$\Phi 1 = \eta_{20}+\eta_{02}$

$\Phi 2 = (\eta_{20}+\eta_{02})^2+4\eta_{11}^2$

$\Phi 3 = (\eta_{30}-\eta_{12})^2+(3\eta_{21}+\eta_{03})^2$

$\Phi 4 = (\eta_{30}+\eta_{12})^2+(\eta_{21}+\eta_{03})^2$

$\Phi 5 = (\eta_{30}-3\eta_{12})(\eta_{30}+\eta_{12})[(\eta_{30}+3\eta_{p12})^2-3(\eta_{21}+\eta_{03})^2]+$
$(3\eta_{21}-\eta_{03})(\eta_{21}+\eta_{03})[3(\eta_{30}+\eta_{12})^2-(\eta_{21}+\eta_{03})^2]$

$\Phi 6=(\eta_{20}-\eta_{02})[(\eta_{30}+\eta_{12})^2-(\eta_{21}+\eta_{03})^2]+$
$(\eta_{11}(\eta_{30}+\eta_{12})(\eta_{21}+\eta_{03})$

$\Phi 7= (3\eta_{12}-\eta_{30})(\eta_{30}+\eta_{12})[(\eta_{30}+\eta_{12})^2-3(\eta_{21}+\eta_{03})^2]+$
$(3\eta_{21}-\eta_{03})(\eta_{21}+\eta_{03})[3(\eta_{30}+\eta_{12})^2-(\eta_{21}+\eta_{03})^2]$

Feature Set II: Zernike Moments

Zernike moments are due to Zernike polynomials introduced by [4] Zernike and have minimum information redundancy. Zernike polynomials are a set of complex polynomials $V_{nm}(x,y)$ defined in equation below where $n \geq 0$, $|m| \leq n$ and $n-|m|$ is even, r is length of the vector from origin to (x,y) and θ is the angle between r vector and the x-axis in the counter clockwise direction. Equation of $R_{nm}(r)$ defines orthogonal radial polynomial R_{nm}® which form a complete orthogonal set over interior of the unit circle. The Zernike moments are projections ofthe input image onto the space spanned by orthogonal V functions. For a digital image, the Zernike moment of order n and repetition m is defined in equation of Z_{nm}. The Zernike moments of a given image is computed by considering the centre of the image as origin and the given image is mapped to the range of the unit circle $x^2+y^2 \leq 1$ and only those pixels which fall inside the unit circle are considered for moment computation. If the image is rotated by an angle α, the transformed Zernike moment function $Z'_{nm}=Z_{nm}e^{jm\theta}$. The magnitude of the moment's $|Z_{nm}|$ remains the same after rotation. Hence the amplitude of Zernike moments are used as features. Although Zernike moments are invariant to rotation, robust to noise and have minimum information redundancy, they have the drawback of computational complexity.

$$Vnm(x,y)=Vnm(r,\theta)=Rnm(r).e^{jm\theta}$$

$$R_{nm}(r) = \sum_{s=0}^{\frac{(n-|m|)}{2}} \frac{(-1)^s (x^2+y^2)^{(\frac{n}{2}-s)}(n-s)!}{s!(\frac{(n+|m|)}{2}-s)!(\frac{(n-|m|)}{2}-s)!}$$

Feature Set III: Zoning

In this method the image is split into different zones and simple features are extracted from each of the zones. In this method, the segmented character is first area normalized so that the number of ON pixels in all the normalized characters are equal. With this normalized technique the classifier is immune to size changes in the characters. The normalized character is divided into smaller zones. Various regional features such as minor axis length, majoraxis length, centroid, eccentricity, convex area are calculated. Along with the regional features, structural features such as geometric moments, variance are calculated and used as feature vector.

Feature Set IV: Fourier- Wavelet Coefficient

Fourier transform[9] is a powerful tool for pattern recognition. Fourier transform is translation and rotation invariant, but the frequency information of Fourier transform is global and so a local variation of the shape will affect the Fourier coefficients. Wavelet transform has multi-resolution ability but is translation variant. A small shift of the original signal will lend totally different wavelet coefficients. Therefore Fourier and Wavelet transforms are combined to obtain a feature vector which is not only invariant to translation and rotation, but also has multi-resolution ability.

5. Classification Using NN Classifier

The feature vector extracted from the segmented character is assigned a label using a classifier. [12]Recognition of segmented characters is performed using NN Classifier. The recognition performance of Back propagation network will highly depend on the structure of the network and training algorithm. Feed forward back propagation neural network has been selected to train the network. The number of nodes in input, hidden and output layers will determine the network structure. All the neurons of one layer are fully interconnected with all neurons of its just preceding and just succeeding layers (if any).

5.1 Back Propagation Neural Network Algorithm

1 Initialize the weights to small random values.
2 Randomly choose an input pattern $x^{(\mu)}$.
3 Propagate the signal forward through the network.
4 Compute Δ_i^L in the output layer($o_i = y_i^L$)
a. Δ_i^L =g'(h_i^L) [d_i^L - y_i^L], where h_i^L represents the net input to the ith unit in lth layer, and g' is the derivative of the activation function g.
5 Compute the deltas for the preceding by propagating the error backwards.
6 Δ_i^L =g'(h_i^L) $\sum_j w_{ij}^{l+1} \Delta_j^{l+1}$,
For l=L-1...........1
7 Update weights using w_{ij}^l =ηΔ_i^L y_j^{l-1}
8 Go to step 2 and repeat for the next pattern until the error in the output layer is below a pre-specified threshold or maximum number of iterations is reached.

6. Conversion to Editable Format

The Unicode corresponding to the character stored at the obtained index value is stored into a variable letter. The letter value is stored into a word array. The recognized characters are printed on to a notepad which can be further edited and saved.

7. Conclusion and Future Enhancement

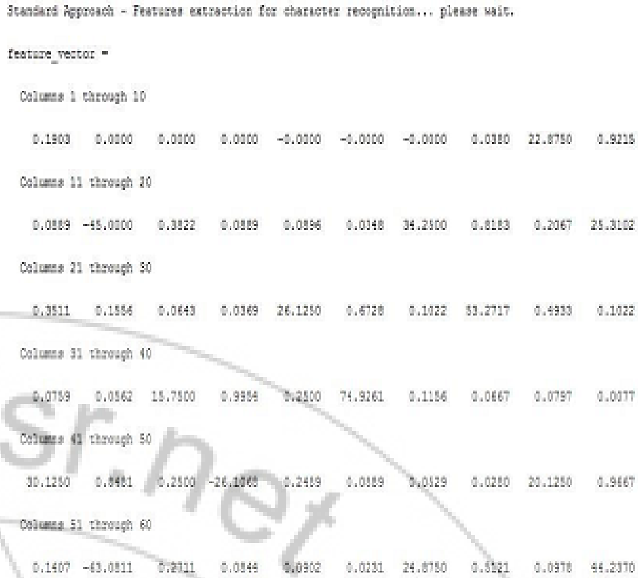
HCR is the process of identifying the handwritten characters. The text in an image is converted into other letter codes which are usable within computer and text processing applications. Here recognition is done using NN classifier. It attempts to increase overall efficiency and accuracy of the HCR. Various feature extraction techniques are incorporated to improve the efficiency. Also the image is converted into an editable format. The editable text can be saved and opened for further editing. The current system can be combined with other features to improve the efficiency. An overall architecture for HCR incorporating all these features can be developed to improve the accuracy. Such a structure will help to exploit further domain information in the recognition process. The current system can be extended to recognize votaksharas.

8. Results Obtained

The developed technique is tested with multiple images of Kannada Handwritten Text where the image undergoes the testing of each individual module. Once the testing is complete, the recognized characters are printed onto a text pad and the editable text file is checked to find the recognition rate. The obtained result is tabulated in Table 8.1. The screenshots are as shown in Fig. 7,8,9.

Table 8.1: Results

Feature Set	Obtained Recognition Accuracy for Vowels	Obtained Recognition Accuracy for Consonants
Hu's Invariant moments	35-40%	30-40%
Zernike moments	40%	30-35%
Zonal features	45-55%	40%
Fourier-Wavelet features	55%	45-50%
Hu's Invariant and Zernike moments	40-45%	30-35%
Hu's Invariant moments & Zonal features	50%	40%
Hu's Invariant and Fourier-wavelet features	50%	40-45%
Zernike moments and Zonal feature	60-65%	40-55%
Zernike moments and Fourier – Wavelet features	60%	35-40%
Zonal features and Fourier-Wavelet feature	75%	55-60%
Hu's Invariant, Zernike, Zonal and Fourier-Wavelet Features	85-90%	80-85%



```
Standard Approach - Features extraction for character recognition... please wait.

feature_vector =

  Columns 1 through 10

    0.1903    0.0000    0.0000    0.0000   -0.0000   -0.0000   -0.0000    0.0380   22.8750    0.9215

  Columns 11 through 20

    0.0889  -45.0000    0.3822    0.0889    0.0896    0.0348   34.2500    0.8183    0.2067   25.3102

  Columns 21 through 30

    0.3511    0.1556    0.0643    0.0369   26.1250    0.6728    0.1022   53.2717    0.4933    0.1022

  Columns 31 through 40

    0.0759    0.0562   15.7500    0.9556    0.2500   74.9261    0.1156    0.0667    0.0797    0.0077

  Columns 41 through 50

   30.1250    0.8481    0.2500  -26.1068    0.2489    0.0889    0.0329    0.0280   20.1250    0.9667

  Columns 51 through 60

    0.1407  -63.0811    0.2011    0.0844    0.0302    0.0231   24.8750    0.5321    0.0978   44.2370
```

Figure 7: Feature Vector

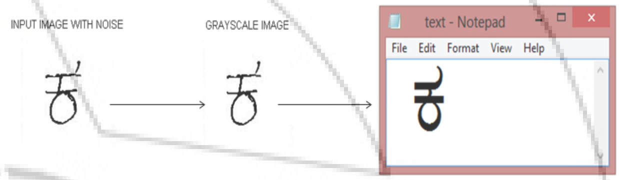


Figure 8: Output

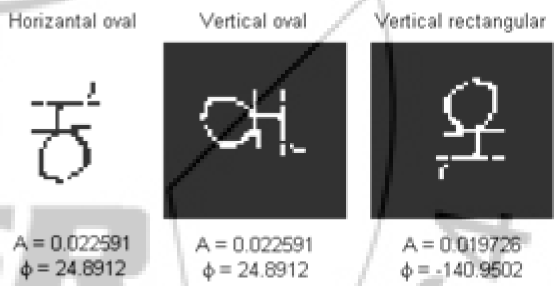


Figure 9: Zernike Moment

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Author Profile

Aravinda C.V Currently working as a Assistant Professor inDept of IS&E at S.J.B.I.T,Kengeri Bengaluru &Pursuing his Ph.D(Computer Science and Engineering) at V.T.U. Belgaum on "Character Recognition for South Indian Languages."

H.N. Prakash received the B.E. degree in Electronics and Communication Engineering from the University of Mysore, Mysore, India, in 1990 and the M.Tech degree in Electronic Instrumentation from Regional Engineering College, Warangal, India in 1995 respectively. He received the Ph.D degree in Computer Science and Engineering from the University of Mysore, Mysore, India, in 2010. He is currently a Professor in the Department of Computer Science and Engineering at Rajeev Institute of Technology, Hassan, India. He is a life member of Indian professional bodies such as Institute of Engineers, Indian Society for Technical Education (ISTE) and System Society of India (SSI) and Member of Indian Institute of Engineers, India. He has authored several peer reviewed papers at national and international conferences and Journals Including IEEE Transactions. His research interest includes signature analysis and retrieval, clustering, biometrics, Image processing, Pattern recognition and symbolic data analysis.

Lavanya S Completed her B.E degree in Elecronics and Communication Engineering from VTU Belgaum., Currently working as a Software Engineering at Openstream Technologies Bangalore.