

# Kannada, Telugu and Devanagari Handwritten Numeral Recognition with Probabilistic Neural Network: A Novel Approach

B.V.Dhandra

Department P.G of Studies and  
Research in Computer Science  
Gulbarga University, Gulbarga

R.G.Benne

Department of P.G Studies and  
Research in Computer Science  
Gulbarga University, Gulbarga

Mallikarjun Hangarge

Karnatak Arts, Science and  
Commerce College, Bidar,  
Gulbarga University, Gulbarga

## ABSTRACT

In this paper, a novel approach for Kannada, Telugu and Devanagari handwritten numerals recognition based on global and local structural features is proposed. Probabilistic Neural Network (PNN) Classifier is used to classify the Kannada, Telugu and Devanagari numerals separately. Algorithm is validated with Kannada, Telugu and Devanagari numerals dataset by setting various radial values of PNN classifier under different experimental setup. The experimental results obtained are encouraging and comparable with other methods found in literature survey. The novelty of the proposed method is free from thinning and size normalization.

## General Terms

Pattern Recognition, Document image processing.

## Keywords

OCR, Probabilistic Neural Network (PNN), Handwritten Numeral Recognition, Structural feature, and Indian script

## 1. INTRODUCTION

Handwritten numeral recognition is an integral part of the handwritten character recognition system. The problem of the handwritten numeral recognition is a complex task due to the variations among the writers such as style of writing, shape, stroke etc., and it has variety of applications in various fields like reading postal zip code, passport number, employee code, bank cheque, and form processing. For recognition of image object one need to extract the potential features. Thus, Feature extraction plays a vital role in Pattern Recognition and Image Processing systems in general and character recognition systems in particular. Ivind and Jain [3] present a survey of various feature extraction methods used in character recognition system. The problem of numeral recognition has been studied for decades and many methods have been proposed, e.g. template matching, dynamic programming, hidden Markov modeling, neural network, expert system and combinations of these techniques [1, 2, and 16]. Recognition of character/numeral in foreign languages like English, Chinese, Japanese, and Arabic reported many authors. In the Indian context, major research work reported in Devanagari, Tamil, Bengali and Kannada numeral recognition system[4, 5, and 6].

Number of authors have been attempt to recognize the handwritten Kannada numerals with various techniques. Dinesh

Acharya *et. al* [7] have used 10-segment string, water reservoir, horizontal and vertical stroke feature for Kannada numeral recognition, U.Pal *et. al* [8] have used zoning and directional chain code for Kannada numerals recognition. Dhandra *et. al*[9] have proposed a method based on directional density feature which is thinning free, independent of size, and font styles of the English numerals. The concept of Script independent handwritten numerals recognition system is suggested by [12, 18] using wavelet feature and structural feature.

From the literature survey, it is evident that handwritten numerals recognition is still a fascinating area of research to design a robust and efficient Optical Character Recognition (OCR) system in general and handwritten numeral recognition system in particular. This has motivated us to design a simple and robust algorithm for handwritten numerals recognition system, which is independent of size, slant, ink, and writing style.

We combine different categories of structural features to obtain high degree of recognition accuracy for handwritten numerals. In this paper, we have kindled and pooled our previous ideas [11, 21] and tested with different classifiers and obtained high recognition accuracy.

The paper is organized as follows: Section 2 of the paper contains the preprocessing of isolated numerals and gives a brief description of the languages selected for recognition and its data set. Feature Extraction method is described in Section 3. The Classification method and its algorithm is the subject matter of Section 4. The experimental details and results obtained are presented in Section 5. Section 6 contains the conclusion part and further enhancement of the problem. Section 7 and 8 follows Acknowledgment and References.

## 2. DATA SET AND PRE-PROCESSING

The standard database for South Indian numeral script is neither available freely nor commercially, hence, we have collected the sample Kannada, Telugu and Devanagari handwritten numerals data from different professionals belonging to schools, colleges, and commercial sectors are collected and created the data set for 2500 unconstrained Kannada numerals from 250 writers, 1250 Telugu numerals from 125 writers and 1250 Devanagari numerals from 125 writers. The collected data set containing multiple lines of isolated handwritten numerals are scanned through a flat bed HP scanner at 300 DPI and binarized using global threshold and is stored in bmp file format. The scanned and segmented isolated numeral images are quite often prone to noise that arises due to

the writer styles, scanners, papers quality, etc. Therefore, it is necessary to filter those noises before processing the numeral images. The noise is removed by using median filter and scanning artifacts are removed by using morphological opening operation.

### 2.1 Languages for Recognition

India is a multilingual and multi script country and uses 18 scripts. Hence, there is a need of multilingual and multi-script OCR system for an Indian context. Thus, development of multilingual OCR system in general and the developments of multilingual numeral system in particular is one of the challenging problems to be addressed. Hence, we have considered Kannada, Telugu and Devanagari numerals recognition as an initial attempt.

A sample of Kannada, Telugu and Devanagari handwritten numerals sets are shown in Fig. 1, Fig. 2 and Fig.3 respectively and are consider for our experiments.

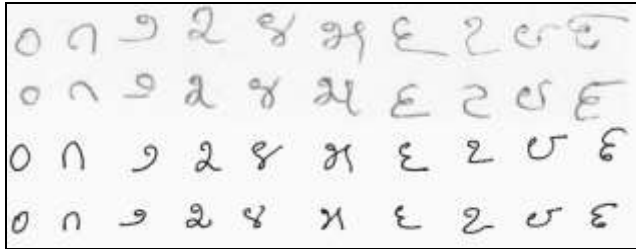


Fig. 1 Sample of Handwritten Kannada numerals



Fig. 2 Sample of Handwritten Telugu numerals

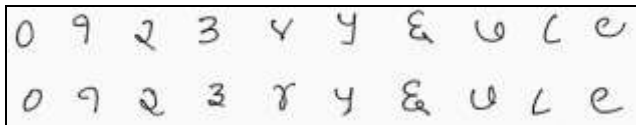


Fig. 3 Sample of Handwritten Devanagari numerals

### 3. FEATURE EXTRACTION METHOD

Extraction of potential feature is an important component of any recognition system. Selection of potential features is probably the single most important factor in achieving high recognition performance. In this paper, structural features are considered as the potential features for the recognition of handwritten numerals. The directional density estimation features, features based on water reservoir principle, maximum profile distance features, and fill-hole density features are the structural features used for the numeral recognition. The normalization of feature vector is carried out by dividing each feature by the maximum value in that vector. All features considered for testing and training images are normalized in the range (0, 1).

**3.1 Directional density estimation:** The outer directional density of pixels is counted row/column wise until it touches the outer border of the character in the four directions viz. left, right, top, and bottom directions as shown in Fig. 4. It also exhibits the corresponding directional pixels considered in the count as black band area [9].

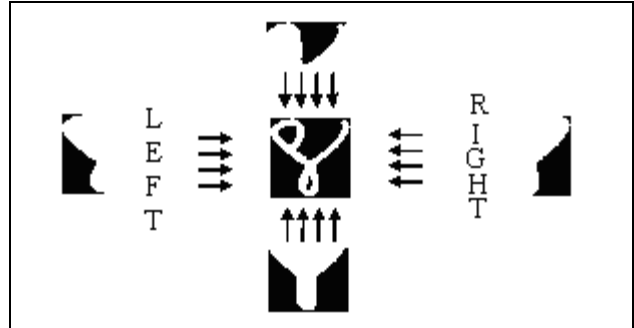


Figure 4:

Directions for Density estimation and pixels consideration

**3.2 Water Reservoir:** The water reservoir based principle is that, if water poured from one side of a component, the cavity regions of the component where water will be stored considered as reservoirs [10].

*Top (bottom) Reservoir:* The reservoir obtained when water poured from top (bottom) of the component.

*Left (right) Reservoir:* The water stored cavity regions of the component, when water is poured from left (right) side of the component will be the left (right) reservoir. Top, bottom, left, and right reservoir of numerals illustrated in Fig. 5.

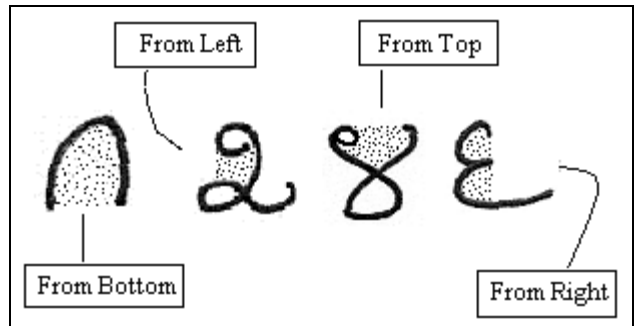
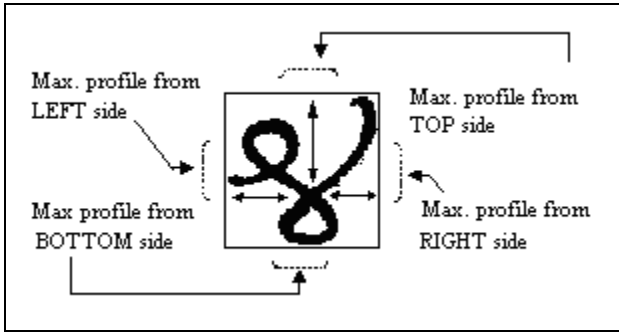


Figure 5: Water Reservoirs in Numerals

**3.3 Fill-hole Density:** The looping area of the numeral is filled with ON pixels [13] and feature considered is the estimated fill-hole density.

**3.4 Maximum profile distances:** After fitting the bounding box on each numeral, their profiles are computed in four directions. While computing the profile, we have considered only 40% of the middle area in four directions of the bounding box. The maximum profile obtained in four directions, and the profile features are illustrated in Fig. 6.

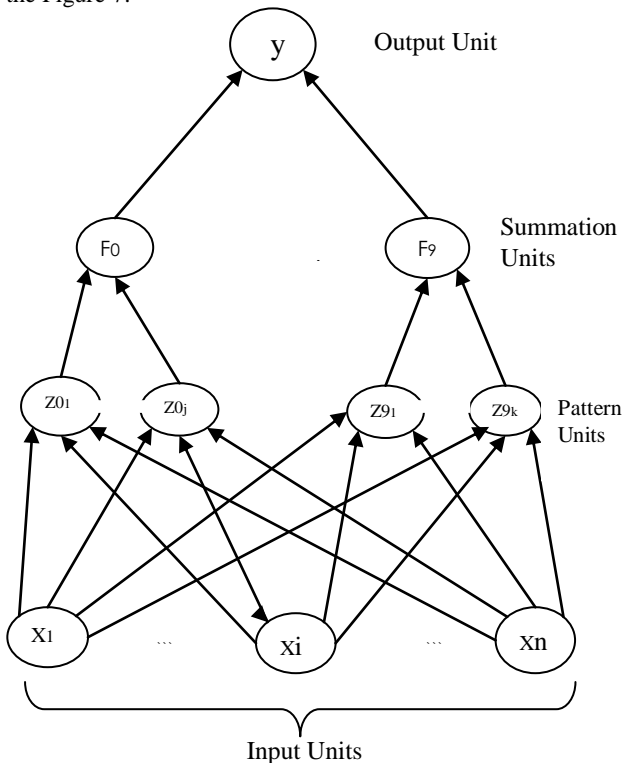
In the following section, we exhibit the proposed algorithm for numeral classification.



**Figure 6:**  
Maximum profile distances from all sides of Bounding Box

#### 4. CLASSIFICATION

*Probabilistic Neural Network (PNN) Classification:* Probabilistic neural network is a kind of radial basis network suitable for classification problems. The PNN classifier provides a good generalization ability and fast learning capability, which are crucial for handwritten character recognition system. This networks uses a radial basis transfer function to calculate a layers output from its net input [17]. The architecture of Probabilistic Neural Net is made up of four units viz. input units, Pattern units[Class 0...9], Summation units and Output units as shown in the Figure 7.



**Figure 7:** Architecture of Probabilistic Neural Net

When an input is presented, the first layer computes distances from the input vector to the training vector, and produces a vector whose elements indicate how close the input is to a training input. The second layer sums these contributions for each class of inputs to produce as its net output vector of probabilities. Finally, a compete transfer function on the output of the second layer picks the maximum of these probabilities, and produces a 1 for that class and a 0 for the other classes.

Experiment is carried out for various spread values (viz. 0.1, 0.5, 0.05) for computing the distance between the input vectors.

**Algorithm: Probabilistic Neural Network Classifier**

*Input :* Isolated Binary Numerals.

*Output:* Recognition of the Numeral.

*Step 1 :*Preprocess the input image to eliminate the noise using median filter and invert the image.

*Step 2:* Fit the minimum rectangle-bounding box for an input image and crop the digit.

*Step 3:* Extract the structural features and stored them in the Library.

*Step 4:*Train the PNN classifier with feature vector stored in the library.

*Step 5:* Classify the test images to its appropriate class label using PNN classifier with various radial values.

#### 5. EXPERIMENTAL RESULTS AND DISCUSSION

In order to classify the handwritten numeral, and evaluate the performance/consistency of the proposed method, we have carried out the experiment by setting various radial values. Following is the brief explanation:

*Experiment 1.* In this setup, proposed algorithm uses 2500 handwritten Kannada numerals, 1250 handwritten Telugu numerals and 1250 handwritten Devanagari numerals for experimentation purpose. The PNN-network trained with 2500 Kannada numeral set (i.e., 250 numeral images for each numeral class) and same set of numerals are used for testing purpose. Similarly, the PNN is trained and tested with 1250 Telugu and Devanagari numerals separately. The experimentation is carried out with different radial values of network for recognition system and how, the network behaves with various radial values of network is shown in the scatter plot (Figure 8). The overall accuracy obtained for Kannada, Telugu and Devanagari numerals is as shown in the Table 1, Table 2 and Table 3 respectively for different distance values (spread values) between the input vectors. The algorithm presents the best performance with least radial value of PNN for Kannada, Telugu and Devanagari handwritten numerals.

**Table 1. Kannada handwritten numerals misclassified with various spread values**

Kannada Numerals	Test/Train Samples (2500)	No. of misclassified numerals for different Radial Values of network		
		0.5	0.1	0.05
0	250	13	9	0
1	250	09	01	0
2	250	50	07	0
3	250	98	14	1
4	250	53	20	0
5	250	66	29	1
6	250	32	14	0
7	250	67	13	0
8	250	94	10	0
9	250	10	01	0
No. of misclassified		<b>492</b>	<b>118</b>	<b>2</b>
Average percentage of recognition		<b>80.32%</b>	<b>95.28%</b>	<b>99.92%</b>

**Table 2. Telugu handwritten numerals misclassified with various spread values**

Telugu Numerals	Test/Train Samples (1250)	No. of misclassified numerals for different Radial Value of network		
		0.5	0.1	0.05
0	125	2	0	0
1	125	7	1	0
2	125	2	1	0
3	125	13	2	0
4	125	29	0	0
5	125	10	1	0
6	125	0	0	0
7	125	53	0	0
8	125	7	0	0
9	125	2	0	0
No. of misclassified		<b>125</b>	<b>5</b>	<b>0</b>
Average percentage of recognition		<b>90.00%</b>	<b>99.60%</b>	<b>100%</b>

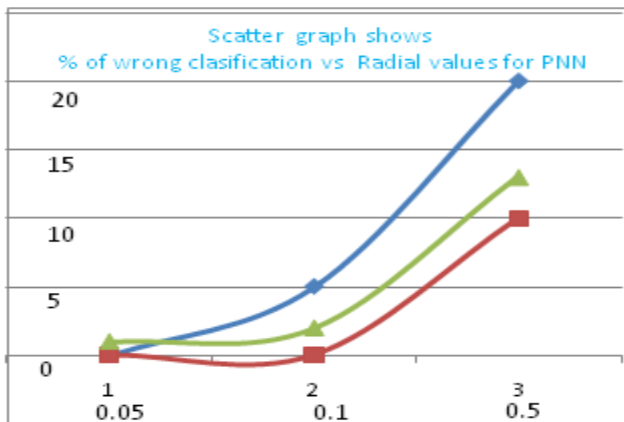
**Table 3. Devanagari handwritten numerals misclassified with various spreads**

Devanagari Numerals	Test/Train Samples (1250)	No. of misclassified numerals for different Radial Values of network		
		0.5	0.1	0.05
0	125	2	0	0
1	125	19	5	1
2	125	12	1	1
3	125	10	2	0
4	125	13	3	0
5	125	23	5	1
6	125	7	0	0
7	125	36	7	2
8	125	27	2	1
9	125	17	3	1
No. of misclassified		<b>166</b>	<b>28</b>	<b>7</b>
Average percentage of recognition		<b>86.72%</b>	<b>97.76</b>	<b>99.44</b>

*Experiment II.* For the proposed algorithm a sample of 2000 handwritten Kannada numeral is considered to train the network and 500 numerals to test. Similarly, a sample of 1000 Telugu and Devanagari numerals each are used for training the network and 250 numerals each for testing (5-fold validation). The overall accuracy for Kannada, Telugu and Devanagari numerals is as shown in Table 4, Table 5 and Table 6 respectively for typical distance value of 0.05 (spread values) between the input vectors.

**Table 4. Results of Kannada Handwritten numeral recognition**

Training samples =2000, Test samples =500 and Number of features = 13 with Radial Value 0.05				
Kannada Numeral	Train Samples	Test Samples	Wrong classify	Recognition Accuracy
0	200	50	0	100.00
1	200	50	0	100.00
2	200	50	0	100.00
3	200	50	1	98.00
4	200	50	0	100.00
5	200	50	1	98.00
6	200	50	0	100.00
7	200	50	1	98.00
8	200	50	0	100.00
9	200	50	0	100.00
Total misclassified numerals = 3 Average percentage of recognition= 99.40				



**Figure 8: Shows the effect of radial values on recognition system (No. of misclassified)**

**Table 5: Results of Telugu Handwritten numeral recognition**

Training samples =1000, Test samples= 250 and Number of features = 13with Radial Value 0.05				
Telugu Numerals	Train Samples	Testing Samples	Wrong classify	Recognition Accuracy
0	100	25	0	100.00
1	100	25	0	100.00
2	100	25	0	100.00
3	100	25	0	100.00
4	100	25	0	100.00
5	100	25	0	100.00
6	100	25	0	100.00
7	100	25	0	100.00
8	100	25	0	100.00
9	100	25	1	96.00
Total misclassified numerals = 1 Average percentage of recognition= 99.60				

**Table 6: Results of Devanagari Handwritten numeral recognition**

Training samples =1000, Test samples= 250 and Number of features = 13with Radial Value 0.05				
Devanagari Numerals	Train Samples	Testing Samples	Wrong classify	Recognition Accuracy
0	100	25	0	100.00
1	100	25	0	100.00
2	100	25	1	96.00
3	100	25	0	100.00
4	100	25	0	100.00
5	100	25	0	100.00
6	100	25	0	100.00
7	100	25	1	96.00
8	100	25	1	96.00
9	100	25	1	96.00
Total misclassified numerals = 4 Average percentage of recognition= 98.40				

It is difficult to compare results for handwritten numeral recognition with those of other methods given in the literature, due to the variations in experimental settings, methodology, and the size of the database used (as there is no standard database). However, Table 7 presents the numeric comparisons of the proposed method with other five methods available for handwritten Kannada numerals. Table 8 presents the comparison of handwritten Telugu numerals; and Table 9 presents the comparison of handwritten Devanagari numerals.

**Table 7: Comparative results for handwritten Kannada numerals with other methods**

Methods	Features and Classifier used	Data set	% of Acc.
[8]	Structural features k- means classifier	500	90.50
[14]	Image Fusion Nearest Neighbour	1000	91.20
[15]	Radon transform Nearest Neighbour	1000	91.20
[16]	Template matching, similarity- dissimilarity, binary distance transform, majority voting.	1000	91.00
[11]	Structural features Nearest Neighbour	2500	95.40
proposed	Structural features Probabilistic Neural Network	2500	99.40

**Table 8: Comparative results for handwritten Telugu numerals with other methods**

Methods	Features and Classifier used	Data set	% of Acc.
[12]	Wavelet descriptors and Feed forward network classifier. Five script are considered	2500	92.30
[18]	Zoning and Back propagation neural network	2000	96.50
proposed	Structural features and Probabilistic Neural Network	1250	99.60

**Table 9: Comparative results for handwritten Devanagari numerals with other methods**

Methods	Features and Classifier used	Data set	% of Acc.
[20]	Invariant Moments and KNN	2000	92.28
[19]	Fourier Descriptor and SVM	2500	97.00
proposed	Structural features and Probabilistic Neural Network	1250	98.40

From Table 7, 8, and 9, it is clear that the proposed method gives high recognition accuracy by using simple structural features with Probabilistic Neural network classifier. Proposed method performs better than the other methods with respect to accuracy, space and time complexity.

## 6. CONCLUSION

In this paper, three South Indian popular scripts (Kannada, Telugu and Devanagari numeral) are considered for handwritten numeral recognition system using global and local structural features and a Probabilistic Neural Network (PNN) classifier. The performance of Probabilistic Neural Network classifier is carried out with various experimental setups, and observed that the

performance of the algorithm is better for least radial value. The average recognition rate of 99.40%, 99.60% and 98.40 obtained for Kannada, Telugu and Devanagari datasets respectively. In any recognition process, the important steps is to address the dominant features and suitable classifier. The proposed algorithm tries to meet both factor in terms of desired accuracy using few structural features and PNN classifier. The novelty of this method is that, it is thinning free, and without size normalization. This work, is an initial attempt towards bilingual/multilingual handwritten numerals recognition system.

## 7. ACKNOWLEDGMENT

This research work is supported by UGC, New Delhi, under Major Research Project grant in Science and Technology, vide F.No-F33-64/2007(SR) dated 28-02-2008. Authors are grateful to the UGC for their financial assistance.

Authors are also grateful to Dr. P. Nagabhushan, Dr. G. Hemanth Kumar, and Dr. D. S. Guru of University of Mysore for their discussion and critical comments.

## 8. REFERENCES

- [1] A.L.Koerich, R. Sabourin, C.Y.Suen, "Large off-line Handwritten Recognition: A survey", *Pattern Analysis Application*, 97-121, 2003.
- [2] J.D. Tubes, A note on binary template matching. *Pattern Recognition*, 22(4):359-365, 1989.
- [3] Ivind due trier, anil Jain, torfiinn Taxt, "A feature extraction method for character recognition-A survey ", *pattern Recg*, vol 29, No 4, pp-641-662, 1996
- [4] A.F.R. Rahman, R.Rahman, M.C.Fairhurst, "Recognition of handwritten Bengali Characters: A Novel Multistage Approach", *Pattern Recognition*, 35,997-1006, 2002.
- [5] R. Chandrashekar, M.Chandrasekaran, Gift Siromaney , "Computer Recognition of Tamil, Malayalam and Devanagari characters", *Journal of IETE*, Vol.30, No.6, 1984.
- [6] P.Nagabhushan, S.A.Angadi, B.S.Anami, "A fuzzy statistical approach of Kannada Vowel Recognition based on Invariant Moments", *NCDAR-2003*, Mandy, India, pp275-285, 2003.
- [7] Dinesh Acharya U, N V Subba Reddy and Krishnamoorthi, "Isolated handwritten Kannada numeral recognition using structural feature and K-means cluster", *IISN-2007*, pp-125-129, 2007.
- [8] N. Sharma, U. Pal, F. Kimura, "Recognition of Handwritten Kannada Numerals", *ICIT*, pp. 133-136, *ICIT'06*, 2006.
- [9] B.V. Dhandra, V.S. Mallimath, Mallikargun Hangargi and Ravindra Hegadi, "Multi-font Numeral recognition without Thinning based on Directional Density of pixels", *ICDIM-2006*, Bangalore, India, pp.157-160, Dec-2006.
- [10] U Pal and P.P.Roy, "Multi-oriented and curved text lines extraction from Indian documents", *IEEE Trans on system, Man and Cybernetics-Part B*, vol.34, pp.1667-1684, 2004.
- [11] B.V. Dhandra, R.G.Benne and M. Hangargi, "Handwritten Kannada Numeral recognition based on structural features", *IEEE-ICCIMA-07*, pp.157-160, Dec-2007.
- [12] R Sanjeev Kunte and Sudhakar Samuel R.D, "Script Independent Handwritten Numeral recognition", *VIE-2006*, pp 94-98, Sep-2006
- [13] R.C.Gonzal, R.E.Woods, "Digital Image Processing", Edn-2002.
- [14] Rajput, G.G., Mallikarjun Hangarge, "Recognition of Isolated Handwritten Kannada Numeral based on Image fusion method", *PREMI07,LNCS*, Vol. 4815, Springer Kolkatta, pp153-160, 2007.
- [15] V. N. Manjunath Aradhya, G. Hemanth Kumar and S. Nousath, Robust Unconstrained Handwritten Digit Recognition Using Radon Transform, *Proc. of IEEE-ICSCN 2007*, pp-626-629, (2007).
- [16] B.V. Dhandra, R.G.Benne and Mallikargun Hangargi, "Isolated Handwritten Kannada Numeral recognition based on Template matching", *IEEE-ACVIT -07*, pp.1276-1282, Dec-2007.
- [17] S.N.Sivanandam, S.Sumathi and S.N.Deepa," Introduction to Neural Networks", The McGraw-Hill publication.
- [18] S.V.Rajashekararadhya and P.V.Vanaja Ranjan,"Neural network based handwritten numeral recognition of Kannada and Telugu scripts",*TENCON 2008*.
- [19] Rajput, G.G., and S.M. Mali, "Recognition of isolated Marathi handwritten numeral using Fourier descriptors and SVM", *RTIPR-2010*, pp 135-138, Feb 2010.
- [20] R.J.Ramteke and S.C.Mehrotra, "Recognition Handwritten Devanagari Numerals", *International journal of Computer processing of Oriental languages*, 2008.
- [21] B.V. Dhandra, R.G.Benne and M. Hangargi, "Bi-lingual handwritten numeral recognition with Probalistic nural network: A approach", *RTIPPR-2010*, pp 91-94.