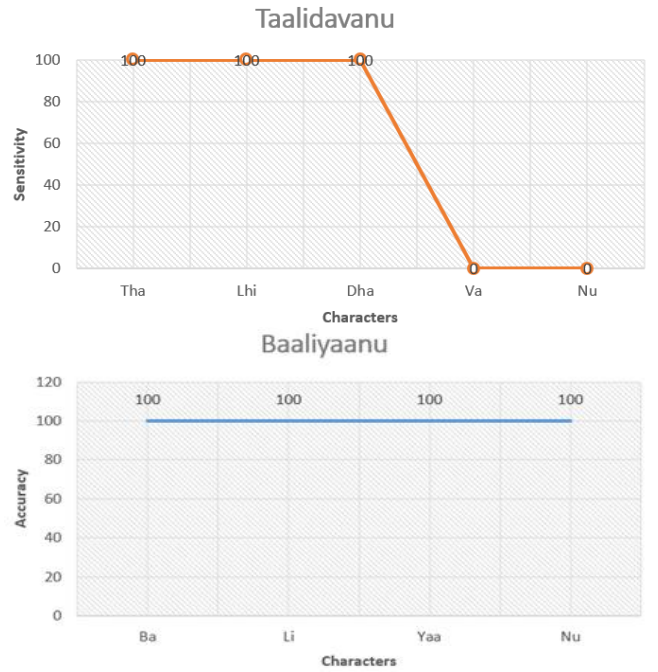

Figure 15: Accuracy for the words Taalidavanu and Baaliyaanu

➢ **Sensitivity:** Sensitivity is the proportion of the actual positive that the classifier correctly identifies as positive. Figure 16 shows the sensitivity for each characters where they are separated by words.

Sensitivity=TP/(TP+FN) (4)

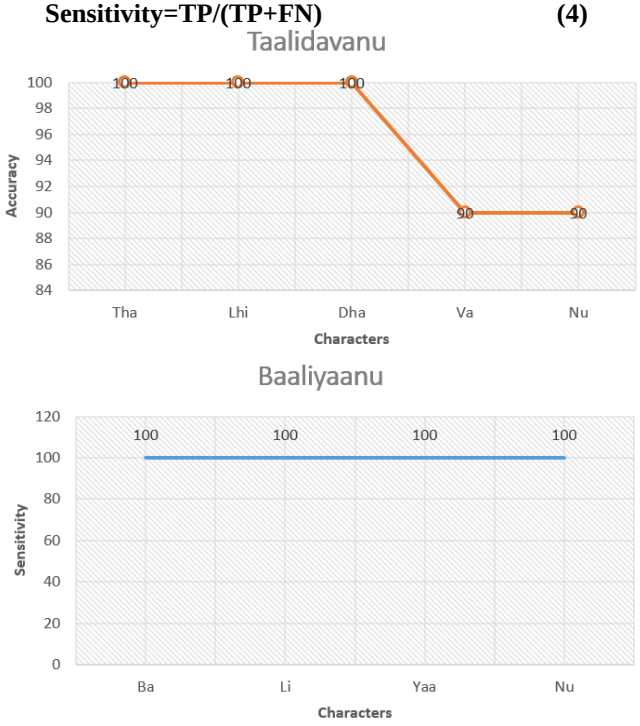

Figure 16: Sensitivity for the words Taalidavanu and Baaliyaanu

➢ **Specificity:** Specificity refers to the ability of the classifier to distinguish negative outcomes. Figure 17 shows specificity of word and characters where it includes the details of how specific is a character or word when it comes to recognition of handwritten words.

Specificity= TN/ (TN + FP) (5)

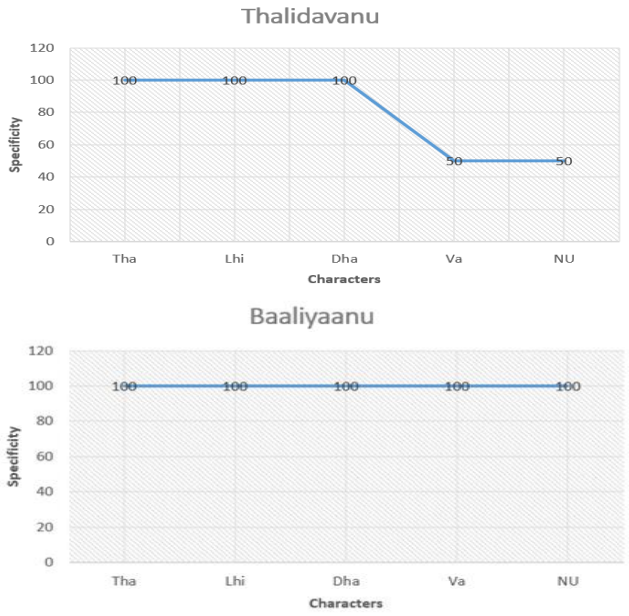

Figure 17: specificity for the words Taalidavanu and Baaliyaanu

- **Precision:** Precision is a measure of retrieving the relevant instances. Figure 18 is the representation of correctly recognized similar characters and words in handwritten word recognition.

Precision =TP / (TP + FP)
(6)

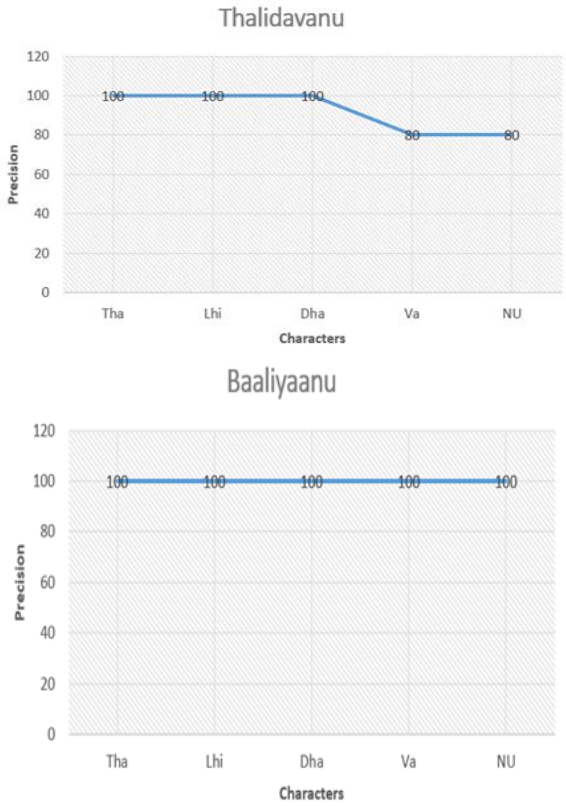

Figure 18: Precision for the words Taalidavanu and Baaliyaanu

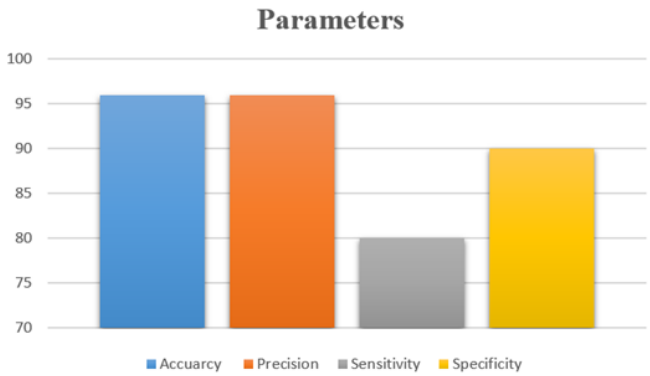

Figure 19: Represents all the parameters in a Bar graph consisting of its percentages correspondingly

Table I Accuracy Achieved in Segmentation

Total number of Words Available in 50 documents	500
Number of Words Segmented	470
Accuracy of Word segmentation	97%
Total number of Characters Available in 50 documents	1100
Number of Characters Segmented	1050
Average Accuracy of Word Segmentation	97.5%

Table II Comparison of segmentation in proposed method with the Existing methods

Authors	Segmentation Technique	Size of Data set	Accuracy in Percentage
R Prajna [17]	Morphological operations, projection profile	100	86%
Wangsheng [18]	Horizontal Projection Profile	204	84%
Parul Sahare [1]	Projection Profile	800	96%
Proposed Method	Modified projection profile, connected component.	50	97.5%

Table III Proposed Work with Previous Works

Authors	Method	Accuracy
Karthik *et al.* [21]	SVM+HOG	96.41
Karthik *et al.* 2018 [12]	Deep Belief Networks	97.04
Parul Sahare et al., 2018 [1]	FCDF + FCCF + NCF (Character)	99.84
Proposed	CNN+SVM (Word)	97.81

X. CONCLUSION AND FUTURE ENHANCEMENT

In this article, we proposed the Segmentation technique is depending on the method of Vertical Projection Profile. This process includes pre-processing steps, then they are subdivided into individual words of entire line. As given in the table, if the user input is an image with text with words that had an enough spacing between them, a segmentation accuracy of 97 percent was achieved. With a precision of 97 percent, when slightly spaced terms are segmented. But for closely spaced text columns, a low precision was obtained. This is because of the overlapping characters and much less space between words. The accuracy related to recognition of word was found to be more than 80 percent for each of the correctly segmented words, but in cases where the word spacing between two words were very small segmentation accuracy is less. For the identification and recognition of the handwritten kannada words and characters, a neural network-based kannada character recognition system was introduced. The pixel information obtained from the characters that are resized were used directly to train the neural network using image processing techniques.

Similar to other forms of recognition schemes, the system that is proposed will therefore be less complex. Several neural network architectures are used to classify the handwritten kannada words and characters. Future enhancement for the already implemented system will be recognition of paragraphs where there will be an extra layer of segmentation that includes Line Segmentation with an existing word and character segmentation.

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AUTHORS PROFILE

Ramesh G is currently a Research Scholar in the Department of Computer Science and Engineering, University Visvesvaraya College of Engineering (UVCE), Bangalore University, Bangalore. He has completed his B.E and M.Tech from Vishveswaraya Technological University (VTU), Karnataka. All the degrees are in Computer Science and Engineering (CS&E) discipline. He has published papers in International Reputed Journals and International Conferences. He has attended various FDP programs. His current research lies in the areas of Image Processing, Machine learning, Deep learning.

Sandeep Kumar N. is currently pursuing his Master of Engineering in Web Technology from University Visvesvaraya College of Engineering (UVCE), Bangalore University, Bangalore. He has completed his B.E in Computer Science and Engineering from Rava Institute Technology affiliated to Visvesvaraya Technological University (VTU). His area of interest includes Image processing, Networking, Cybersecurity, Cloud security.

Dr. Champa H N has completed Bachelor of Engineering, Masters of Technology and Doctoral Degree in Computer Science and Engineering. She has 30 years of teaching experience. Currently she is Professor in the Dept. of CSE, University Visvesvaraya College of Engineering, Bangalore. She has over 20 research papers to her credit. She is currently guiding 04 Ph.D Students. Her research interests include Image processing, Artificial Intelligence, Machine learning and Database systems.