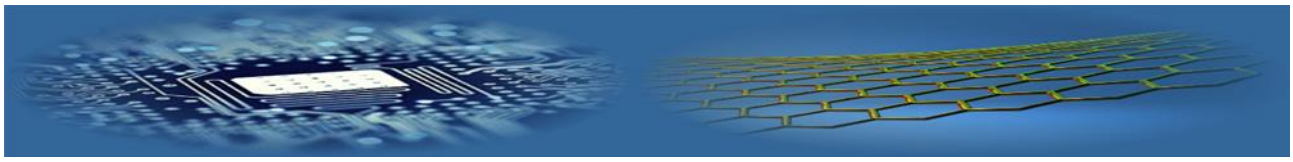

# Handwritten offline Hindi character recognition using advanced feature extraction techniques

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**Abstract**

Feature extraction technique plays an important role in character recognition since last so many years. In this paper, two advanced feature extraction techniques namely 16-Directional Gradient Feature Extraction Technique (16-DGFET) and 24-Directional Gradient Feature Extraction Technique (24- DGFET) have been proposed and implemented. This paper demonstrates the concept of Handwritten Hindi Character Recognition (HCR), feature extraction mechanisms adopted for character recognition starting from Conventional Feature Extraction Technique (CFET), Gradient Feature Extraction Technique (GFET), and Directional Gradient Feature Extraction Technique (DGFET). In DGFET, few techniques have been initiated which involve dividing the gradient values to 8/16 directional values, these techniques attained recognition accuracy of around 94%. We have aimed at further splitting of the gradient values in 24 parts in order to find if it achieves the objective of increasing the performance of character recognition with more accurate analysis and acceptable training time. An experimental evaluation and comparative analysis have been made at the end of the paper to prove the result whether further splitting is providing a better result in comparison to 8 or 16 parts division taking in account the training time, the accuracy of recognition and performance appraisal. The network used here is Multilayer Perceptron (MLP) with Error Back Propagation (EBP) algorithm to train the network.

A sample of count 1000 has been taken for experimentation including the personnel of different age groups involving both male and female handwriting. A comparative synthesis is made for 8/16-Directional and 24-Directional input values comparing the recognition performance and training time.

*Keywords*

Pattern Recognition
Hindi Character Recognition
Gradient Feature Extraction Technique (GFET)
Directional Gradient Feature Extraction (DGFET)
Multilayer Perceptron (MLP)
Error Back Propagation (EBP)

## 1 Introduction

Artificial Neural Network has its effective implementation in certain areas due to its application potentials; Character Recognition is one among them, character recognition being an area of pattern recognition aims at feature extraction to identify the character samples.

Many efforts have been applied in scientific scenario for the development of an effective recognition system which could effectively identify and analyse the entity, object or characters. Identifying a typed/printed character is easy while handwritten character recognition raises a difficulty because every individual has its own style of writing including its size, style and orientation angle. A number of works have been reported for character recognition of languages such as English, Chinese, Japanese, Arabic, etc. but only a few attempts have been made for resolution of Hindi Character aiming at Handwritten Hindi Character Recognition. In this paper, a MLP network has been used featured with Advanced Feature Extraction, with neurons trained with EBP algorithm to obtain offline recognition of handwritten Hindi Characters. Feature Extraction Mechanisms which have been implemented in this paper are Directional Values Gradient Feature Extraction with splitting of gradient values into 16 and 24 parts/directions respectively. [13 - 15]

While application of 8-DGFET, the performance obtained is 95% and when applied with 16-DGFET the accuracy performance raised to 96% with a little rise in training time. The work aims at further dividing it in 24 parts and then analysing the network performance in recognizing the character. On further division in 24 sectors, the result found that there was a slight enhancement in performance accuracy i.e. 97% with a great rise in training time of neurons which could be considered ineffective. As while developing a character recognition system both performance accuracy and little training time serve as essential parameters. The network architecture that considers the input layer and the number of hidden and output layer and training algorithm is also considered while deriving the conclusion.

The organization of paper is as follows- Section II provides a background study of neural network, the language selected, the training methods, the training algorithm used with specifying the reason of its adoption. Section III discusses the pre-requisites to perform the recognition, operation to be performed before application to the neural network for training. Section IV highlights several mechanisms discussed so for character recognition.

Section V provides comparison of 8 Directional, 16-

Directional and 24- Directional Gradient Feature Extraction mechanism defining which scheme proves to be effective in achieving the Character Recognition objectives with consideration of training time of neuron.

## 2 Research background

### 2.1 HINDI LANGUAGE

Hindi, the national language of India is the second most widely spoken language of India. It is being used as an official language in various Government offices and sectors which include banks, sales tax offices, Railway, Passport office, Embassy, etc. Around 40 million people speaks Hindi language all over India, especially by the north Indians. The characters involve 13 vowels and 36 consonants directing from left to right. [1]

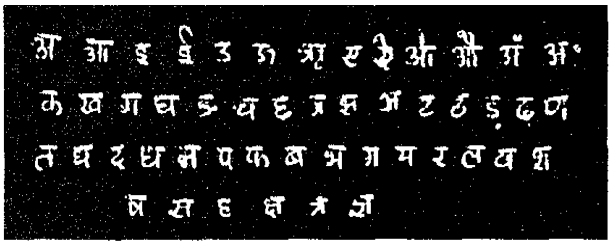

FIGURE 1 Hindi Characters of alphabet [1]

### 2.2 NEURAL NETWORK

A Neural Network can be defined as a highly-interconnected network with a number of processing elements termed as neurons, having the ability to gain knowledge which could be used for further future applications. The inspiration on these parallel processing elements is attained from the biological neurons.

### 2.3 FEATURE EXTRACTION

Feature Extraction is an essential component in Pattern/ Character Recognition. It aims at finding an appropriate mapping for the characters reducing the dimension of the pattern. The neural network here is incorporated with advanced mechanism for feature Extraction with several methods for it. Edge detection, Boundary detection, etc. are also some methods for Character Recognition.

The Hindi Character recognition follows the following steps:

- Sample acquisition
- Pre-processing operations including image thinning, compression, Skeletonization and normalization
- Directional Gradient Feature Extraction
- Classification and Recognition

### 2.4 TRAINING MECHANISM

A neural network is trained to perform certain applications. The network training involves feeding the input vectors into the system and performing weight adjustments to obtain the desired output/target vector.

The learning or training mechanism includes- Supervised Training, Unsupervised Training, and Reinforcement training.

Supervised Training: Supervised training involves an assumption of teacher during training aiming to minimize the error between the desired output and attained output. The input vector and the target vector are together termed as training pair. Generally, a network requires several such training pairs. Every time a result is obtained on application of input vector is matched with the desired output. If it not, the weight is manipulated and again fed to the network tending to minimize the error. This continues until a result is obtained with error potentially low [7, 8].

- Unsupervised Learning: Involves no pre-feeding of output vector. The only provided value is the input vector thus no comparison could be made to determine the correctness of the result obtained. The training is performed to the time the system is found to obtain a consistent result. The network here tries to learn on its own. [7, 8]
- Reinforcement Learning: The learning performed based on rewards or criticism is Reinforcement learning. If positive or reward defines a good training and in case of criticism is regarded as error or inappropriate output. [7, 8]

### 2.5 PERCEPTRON

The architecture of neural network consists of several neurons to which input are provided such that each input "$x_i$" is multiplies to its respective weight "$w_i$". The result is summed up using Σ unit. The output is then compared with the predefined threshold value and if is found greater is set to 1 otherwise the value is taken 0. The perceptron learning is categorized under supervised learning. It can be a single layer model or multi-layer model comprising of several hidden layers. In the present word, we have taken 2 hidden layers. The number of neurons at the output layer is the number of characters to be recognized.

### 2.6 PERCEPTRON TRAINING ALGORITHM

This training algorithm is used to train the perceptron which involves presentation of the input pattern one at a time and adjusting the weights to minimize the error raising the accuracy. "Delta Rule" is a generalized perceptron training algorithm to train the neurons. Δ provides the difference between target output "T" and the obtained output "A" i.e. $\Delta = T-A$.

In case $\delta=0$, means no training us required and the attained output is the desired output. In other cases, training is required. Each input is multiplied with its respective weights and a learning coefficient η is multiplied to the product to control the average weight change. Accordingly, the weight is adjusted by applying the formula: $W_{i+1} = W_i + \Delta$.

### 2.7 ERROR BACK PROPAGATION ALGORITHM

The recognition performance of the network depends on the training algorithm and structure of the network. Here, in this paper have adopted Error back propagation algorithm as it provides a better training/learning rate. This network does not have any feedback connection but only requires back propagation of errors during training. The errors obtained at the output layer are the result of hidden layer errors. These

errors serve as a basis of adjustment of connecting weights interleaved between the hidden layer and the input layer. The adjustment of weight continues to the time the error is found to be below the tolerance level.

The implementation of error back propagation algorithm includes the weight updating and is biased in the direction where the performance function falls rapidly- the negative part of the gradient. The iteration is represented as $W_{n+1} = W_n - \alpha_n g_n$.

Here $W_n$ represents the weight, α is the learning rate and $g_n$ is the gradient value. The gradient value is calculated for each pixel and after each iteration and is compared with the threshold value. If is smaller is passed else sent for next iteration. The implementation of gradient descent algorithm takes place in two modes – Incremental mode and Batch mode. In this paper, Batch Gradient Descent (traingd) is adopted for training the network. The parameters adopted for traingd are- epoch (defining the number of iterations), show, goal, min, lr (learning rate). The lr should be neither too high nor too low. The smaller the lr the learning time will be raised and if is too high could make the algorithm unstable.

### 2.8 OBJECTIVE OF THE WORK

The basic objective of the paper includes:

- Directional Gradient Feature Extraction using back propagation feed forward network.
- Analysing the performance if the directional gradient feature extraction measure is further split to 24 parts ie. What will be the performance of Character Recognition if we propose 24-Directional Gradient Feature Extraction in comparison to 16-Directional Gradient Feature Extraction?
- Comparison parameters covers - Recognition performance accuracy, network training time and classification time.

## 3 Pre-requites of feature extraction

### 3.1 PRE-PROCESSING

The handwritten samples of Hindi characters are collected from several personnel including male and female of different age groups. The samples are then scanned by scanner and image is converted into binary form.

### 3.2 IMAGE SMOOTHENING

Smoothening of the images by removing unnecessary variations from the image is called image smoothing. These variations are the noise. Gaussian filter approach is adopted for it.

### 3.3 IMAGE THINNING

It is also referred as skeletionization which is applied to binary pixel image aims at removal of extra pixel that are not part of backbone of a character. This image thinning results in transformation of broad strokes of image to thin lines. [4, 6]

### 3.4 NORMALIZATION AND IMAGE COMPRESSION

After skeletionization of the image, normalization is done by placing the character to the top left corner of the computer screen in 30*30-pixel window. [1, 3, 6]

## 4 Feature Extraction Methods

### 4.1 CONVENTIONAL FEATURE EXTRACTION TECHNIQUE (CFET)

It involves the selection of region holding the character. The screen is taken to be of 30*30 pixels. If a line is passing through a pixel; the pixel value is taken to be 1 whereas the left pixels are assigned the value 0. This combination of pixel value is stored in the character database for every Hindi character meant for recognition purpose. In Hindi, every character holds a different font size varying person to person; hence there is a possibility that the character taken from individual for recognition has a different line. Hence this generalized method of character recognition cannot be specialized. It also requires a large storage space to hold the pixel value combination for every character. This technique requires more training time and yields less recognition accuracy. [1, 2, 12]

### 4.2 GRADIENT FEATURE EXTRACTION TECHNIQUE (GFET)

This method incorporates the use of **"Sobel Operator"** to obtain the gradient values for each pixel. This sobel operator is used in gradient values calculation. E.g. if the screen has resolution of 30*30, gradient value is calculated for each pixel. The sobel operator uses a horizontal or vertical template for gradient component extraction [5, 13 - 15].

| | | |
|---|---|---|
| -1 | 0 | 1 |
| -2 | 0 | 2 |
| -1 | 0 | 1 |

Vertical Template

| | | |
|---|---|---|
| 1 | 2 | 1 |
| 0 | 0 | 0 |
| -1 | -2 | -1 |

Horizontal Template

FIGURE 2 Sobel operator template [13 - 15]

The gradient component is evaluated using the following expression:

Horizontal Component is represented by

$$Gx = grad_v(i,j) = g(i-1,j+1) + 2\,g(i,j+1) + g(i+1,j+1) - f(i-1,j-1) - 2\,g(i,j-1) - g(i+1,j-1), \quad (1)$$

$$Gy = grad_h(i,j) = g(i-1,j-1) + 2\,g(i-1,j) + g(i-1,j+1) - g(i+1,j-1) - 2\,g(i+1,j) - g(i+1,j+1). \quad (2)$$

After obtaining the values the gradient strength and its direction can be evaluated using the formula:

$$G(i,j) = \left(grad_v^2(i,j) + grad_h^2(i,j)\right)^{\wedge} 0.5,$$

$$\theta = arctan\left(G_y / G_x\right)$$

## 4.3 DIRECTIONAL GRADIENT FEATURE EXTRACTION (8-DGFE)

Further enhancement was made in the field of feature extraction by dividing the gradient values into 8 equal parts to obtain directional value ranging from 1 to 8. For gradient value -1, the directional value was taken to be 0. The directional gradient value was calculated according to the gradient angle range.

Before calculation a padding operation was performed to transform the 30*30-pixel image to 32*32 matrixes. This padding involved the addition of 0 across the boundary of image. The pixel surrounded by 8 black pixels was assigned the gradient value -1. Next the 32*32 matrix was converted to 1024*1 matrixes and fed to feed forward neural network for character recognition.

The division was such that if angle ranged between 0-45 degrees was taken the value 1, for angle between 46-90 degree was assigned the value 2 and so on. This division can be represented as follow in the figure 3. [13, 14, 15]. The directional values can be calculated as per following table given below as table 1.

TABLE 1 Direction equivalent of gradient values

| Calculated Gradient values | Equivalent Directional values |
|---|---|
| grad = -1 | 0 |
| 0 < = grad < 0.786 | 1 |
| 0.786 < = grad < 1.58 | 2 |
| 1.58 < = grad < 2.37 | 3 |
| 2.37 < = grad < 3.14 | 4 |
| 3.14 < = grad < 3.94 | 5 |
| 3.94 < = grad < 4.72 | 6 |
| 4.72 < = grad < 5.46 | 7 |
| 5.46 < = grad < 6.28 | 8 |

The division of gradient values into 8 equal parts can also be represented as follows in figure 3.

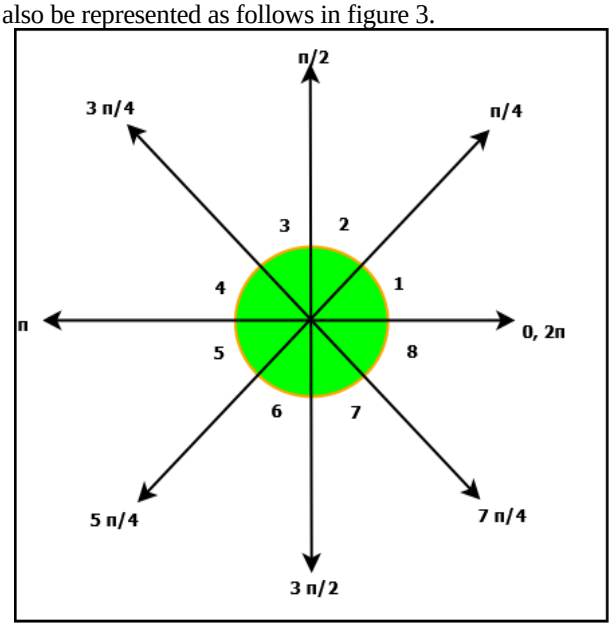


FIGURE 3 8 Directional Values equivalent to gradients

## 4.4 16- DIRECTIONAL GRADIENT FEATURE EXTRACTION (16-DGFE)

The image is normalized into 30 * 30 matrixes and then transformed to 32*32 matrixes by adding zeros across the boundaries. Gradient value is calculated for each pixel using the sobel operator. The same mechanism as for 8-DGFET is adopted with a difference that the gradient was partitioned to 16 equal parts. The division can be represented as in table 2 and figure 4.

The division of gradient values into 16 equal parts can also be represented as follows: For this feature extraction technique, the same parameter of training, classify have been taken as we have taken for 8-DGFET.

TABLE 2 8 directional values equivalent to gradients

| Calculated Gradient values | Equivalent Directional values |
|---|---|
| grad = -1 | 0 |
| 0<= grad <0.395 | 1 |
| 0.395<= grad <0.795 | 2 |
| 0.795<=grad<1.19 | 3 |
| 1.19<=grad<1.57 | 4 |
| 1.57<=grad<1.97 | 5 |
| 1.97<=grad<2.37 | 6 |
| 2.37<=grad<2.76 | 7 |
| 2.76<=grad<3.14 | 8 |
| 3.14<=grad<3.55 | 9 |
| 3.55<=grad<3.94 | 10 |
| 3.94<=grad<4.33 | 11 |
| 4.33<=grad<4.72 | 12 |
| 4.72<=grad<5.12 | 13 |
| 5.12<=grad<5.50 | 14 |
| 5.50<=grad<5.89 | 15 |
| 5.89<=grad<6.28 | 16 |

The division of gradient values into 16 equal parts can also be represented as follows in figure 4.

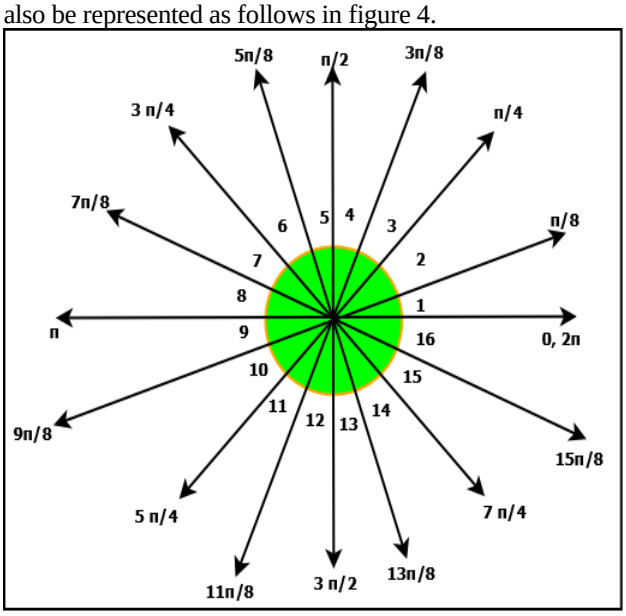


FIGURE 4 16 Directional Values equivalent to gradients

## 4.5 24-DIRECTIONAL GRADIENT FEATURE EXTRACTION (24-DGFE)

The paper aims at further splitting the gradient value into 24 equal parts i.e. to the angle of 15 degree variations.

The work aims at finding that if further splitting could successfully improve the performance and accuracy of

character recognition with consideration to neuron training time or could result in no better or effective result. An effective approach does not compromise with the neuron training time i.e. if further splitting of gradient values is found to bring no potential difference compared to that found in 16-DGE and it consumes much training time, and then the approach cannot be considered efficient.

The mechanism remains the same with the only difference in the number of sectors partitioned. The directional value is calculated as per following table 3.

TABLE 3 24 directional values equivalent to gradients

| Calculated Gradient values | Equivalent Directional values |
|---|---|
| grad=-1 | 0 |
| 0<=grad<0.26 | 1 |
| 0.26<=grad<0.52 | 2 |
| 0.52<=grad<0.79 | 3 |
| 0.79<=grad<1.05 | 4 |
| 1.05<=grad<1.31 | 5 |
| 1.31<=grad<1.57 | 6 |
| 1.57<=grad<1.83 | 7 |
| 1.84<=grad<2.10 | 8 |
| 2.10<=grad<2.36 | 9 |
| 2.36<=grad<2.62 | 10 |
| 2.62<=grad<2.88 | 11 |
| 2.88<=grad<3.14 | 12 |
| 3.14<=grad<3.41 | 13 |
| 3.41<=grad<3.67 | 14 |
| 3.67<=grad<3.93 | 15 |
| 3.93<=grad<4.19 | 16 |
| 4.19<=grad<4.45 | 17 |
| 4.45<=grad<4.71 | 18 |
| 4.71<=grad<4.98 | 19 |
| 4.98<=grad<5.23 | 20 |
| 5.23<=grad<5.50 | 21 |
| 5.50<=grad<5.76 | 22 |
| 5.76<=grad<6.02 | 23 |
| 6.02<=grad<6.28 | 24 |

The division of gradient values into 24 equal parts can also be represented as follows in figure 5.

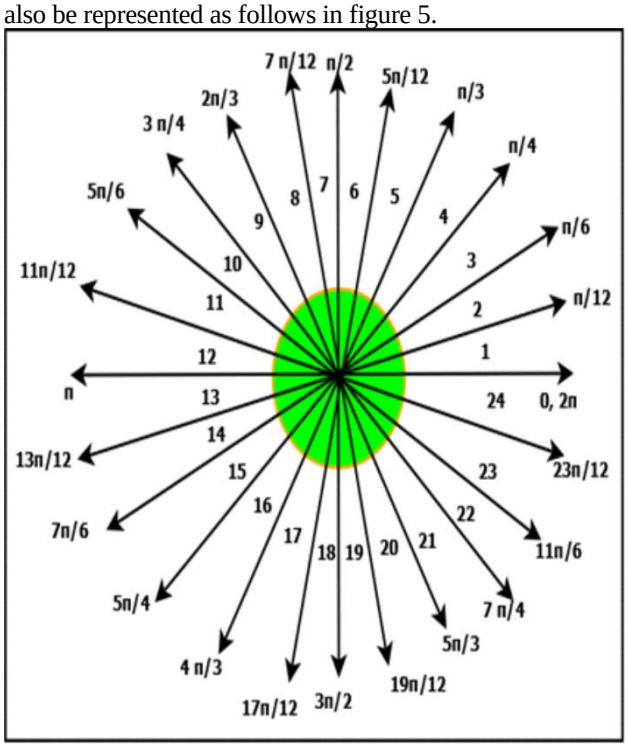


FIGURE 5 24 Directional Values equivalent to gradients

## 5 Experimental Result and Comparative analysis

In this paper, Back propagation neural network with 12 number of hidden units has been used for training the network.The gradient descent training method has been implemented for training the back propagation neural network. This training method calculates the gradients and compare it with threshold value $10^{-10}$.Whenever gradient exceeds the threshold valus,network performs next iteration. The batch steepest descent training function is traingd.

For performing the experiment in Matlab, 1000 number samples of Hindi characters have been collected from different person of different department of different age groups. Out of 1000 samples, 500 samples were used for training purpose and remaining 500 samples were used for testing purpose. Flowchart for performing the experiment.

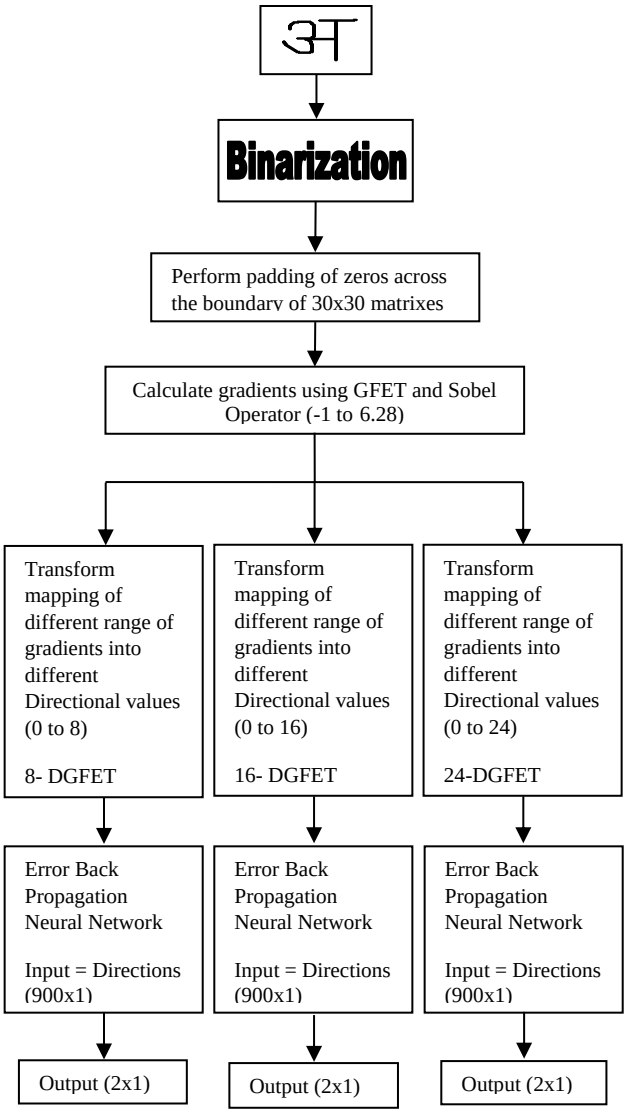


FIGURE 6 Flowchart

### 5.1 PROCEDURE

The various steps of implementing all the feature extraction techniques are given in procedure

- Normalize handwritten Hindi character in 30x30 pixels

- Convert 30x30 pixel images into binary i.e. perform binarization.
- Convert above 30*30 binary values into 32x32 matrixes by padding with zeros across the boundary.
- Apply Sobel operator on above 32x32 matrixes for calculating the gradient values.
- Calculated gradient values will be in a 30x30 matrix (Gradient values will be between 0 to 2π). If pixel is surrounded with all zeros, set the gradient value -1.
- Set the gradient values into 8/16/24 directions as per tables given above.
- All three methods of feature extraction will supply 30x30 matrix directional values in 900x1 column matrix to the feed forward neural network independently as an input.
- The above values can be used for training and simulation both
- Set goal as a 2x1 matrix (e.g. for first vowel of Hindi character, goal = [1 0] ′ and for first consonant of Hindi character, goal = [0 1] ′.

Results of experiment have been given in following table 4.

TABLE 4 Results of experiment

| Advanced Feature Extraction Techniques | Input to Neural Network | Number of Hidden Units | No of Iterations | Training Time (sec) | Classification Time (ms) | Performance on Training set (%) | Performance on Test Set (%) |
|---|---|---|---|---|---|---|---|
| 8-DGFE | 30x30 inputs | 12 | 50 | 416.53 | 65.62 | 100 | 95 |
| 16-FGFE | 30x30 inputs | 12 | 50 | 665.37 | 62.52 | 100 | 96 |
| 24-DGFE | 30x30 inputs | 12 | 50 | 884.85 | 60.38 | 100 | 97 |

From above table, it has been analyzed that recognition accuracy is increasing at the cost of training time as we move from 8-DGEF to 24-DGEF. 24 Directional gradient feature extraction technique is giving high accuracy up to 97% and requires less classification time, this feature extraction technique requires some more training time. But, once system is fully trained then training time does not matter more, only recognition accuracy matters more. In this way, 24- DGFE technique is developed and implemented for handwritten Hindi character recognition.

## 6 Conclusion and Future Scope

In this paper, three feature extraction techniques have been implemented for handwritten Hindi character recognition. The 24-DGFE technique is yielding recognition accuracy little bit more but it requires more training time as compared to other methods. This concludes that as we keep on splitting the gradient values in increasing number of directional values, the recognition accuracy is little bit increasing but training time is increasing more. If we focus on recognition accuracy, then the 24-DGEF technique is better. This accuracy can be further increased by implementing some innovative feature extraction technique. In this paper, since, scanned samples have been taken therefore this automatic character recognition system can be used for any other character of any other language by giving it proper training.

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