Enhancing Performance of Devanagari Script Recognition using Hopfield ANN

Pooja Yadav[#1], Sonia Sharma[*2]

[1]*M.Tech., CSE Department, JMIT, Radaur, Kurukshetra University, India*
[2]*Assistant Professor, CSE Department, JMIT, Radaur, Kurukshetra University, India*

Abstract *—Character Recognition (CR) has broad area of research in English as well as Hindi character. Hindi is the most widely spoken language in India, as there is no separation between the characters of texts written in Hindi as there is in English, Character Recognition systems developed for the handwritten Hindi language carry a very poor recognition rate. Devanagari character recognition provides less correctness and efficiency.In this paper, we propose a method for recognition of characters which implement Gabor filters and Freeman Chain Coding (FCC) for featureextraction and Hopfield neural network as classifiers to get best recognition rate of Hindi characters recognition*

Keywords —*Devanagari Script, Offline Character Recognition, Gabor Filter, Freeman Chain Coding (FCC), Hopfield ANN*

I. INTRODUCTION

Pattern recognition is the field which concerned with machine recognition of meaningful regularities in noisy and complex environments.*Character recognition* is part of pattern recognition field whichis the process of recognizing typed,printed or handwritten characters and converting into machine readable code. *Offline System*have handwritten, type written or printed text which is well transformed into digital format.*Online System*is thetwo dimensional coordinates represented as function of time and order of strokes.

Online character recognition is much easier and achieved better results than offline character recognition because more information may be captured in online like direction, speed and order of strokes of the handwriting.Online character recognition is much easier and achieved better results than offline character recognition because more information may be captured in online like direction, speed and order of strokes of the handwriting [22].

The whole paper consisted mainly*six sections*: Section 2 gives introduction and features of Devanagari script. Section 3 discusses the status of the research in the field of handwritten Hindi character recognition. Section 4 presents the proposed work in recognition system. In Section 5, we present the purposed resultswork and analysis. Section 6 is devoted to conclusions and future work [9].

II. .DEVANAGARI SCRIPT

*Devanagari script*is composition of symbols in two dimensions. Devanagari is phonetic, as words are written exactly as they are pronounced and syllabic means that to form syllables we use text is written using consonants and vowels together.

Devnagari script consist main component as 11 vowels and 33 consonants and 10 modifiers inscript, horizontal writing style, from left to right and as English language, Hindi characters do not have any uppercase/lowercase system.

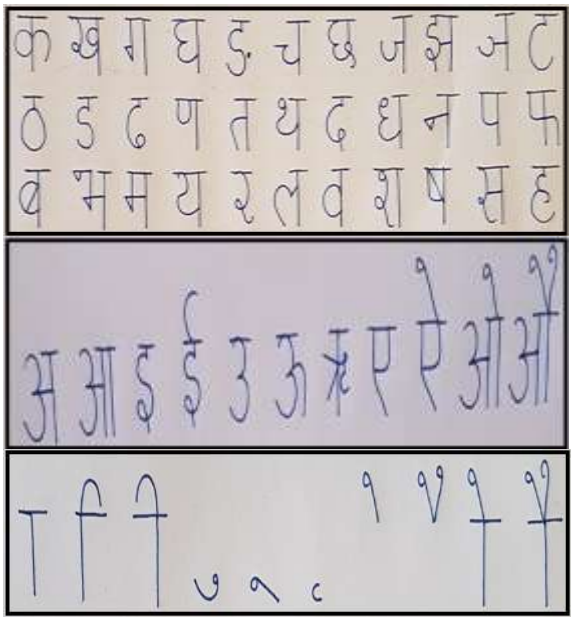

Fig. 1 Consonants, vowels modifiers

Some *special Symbols* whereconsonants like new character and the half forms of may appear in the lower half of the new composite forms [22].

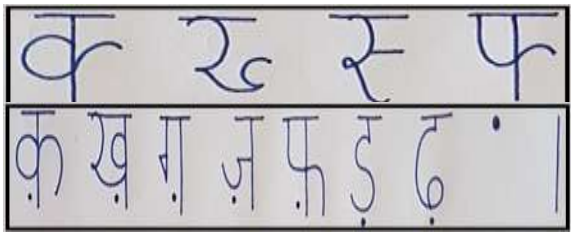

Fig. 2Half consonant and Special symbol

The *header line* is a horizontal line which is drawn at the top of each character and extends throughout all of the word in Devanagari. The existence of a horizontal line on the top of all characters call "Shirorekha".

The words are normally being divided into *three main strips*: top, core, and bottom, as shown in Fig. When two or more characters appear side by side and gradually it form a word in language script.The header lines touch and generate a bigger header line [14].

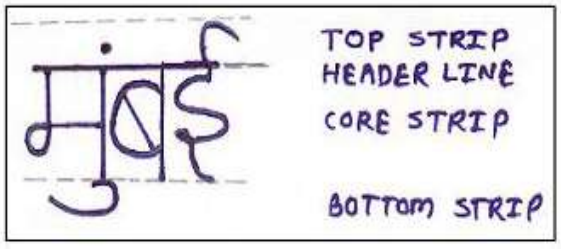

Fig. 3 Lines and zones of a word

III.LITERATURE REVIEW

As through Review various literature it clear that first research on handwritten Devanagari characters was published in 1977from this there is not much research work is done after that. At present,we found that many researchers had perform some development towards the off-line handwritten Devanagari characters and in a meanwhile, few research reports are published recently & tried to solve the problem associated with them [6].

V. Shiv Naga Prasad and Justin Domke [1],presented a system for the visualization of an importantsignal processing technique- a Gabor Filter bank's responseto an image. For this overcome the problemthat no multi-dimensional space can be shown in aa single,static graph. Authors use an interactive widget to combine theadditionalgraphics and change some visible range of the projected dimensions in which projecteddimensions will summarize the responses.

Tai Sing Lee [2] extended to two dimensions the frame criterion enhanced by Daubechies author for one-dimensional wavelets form method, itcomputes the frame bounds formation images for some particular case of 2D Gabor wavelets. Author derived various conditions under which few set of continuous 2D Gabor wavelets will provide complex and completerepresentation of any image, and Author also find self-similar wavelet parameterizations which allow some stable reconstruction of recognition bysummation as through the wavelets formed an orthonormal basis.

Cheng-Lin Liu,Masashi Koga and iromichiFujisawa [3] propose a principled method for implementing Gabor filter for feature extraction method and compare thewhole performances part of Gabor feature and gradient feature on three databases. His results show that Gabor filters with low orientation sensitivity and broadfrequency band favor recognition rate. The Gaborfeature method performs the work better than the gradientfeature on two of the three databases, but is inferior onthe rest one.

*NicolaePopoviciu and MioaraBoncut[4]*worked deals with the Hopfield networks with the vectordescription of the whole theory, rather than element by element one. Thetheoretical work has been mainly related with the energy theorem and basic Hopfield algorithm based on vector form which is elaborated like allthe corresponding dimensions are described briefly. Author mainly used this algorithm solves the store-recall problem, so his algorithm can alsouse to solve several numericalexamples.

Nor AmizamJusohand JasniMohamad Zain [6]

Author's applications developed only suitable for the specific country in the world due to its defined standardspecification which are endorsed by their related transport department of particularcountries. As variousapplications being developed for the Malaysia to overcome thisproblem. Authors mainly focused onconducting an experiment using chain codes method to implement recognition for various types of fonts used in Malaysiancar plates.

Pulipati Annapurna, SriramanKothuri and SrikanthLukka[17]Freemen Chain code techniques are mostly implement for therepresentation of an objectbecause they use for preserve information and also allow data reduction. Author proposed an effective chain codealgorithm detecting some contour images for the binary object and also this chain code implementing machine learning by which the system deliberatlyrecognize the input digitfastly.

Anshul Gupta, Manisha Srivastavaand ChitralekhaMahanta [8] represented two approaches as holistic and segmentation. Holistic approach used for the recognition of at least limited size vocabularywhere maximum global features extracted from the whole word image. When size of the vocabulary will be increases, then basically complexityof the holistic based algorithms increases and recognition rate decreases. They used segmentation basedstrategies, bottom-up approaches,where stroke or the character level considered andproducing a meaningful word.

*Ved Prakash Agnihotri [13]*described Diagonal based method for feature extraction which he used for extracting features in their handwrittenDevanagari script. Features of the each character image is normally converted intothe chromosome bit string of length. Diagonal based feature extraction method extract 54 features from each character. Character recognize image in which extracted features are converted in Chromosome bit string of size 378.

Yash Pal Singh, AbhilashKhare and Amit gupta [7] analyzed neural network method in pattern recognition. He focused on solutions which applied Hopfield Auto associative memory model for pattern recognition. This network is an associative memory. The primary function of this memory is to retrieve the pattern which stored in memory, when there is an incomplete or noisy version of that pattern is discussed.

*DivakarYadav, Sonia Sánchez-Cuadrado and Jorge Morato [14]*proposed an OCR for printed Hindi text in Devanagari script, by used techniques of Artificial Neural Network (ANN), and then improved recognition efficiency. He performed conversion of gray scaled images to binary images and a back-propagation neural network having two hidden layers is used.The classifier is trained and tested for printed Hindi texts.

IV. PURPOSED SYSTEM

For theclassification of characters in Hindi Devanagari fonts, we developed Hopfield artificial neural network based on classifiers [19].In purpose method,there are total 67 characters for train the neural network so it make matrix 67X100 form where total 100 features are extracted as 50 from Gabor Filter and 50 from Freeman Chain Code.Following figure shows the methodology for our approach.

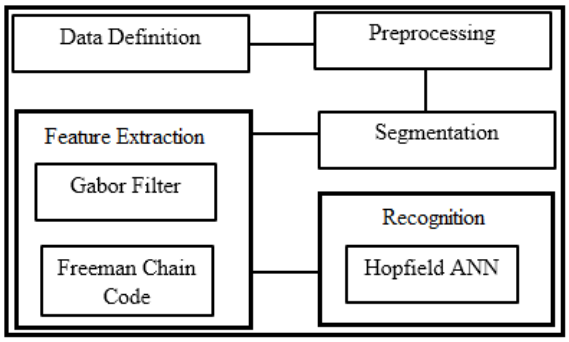

Fig. 4 The proposed methodology

1. Data Definition

Data that comes from the form of images of different handwritten styles and thickness need to be identified and before testedit need to analyze first. Theinformation need to be gathered like types of fonts since our problem is that the different types of fonts havebeen used by different authors which lead to problem inrecognizing characters by using computer. Therefore, such type of information of fonts, all data to be tested will get goodresults [6].

Fig. 5 Classification of similar patterns of character 'Sa'

2. Preprocessing

Threshold and filtering are mainly two processes which are involved in pre-processing. Images used are gray-scaledimages and are converted into values.

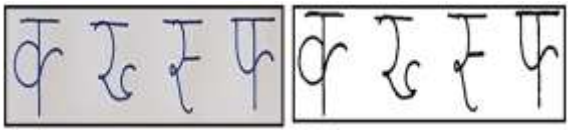

Fig.6 Gray-scaled image and image after threshold process.

3. Segmentation

In this phase, there are mainlytwo processes have been done; the boundaryextraction and segmentation. The boundary image of Hindi character extraction is done in order to ease the process ofderiving the chain codes and Gabor filtering. Thesegmentation phase isolation keep the regionof interest (from the boundary image) and attempts todivide the region into individual characters. The segmentation hasbeen done using the pixel count technique first. Thelabeling technique has beenperformed for other

images isconnected component which were failed to besegmented using previous technique [6].

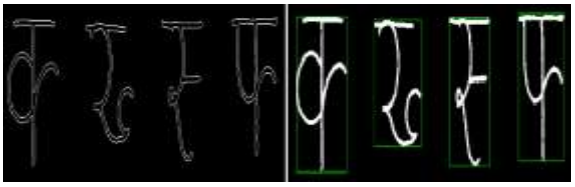

Fig. 7 The boundary image and segmented regions

4. Feature Extraction

a. Gabor Filter

Gabor filters is basically used for extractcomponents corresponding to various scales and orientations from images. Frequency and orientation factor of Gabor filters are similar to human visual system, and this filter is found to be suitable for texture representation and discrimination.

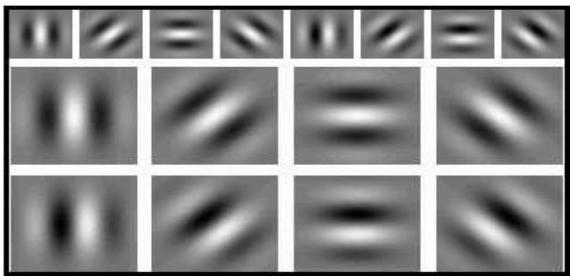

Fig. 8 Evensymmetricand oddsymmetriccomponents of Gabor filters (two scales andfour orientations) [3]

The 2D Gabor functions proposed byDaugman are local spatial band pass filters which efficiently achieve thetheoretical limit for conjoint resolution of information in the2D spatial and 2D Fourier domains.The 2DGabor function is thus a product of an elliptical Gaussianand a complex plane wave [9].

i) Gabor Function

Daugmangeneralized the *Gabor function* for thefollowing 2D form to model the receptive fields of the orientation-selective simple cells:

Let g(x, y, θ, ϕ) bethe function defining a Gabor filter centered at the origin with θ as the spatial frequency and ϕ as the orientation. Wecan view Gabor filters as:

$$g(x, y, \theta, \phi) = \exp\left(-\frac{x^2+y^2}{\sigma^2}\right) \exp(2\pi\theta(x\cos\phi + y\sin\phi)))$$

Let I(p,q) denote the image and G(x, y, θ, ϕ) denote the *Gabor filter response*with frequency θ and orientation ϕ component to an image at point value as (x, y) onthe image plane[1].

$$G(x, y, \theta, \phi) = \iint I(p, q)\, g(x - p, y - q, \theta, \phi)\, dpdq$$

ii) Convolution Property

The convolution property as the Fourier transform of a Gabor filter's impulse response is the convolution of the harmonic function and Gaussian function of theFourier transform.

Complex

$$g(x, y, \lambda, \theta, \psi, \sigma, \gamma) = \exp\left(-\frac{x'^2+\gamma^2y'^2}{2\sigma^2}\right)\exp\left(i\left(2\pi\frac{x'}{\lambda}+\psi\right)\right)$$

The filter has some properties for representing orthogonal directions as a real and an imaginary component. The two components formed bycomplex number or used individually.

Real

$$g(x, y, \lambda, \theta, \psi, \sigma, \gamma) = \exp\left(-\frac{x'^2+\gamma^2y'^2}{2\sigma^2}\right)\cos\left(2\pi\frac{x'}{\lambda}+\psi\right)$$

Imaginary

$$g(x, y, \lambda, \theta, \psi, \sigma, \gamma) = \exp\left(-\frac{x'^2+\gamma^2y'^2}{2\sigma^2}\right)\sin\left(2\pi\frac{x'}{\lambda}+\psi\right)$$

Where

$$x' = x\cos\theta + y\sin\theta\,, \quad y' = -x\sin\theta + y\cos\theta$$

In this equation, λrepresents the wavelength of the sinusoidal factor, ψ is the phase offset, σ is standard deviation and γ is the spatial aspect ratio which specifies the Gabor function's ellipticity support.

The 2D Gabor functions proposed byDaugman are local spatial band pass filters which efficiently achieve thetheoretical limit for conjoint resolution of information in the2D spatial and 2D Fourier domains [1].

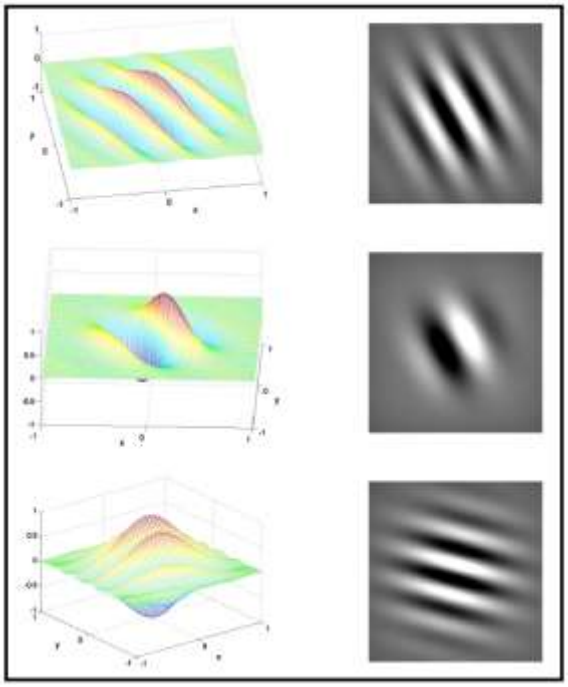

Fig. 9: Example of Gabor filters with different Frequencies and orientations [1]

b. Freeman Chain Coding

Freeman chain code is a chain codes for shape representations used to represent a boundary by a connected sequence of straight line segments in the specified length and direction.The direction of each segment is coded by using a numbering scheme. Code of a boundary depends on the starting point[17].

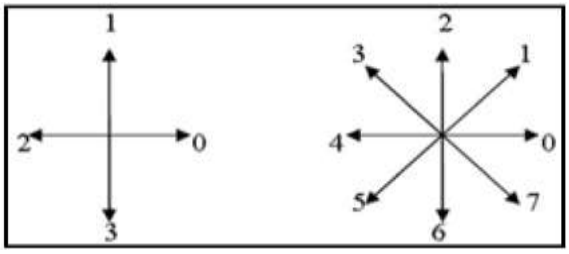

Fig. 10 Direction numbers for 4-directional chain codes, 8-directional chain code [17]

Firstly, we have to select a starting pixel location which is anywhere on theobject boundary. The main thing is to find the next pixel in theboundary values. There must be exist some adjoining boundary pixel atone of the eight locations surrounding both side of the currentboundary pixel value.

We can find at least one pixel that is also a boundarypixel, by looking at each of the eight adjoiningpixels. Depending on this value, we assign a numeric code exist between 0 and 7.

The process of locating the next boundary pixeland after that assigning a code is repeated until we reach on ourfirst location or boundary pixel [17].

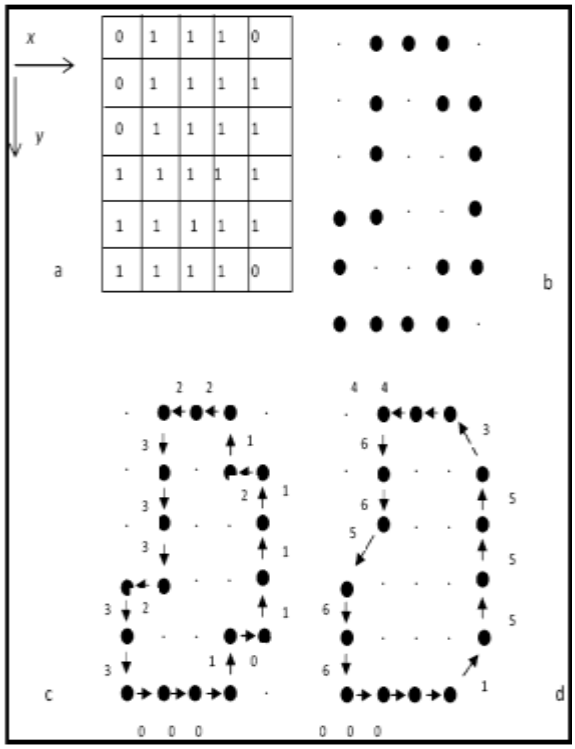

Fig. 11 Direction differences for an object in 4-directional chain codes, 8-directional chain code [6]

i) Chain Code Algorithm:

In this section, we have discuss the freeman chain codes algorithm for each character in the specific region. The algorithm is as follows:

- Find the pixel in the object that has in the topmost row at the leftmost value and this value call as pixel P0.
- Define a variable *dir*(for direction), and set it as equalto 7(since P0 is taking as the top-left pixel in the object, so the directionpixel must be 7to the next pixel).
- Traverse the all neighborhood in counter-clockwise direction of the current pixel, *ifdir is even* ordir + 6 (mod 8) *if dir is odd* the searchat the pixel in direction dir + 7 (mod 8).This will sets the currentdirection by traversingthe first direction IN THE counter-clockwise unit from*dir*:

  *dir*0 1 2 3 4 5 6 7
  dir+ 7 (mod 8) 7 0 1 2 3 4 5 6

dir+ 6 (mod 8) 6 7 0 1 2 3 4 5

- The first foreground pixel will be set to the new boundaryelement. As well as Update *dir variable also.*
- Stop when the current boundary element Pn finally equal to second element P1 and secondly the previous boundary pixel Pn-1is most probably equal to the defined first boundary element P0.[6]

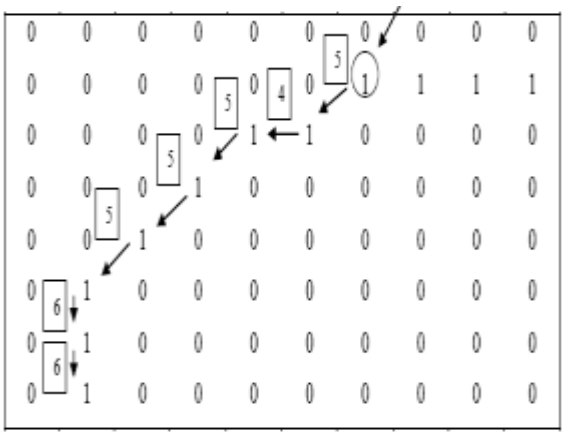

Fig. 12 The initial location, P_0 and the direction to derive chain codes [6]

5. Classifier Tool

Artificial Neural Network (ANN), is a model consists of an interconnected group of artificial neurons and information which used by connectionist approach for computation. ANN is adaptive system, where when information pass through the network system during the learning phase and then may be changes its structure of information[19].

Hopfield ANN is consists of a set of *n*interconnected neurons. All neurons will work as both inputand output neurons.The input to the neural network consists ofeach of the feature sets that have extracted from feature extraction techniques.

Thus in theinput layer,the number of nodes is mainly equal to the size of the feature set that we use in each case of testing. The outputlayer contains one node for each of the output classes [4].

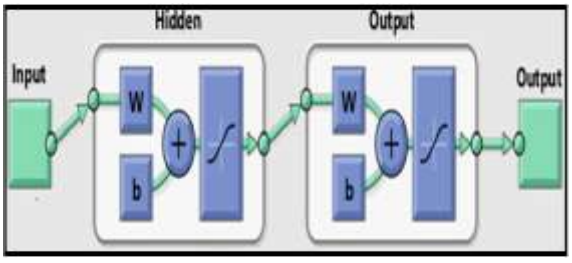

Fig. 13 Model of Neural Network [19]

The proposed Hopfield neural net is designed with 5 hidden layers. The input layer contained total 100 nodes as total 100 features were extracted for each character. The output layer contained total 67 characters. Size of the matrix has 67X100, where each character is represented as a 1X100 output vector.

a. Memorizesingle pattern

Hopfield ANN is consists of a set of ninterconnected neurons.When information pass through the network system during the learning phase and then may be changes its structure of information [4]. Suppose we set the weights thus:

$$Wij = \frac{1}{N} PiPj$$

where,

Wij - the weight between nodes i& j
N -the number of nodes in the network

Pi- the value required for the i-th node

For each node, i, its activation, Si, will be given by –

$$Si = sign(\sum_{j=1}^{N} WijPj)$$

$$= sign(\sum_{j=1}^{N} \frac{1}{N} PiPjPj)$$

$$= sign(\sum_{j=1}^{N} \frac{1}{N} PiX1) \; [(Pj)^2=1 \forall j]$$

$$= sign(Pi) = Pi \forall i$$

The activation of each node will remain unchanged. The memorized pattern is a stable state ofthe network.Any pattern presented to the network which is similar to the memorized pattern will migrate towardsthe memorized pattern as the activation rule is repeatedly applied.

In fact, if more than half the bits of a presented pattern are the same as the memorized pattern then thememorized pattern will eventually be recreated in its entirety. If less than half are the same then the inverse ofthe memorized pattern (+1s instead of –1s and vice versa) will be generated. The memorized pattern and itsinverse are attractors and the network will eventually end up at one of them [23].

b. To memorize more than one pattern

Now suppose we have n patterns which we wish to memorize. Extending the equation we used to set the

Weights for a single memory, we could try –

$$Wij = \frac{1}{\mathrm{N}}\sum_{k=1}^{n} Pi^{k} Pj^{k}$$

Where,
Wijis the weight between nodes i& j
N is the number of nodes in the network
n is the number of patterns to be learnt
$Pi^{k}$is the value required for the i-th node in pattern k

This equation will increase the weight between two nodes, i& j, whenever they are both active together. Notehowever that it is not uncommon to set Wii to 0 for all i.This should remind you of the Hebb Rule. In fact theequation does more than this, it also reduces the weight between any pair of nodes where one node is active andthe other is inactive. For this reason it is sometimes called the Generalized Hebb Rule [23].

V. EXPERIMENTAL RESULT AND ANALYSIS

The implementation of the whole system carried out using MATLAB as version R2013a. MATLAB (matrix laboratory) is a multi-paradigm which use forNumerical computing method and fourth-generation programming language. MATLAB allows algorithmsimplementation, matrix manipulations, plotting of functions and data,creation of user interfaces, , and interfacing with programs written in other languages.

Various research papers which reveal that Online character recognition is much easier and achieved better results than offline character recognition[22] and the difficulty of character recognition in handwritten has mainly two aspects. The first aspect is attributed to the writer variations in ink color, ink flow and thickness,style, size, shape and digitization imperfections etc. The second most important aspect is the deficiencies of the particular method used for feature extraction. Neural network training and testing implementation been performed and recorded observations mainly with consideration of these two aspects.

Firstly, training of system is perform by taking different training sample with different handwriting styles. And system is then tested for all of the taking sample, and then result is concluded.

The data set was partitioned into two parts. The first part is used for training the system and the second was for testing purpose [19]. We have created some datasetconsisting of total 167 patterns out of which we have used 67 patterns for training and 100 patterns for test. During testing we have recorded accuracy in terms of number of characters recognized accurately with percentage of accuracy for each character.Our testing database consists of 100 different characters in which having up to five different Hindi fonts.

$$\text{Accuracy}=\frac{Total\ no.of\ samples\ correctly\ recognize}{Total\ no.of\ samples} X100$$

$$=\frac{96}{100}X100 = 96(\%)$$

In purposed system, testing samples categories at two levels: individual character level and word level [14]. We have divided testing dataset into two as Dataset1 which contains 18 words and Dataset2 which contains 82 patterns of different consonants, vowel, and modifiers respectively.

A hybrid of two different feature extraction methods is used for character recognition in the proposed system [5]. Feature selection is mostly done by Gabor Filter and Freeman Chain Code for specific type of character recognition application. The results are summarized in table I. The results show that combining the two types of features (Hybrid features) yields 96% recognition rate as more information related to a character image is obtained by combining different features.

Comparisons of the proposed method with different feature extraction approaches methods have been shown in table I.

TABLE I
COMPARISON WITH OTHER METHODS

Author	Feature Extraction	Classifier	Test Set	Accuracy (%)
Seema A. Dongare[21]	Grid Feature	Feed Forward Neural Network	820	75
Ved Prakash Agnihotri[13]	Diagonal Feature	Genetic Algorithm	200	85.7
DivakarYadav[14]	Histogram And Vertical Zero Crossing Feature	Back Propagation Network	650	90
Prashant M. Kakde [10]	Scaled Conjugate Gradient Feature	Back Propagation Network	_	90
NehaSahu[19]	Gradient Feature	Back Propagation Network	210	91.2
Shruti Agarwal[15]	Statistical Structural Feature	Templates Matching	_	92.6
Gunjan Singh[12]	Gradient-Descent Feature	Back Propagation Network	1000	93
Ashutosh Aggarwal[10]	Gradient Features	Support Vector Machines	7200	94
SonalP.Patil[18]	View Based Shadow Based, Freeman Chain Code	Support Vector Machines	250	94
Sukhpreet Singh[9]	Gabor Filter	Support Vector Machines	700	94.2
Satish Kumar [5]	Gradient, Freeman Chain Code	MLP, SVM	2500	94.3
Our Method	**Gabor Filter,Freeman Chain Code**	**Hopfield ANN**	**167**	**96**

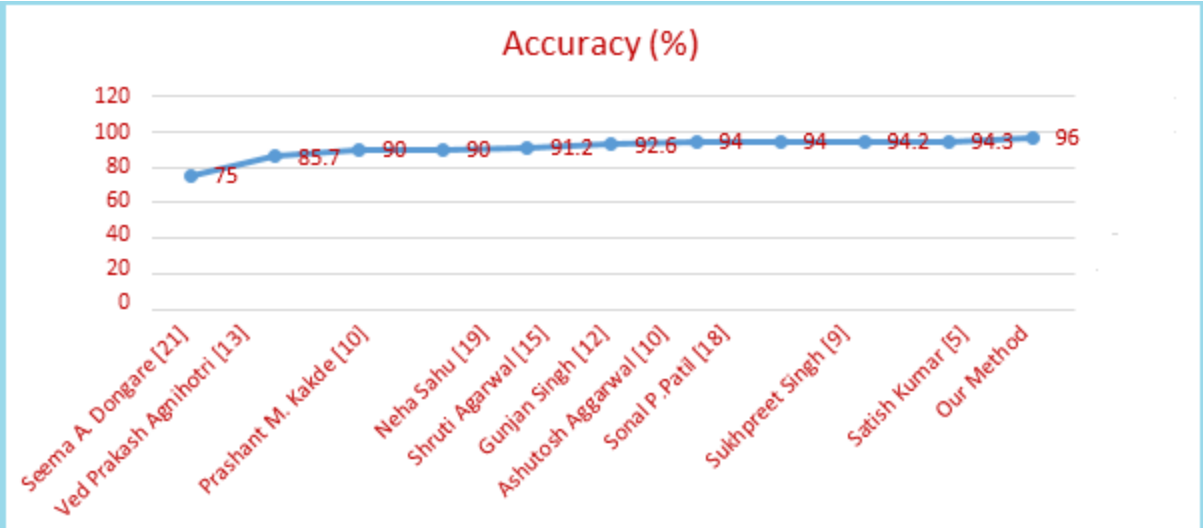

Fig. 14 Comparison graph of various research

By carefully observing the table and graph, we can say that the extraction and classifier is robust enough that able to correctlyrecognize even some highly distorted characters [14].

Overall performance of system is tested with whole test samples and it achieved recognition rate in the range up to 96% for various samples.Character having noise up to 40% will also recognize easily and effectively by the system. The results also show that the recognition accuracy and efficiency of the network increases with increase in number of training samples [10].

VI. Conclusion and Future Scope

We have presented a system for offline handwritten Hindi character recognition.Online character recognition is much easier and achieved better results than offline character recognition [22].The experimental results illustrate that the Hopfield artificial neural network (ANN) concept can be applied successfully to solve the Hindi character recognition problem. In the system, we have Total 100 features are extracted as 50 from Freeman Chain Code and 50 from Gabor Filter. Using only Freeman chain codes technique cannot be able to recognizewith high recognition accuracy rate. So use this technique with Gabor filter by which it able some specific or unique features of each character to avoid the error in recognition or to improve the recognition rate [6].The Gabor feature performs comparably better than the gradient feature. Hopfield Neural Network used to train the characters. Experimental results show that Hopfield network yields recognition accuracy of 96 %.

The future enhancement that can be incorporated with the work will to use a dictionary of words to correct the output. Certainly this will improve the performance[14]. Different fontfamilies represent the same character differently and there exist some typical relation between similar characters as itwill be variesfrom font to font.Further this system can be used for making a system for reading aids tothe blind by adding some speechsynthesizer with the recognitionsystem.

References

[1] V. Shiv Naga Prasad and Justin Domke, "*Gabor Filter Visualization*",IEEE Trans. Visualization and Computer Graphics, vol. 8, no. 1, pp. 1–8, March1996

[2] Tai Sing Lee,"*Image Representation Using 2D Gabor Wavelets*",IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 18, no. 10, october 1996

[3] Cheng-Lin Liu,Masashi Koga and iromichiFujisawa," *Gabor feature extraction for character recognition: Comparison with gradient feature"*DOI: 10.1109/ICDAR.2005.119 · Source: IEEE Xplore Conference Paper · January 2005

[4] NicolaePopoviciu and MioaraBoncut,"*On the Hopfield algorithm. Foundations and examples"*,General Mathematics Vol. 13, No. 2 (2005)

[5] Satish Kumar," *Performance increment of Features on Devanagari Hand-printed Dataset*", International Journal of Recent Trends in Engineering, Vol. 1, No. 2, May 2009

[6] Nor AmizamJusohand JasniMohamadZain ,"*Application of Freeman Chain Codes: An Alternative RecognitionTechnique for Malaysian Car Plates*", IJCSNS International Journal of Computer Science and Network Security, VOL.9 No.11, November 2009

[7] Yash Pal Singh, AbhilashKhare and Amit gupta,"*Analysis of Hopfield Autoassociative Memory in the Character Recognition*", (IJCSE) International Journal on Computer Science and EngineeringVol. 02, No. 03, 2010, 500-503

[8] Anshul Gupta, Manisha Srivastava and ChitralekhaMahanta," *Offline Handwritten Character Recognition Using Neural Network*", International Conference on Computer Applications and Industrial Electronics (ICCAIE 2011),2011

[9] Sukhpreet Singh, Ashutosh Aggarwal and RenuDhir," *Use of Gabor Filters for Recognition of Handwritten Devanagari Character*",International Journal of Advanced Research in Computer Science and Software Engineering Volume 2, Issue 5, May 2012 ISSN: 2277 128X

[10]Ashutosh Aggarwal, Rajneesh Rani and RenuDhir,"*Handwritten Devanagari Character Recognition Using Gradient Features*", International Journal of Advanced Research in Computer Science and Software Engineering Research Paper,Volume 2,Issue 5, May 2012, ISSN: 2277 128X

[11]Prashant M. Kakde and Vivek R. Raut," *Performance Analysis of Handwritten Devnagri Characters Recognition through Machine Intelligence*", International Journal of Emerging Technology and Advanced Engineering, Volume 2, Issue 7, July 2012, ISSN 2250-2459

[12]Gunjan Singh and SushmaLehri,"*Recognition of Handwritten Hindi Characters using Backpropagation Neural Network*", (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 3 (4) , 2012,4892-4895

[13] Ved Prakash Agnihotri,"*Offline Handwritten Devanagari Script Recognition*",378-1-3299-3020-6190/$31.00 ©2012 IEEE,2012

[14] DivakarYadav, Sonia Sánchez-Cuadrado and Jorge Morato,"*Optical Character Recognition for Hindi Language Using a Neural-network Approach*", J Inf Process Syst, Vol.9, No.1, March 2013

[15]Shruti Agarwal and Dr. Naveen Hemarjani,"*Offline Handwritten Character Recognition with Devnagari Script*", IOSR Journal of Computer Engineering (IOSR-JCE) ,Volume 12, Issue 2 (May. - Jun. 2013), PP 82-86, e-ISSN: 2278-0661, p- ISSN: 2278-8727

[16]S SSayyad, AbhayJadhav, ManojJadhav, SmitaMiraje, PradipBele and AvinashPandhare,"*Devnagiri Character Recognition Using Neural Networks*", 2277-3754-7156/$31.00 ©20l3 IEEE, July 2013

[17] Pulipati Annapurna, SriramanKothuri and SrikanthLukka,"*Digit Recognition Using Freeman Chain Code",*IJAIEM Volume 2, Issue 8, August 2013 ISSN 2319 – 4847

[18] Prof. SonalP.Patil and Ms. Priyanka P. Kulkarni ," *Online Handwritten Hindi Character Recognition Using Support Vector Classification*", *Int. Journal of Engineering Research and Applications* www.ijera.com *ISSN : 2248-9622, Vol. 4, Issue 5(Version 1), May 2014, pp.82-91*

[19]NehaSahu,Shipra Gupta and Shilpa Srivastava Khare," *Neural Network based approach for Recognition for Devanagiri Characters*", International Journal of Advanced Technology in Engineering and Science Volume No.02, Issue No. 05, May 2014 ISSN (online): 2348 – 7550

[20] Andrea Torsello,"*Artificial IntelligenceHopfield Networks"*IJAIEM Volume 2, Issue 8, August 2014 ISSN 2319 – 4847

[21] Ms. Seema A. Dongare, Prof. Dhananjay,Kshirsagar, Mr. NitinJ.Khapale and Ms. Amruta D. Pawar,"*Artificial Neural Network For Recognition Of Handwritten DevanagariCharacter*", IOSR Journal of Computer Engineering (IOSR-JCE) e-ISSN: 2278-0661, Volume 17, Issue 1, Ver. I (Jan – Feb. 2015), PP 60-64, ISSN: 2278-8727

[22] Pooja Yadav and Sonia Sharma," A Review on Various Techniques of Devanagari Script Recognition", International Journal of Engineering Trends and Technology (IJETT) – Volume 33 Number 6- March 2016

[23]http://www.macs.hw.ac.uk/~nkt/leares/Artificial%20Neural%20Networks/ANN%203a%20Hopfield%20Analysis.pdf,"*"Hopfield Training Rules"*