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Use of Gabor Filters for Recognition of Handwritten Gurmukhi Character

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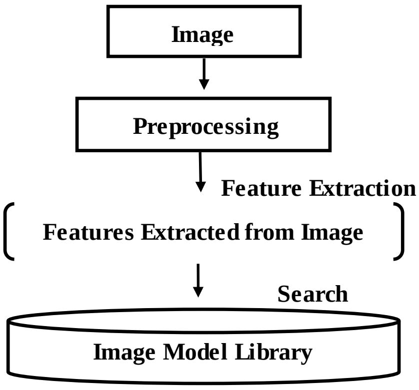
Abstract- **In this manuscript handwritten Gurmukhi character recognition for isolated characters is proposed. We have used Gabor Filter based method for feature extraction. Our database consists of 200 samples of each of basic 35 characters of Gurmukhi script collected from different writers. These samples are pre-processed and normalized to 32*32 sizes. The highest accuracy obtained is 94.29% as 5-fold cross validation of whole database with SVM classifier used with RBF kernel.**

Keywords **- OCR; Isolated Handwritten Gurmukhi Character Recognition; Gabor Features; Gabor Filters; SVM**

I. INTRODUCTION

1.1. Optical character recognition, abbreviated as OCR, is the process of converting the images of handwritten, typewritten or printed text (usually captured by a scanner) into machine-editable text or computer processable format, such as ASCII code. Computer systems armed with OCR system improve the speed of input operations, reduce data entry errors, reduce storage space required by paper documents and thus enable compact storage, fast retrieval, scanning corrections and other file manipulations. OCR has applications in postal code recognition, automatic data entry into large administrative systems, banking, automatic cartography, 3D object recognition, digital libraries, invoice and receipt processing. OCR includes essential problems of pattern recognition. Accuracy, flexibility and speed are the three main features that characterize a good OCR system. OCR aims at enabling computers to recognize optical symbols without human intervention. This is accomplished by searching a match between the features extracted from a given symbol's image and the library of image models. The basic process of OCR Systems is shown in Figure1.



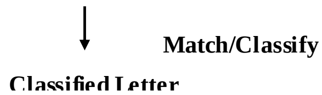


Fig. 1 The Basic process of an OCR System

The process of optical character recognition of any script can be broadly broken down into 6 stages as shown in Figure2:

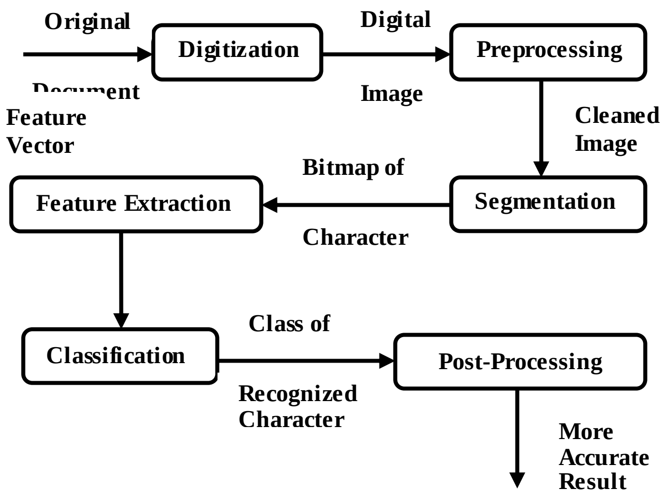


Fig. 2 Block diagram of OCR system

1. Digitization: Digitization produces the digital image, which is fed to the pre-processing phase.
2. Preprocessing: After digitization image may carry some unwanted noise. The preprocessing stage reduces noise and distortion, removes skewness and performs skeltonizing of the image. After preprocessing phase, we have a cleaned image which goes to the segmentation phase.
3. Segmentation: The segmentation stage takes in the image and separates the different logical parts, like lines of a

paragraph, words of line and characters of a word.

4. Feature Extraction: After segmentation, set of features is required for each character. In feature extraction stage every character is assigned a feature vector to identify it. This vector is used to distinguish the character. Various feature extraction methods are designed like zoning, PCA, Central moments, structural features and Directional Distance Distribution.

5. Classification: Classification is the main decision making stage of OCR system. It uses the features extracted in the previous stage to identify the text segment according to preset rules. Many type of classifiers are applicable to OCR like K-nearest neighbour, MQDF and SVM.

6. Post processing: The output of classification may contain some recognition errors. Post-processing methods remove these errors by making use of mostly two methods namely, dictionary lookup and statistical approach

1.2. Types of Handwriting recognition

Handwriting recognition is broken into two different types.

i. Online Handwriting Recognition:

In online recognition systems, the computer recognizes the symbols as they are drawn. Online recognition basically goes along the writing process.

ii. Offline Handwriting Recognition:

Offline handwriting recognition is performed after writing is complete. Offline handwriting recognition is performed after the writing or printing is complete.

II. INTRODUCTION TO GURMUKHI SCRIPT

Gurmukhi script, which is mainly used to write Punjabi language, consists of 35 basic characters. In addition to these 35 characters, there are 10 vowels and modifiers, 6 additional modified consonants, forming 41consonants including 35 basic characters [1], [2]. (Table.1)

Table 1: Gurmukhi Alphabet

Vowels and corresponding modifiers				
ਅ(none)	ਆ (◌ਾ)	ਇ (ਿ◌)	ਈ (◌ੀ)	ਉ (◌ੁ)
ਊ (◌ੂ)	ਏ (◌ੇ)	ਐ (◌ੈ)	ਓ (◌ੋ)	ਔ (◌ੌ)
Basic Characters (Consonants)				
ੳ	ਅ	ੲ	ਸ	ਹ
ਕ	ਖ	ਗ	ਘ	ਙ
ਚ	ਛ	ਜ	ਝ	ਞ
ਟ	ਠ	ਡ	ਢ	ਣ
ਤ	ਥ	ਦ	ਧ	ਨ
ਪ	ਫ	ਬ	ਭ	ਮ
ਯ	ਰ	ਲ	ਵ	ੜ
Additional Characters (with lower bindi)				
ਸ਼	ਖ਼	ਗ਼	ਜ਼	ਫ਼
ਲ਼				

Most of the Gurmukhi characters are like Devnagari script grouped in the sets of 5-5 characters which make 7 sections (*vergas*) of 35 basic characters. The sections from ਕ to ਪ are arranged in the row depending on which part of mouth these characters are originated from and these are arranged in columns depending on how these are pronounced [1].

III. RELATED WORK

Many researchers have worked on Indian script recognition in general and Gurmukhi in particular. A detailed survey on research work on Indian languages is presented in [3-4].In this paper, properties of Indian scripts, methods and approaches applied to recognize characters are discussed.

Vikas Dungre et al. [5] reviewed feature extraction using Global transformation and series expansion like Fourier transform, Gabor transform, moments; statistical features like zoning, projections crossings and distances; and some geometrical and topological features commonly practiced.

Prachi Mukherji and Priti Rege [6] have used structural features like endpoint, cross-point, junction points, and thinning. They classified the segmented shapes or strokes as left curve, right curve,horizontal stroke, vertical stroke, slanted lines etc.

Giorgos Vamvakas et al. [7], [8] described the statistical and structural features they have used in their approach of Greek handwritten character recognition. The statistical features they have used are zoning, projections and profiling, and crossings and distances. By zoning they derived local features and also described in- and out- profile of contour of images. The structural features they depicted are end point, crossing point, loop, horizontal and vertical projection histograms, radial histogram, out-in and in-out histogram.

Sarbajit Pal et al. [9] have described projection based statistical approach for handwritten character recognition. They proposed four sided projections of characters and projections were smoothed by polygon approximation.

Nozomu Araki et al. [10] proposed a statistical approach for character recognition using Bayesian filter. They reported good recognition performance in spite of simplicity of Bayesian algorithm.

Wang Jin et al. [11] evolved a series of recognition systems by using the virtual reconfigurable architecture-based evolvable hardware. To improve the recognition accuracy of the proposed systems, a statistical pattern recognition-inspired methodology was introduced.

Chain code histogram and moment based features were used in [12] while recognizing handwritten Devnagari characters. Chain code was generated by detecting the direction of the next in-line pixel in the scaled contour image. Moment features were extracted from scaled and thinned character image.

Fuzzy directional features are used in [13] in which directional features were derived from the angle between two adjacent curvature points. This approach was used to recognize online handwritten Devnagari characters.

12 directional features were derived in [14] by computing gradient features by Sobel's mask, finding angles using

tangent and categorizing the angle in one of the 12 directions.

In particulate to Gurmukhi script, C. Singh and G. S. Lehal have done major work in the field of Gurmukhi character recognition. They have designed a complete printed Gurmukhi character recognition system [15].

Anuj Sharma et al. [18], [21] have presented the implementation elastic matching technique giving accuracy of 90.08% and HMM based technique giving accuracy of 91.95%, to recognize online handwritten Gurmukhi characters.

Dharam Veer Sharma et al. [19] first extracted Gurmukhi digits from printed documents and then recognised. They have used many structural features like loops, entry points, curve, line, aspect ratio, and statistical features like zoning, directional distance distribution for recognition and observed 92.6% recognition rate for Gurmukhi digits for offline handwritten.

Gurmukhi character recognition two approaches are reported. First one is proposed by Puneet Jhajj et al. [16] and second one by Ubika Jain et al. [17]. A little more detailed survey on Gurmukhi recognition is presented in [3].

Puneet Jhajj et al. Used a 48*48 pixels normalized image and created 64 (8*8) zones and used zoning densities of these zones as features. They used SVM and K-NN classifiers and compared the results and observed 72.83% highest accuracy with SVM kernel with RBF kernel.

Ubeeka Jain et al. created horizontal and vertical profiles, stored height and width of each character and used neocognitron artificial neural network for feature extraction and classification. They obtained accuracy of 92.78% at average.

In the following sections, section IV describe about preprocessing performed, section V covers the topic of Feature Extraction and explains the use and functionality of Gabor filters used in our proposed system, section VI explain the classification technique used and finally results obtained are discussed and compared with other approaches.

IV. PREPROCESSING

In our proposed methodology of isolated handwritten Gurmukhi character recognition we have considered 35 basic characters of Gurmukhi alphabet for our experiment. These characters are assumed to bear header line on top. 20 writers of different profiles, age and genders have written these samples in isolated manner on A-4 size white papers. 10 samples of each character by each writer are taken, thus forming a total of 7000 size of our database. The samples were collected such that these can be separated line by line through straight horizontal white spaced lines. Also the space between adjacent characters within line was present. The contributors to these data samples were of different educational backgrounds of metric, graduate, post graduate level qualification and different professions as student, teacher, security guard and hostel care-taker. We preprocessed and segmented these samples. Initially, we scanned handwritten these samples in RGB format.

In pre-processing step, we converted these samples into gray scale. Then, we applied following techniques:

- We converted these gray scale images into binary images using threshold value obtained by Otsu's method plus adding 0.1 to it.
- We applied median filtration, dilation, and removed noise having less than 30 pixels.
- We applied some morphological operation to bridge unconnected pixels, to remove isolated pixels, to smooth pixels boundary by majority and to remove spur pixels.
- Now, we segmented these samples first line wise then column wise within line in an iterative approach. The white space present was used to separate these lines and columns.
- We clipped the character images by removing extra white spaced rows and columns residing in four sides of image.
- We resized each character image into 32*32 pixel size.

Now, we stored all sample images such obtained in our database in matrix form for further recognition process.

V. FEATURE EXTRACTION

Feature extraction is an integral part of any recognition system. The aim of feature extraction is to describe the pattern by means of minimum number of features that are effective in discriminating pattern classes. We have used following sets of features extracted to recognize Gurmukhi characters.

1. Gabor Features – GABM
2. Gabor Features – GABN

5.1 Gabor Feature Extraction

Gabor filters are defined by harmonic functions modulated by a Gaussian distribution. The use of the 2D Gabor filter in computer vision was introduced by Daugman in the late 1980s. Since that time it has been used in many computer vision applications including image compression, edge detection, texture analysis, object recognition and facial recognition.

Marcelja and Daugman discovered that simple cells in the visual cortex can be modelled by Gabor functions [22]. The 2D Gabor functions proposed by Daugman are local spatial bandpass filters that achieve the theoretical limit for conjoint resolution of information in the 2D spatial and 2D Fourier domains.

Families of self-similar 2D Gabor wavelets have been proposed and adopted for image analysis, representation, and compression (e.g., [23, 24]). Gabor filters have also been used extensively in various computer vision applications such as texture analysis, texture segmentation and classification, edge detection, etc. Furthermore, features extracted by using Gabor filters (we call them Gabor features) have been successfully applied to many pattern recognition applications such as face recognition, Iris pattern recognition, fingerprint recognition. It is interesting to notice that in OCR area Gabor features have not become as popular as they have in face and Iris pattern recognition areas. This situation is difficult for the new comers like us to understand, especially considering the following facts:

1) Gabor features are well motivated and mathematically well-defined,
2) They are easy to understand, fine-tune and implement,
3) They have also been found less sensitive to noises, small range of translation, rotation, and scaling.

5.1.1 Introduction to Gabor Filter

Gabor filters have been used extensively in image processing, texture analysis for their excellent properties: frequency and orientation representation of Gabor filters are similar to those of the human visual system, and they have been found to be particularly appropriate for texture representation and discrimination.

A Gabor Filter is a linear filter whose impulse response is defined by a harmonic function multiplied by a Gaussian function.

$$h(x, y) = g(x, y)\, s(x, y)$$

Where s(x, y) is a complex sinusoid, known as carrier and g(x, y) is a Gaussian shaped function, known as envelope. The Gabor filters are self similar, i.e. all filters can be generated from one mother wavelet by dilation and rotation.

Thus the 2-D Gabor filter with the response in spatial domain is given by Eq. (1) and in spatial-frequency domain is given by Eq.(2). Since Gaussian Function is a complex function so on convolving Gabor Filter with input image the output obtained can be used in various ways. Two of ways of manipulating the output of Gabor Filter to extract features are described below.

$$h(x, y; \lambda, \phi, \sigma_x, \sigma_y) = \frac{1}{2\pi\,\sigma_x\,\sigma_y} \exp\left\{-\frac{1}{2}\left[\frac{{R_1}^2}{\sigma_x^2} + \frac{{R_2}^2}{\sigma_y^2}\right]\right\} \times \exp\left[i\,.\frac{2\pi R_1}{\lambda}\right] \qquad (1)$$

where

$$R_1 = x\cos\phi + y\sin\phi,$$
$$R_2 = -x\sin\phi + y\cos\phi.$$

$$h(u, v; \lambda, \phi, \sigma_x, \sigma_y) = C\exp\left\{-2\pi^2\left(\sigma_x^2\left(F_1 - \frac{1}{\lambda}\right)^2 + \sigma_y^2 (F_2)^2\right)\right\}, \qquad (2)$$

where

$$F_1 = u\cos\phi + c\sin\phi,$$
$$F_2 = -u\sin\phi + v\cos\phi.$$
$$C = const.$$

The other form of 2-D Gabor Filter in terms of frequency can be represented as:

$$h_{x,y,\theta,f} = e^{-\frac{1}{2}\left(\frac{x'^2}{\sigma_x^2}+\frac{y'^2}{\sigma_y^2}\right)} . e^{i2\pi f x} \qquad (3)$$

Where σ_x and σ_y explain the spatial spread and are the standard deviations of the Gaussian envelope along x and y directions. x' and y' are the x and y co-ordinates in the rotated rectangular co-ordinate system given as:

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

Any combination of θ and f, involves two filters, one corresponding to sine function and other corresponding to cosine function in exponential term in Eq. (3). The cosine filter, also known as the real part of the filter function, is an even-symmetric filter and acts like a low pass filter, while the sine part being odd-symmetric acts like a high pass filter.

Gabor filters having Spatial frequency (f = 0.0625, 0.125, 0.25, 0.5, 1.0) and orientation (θ =nπ/6) where n varies in the range 0 to 6, have been used in our reported work.

5.2 Gabor Features-GABM

This set of features is based on extracting features from Energy magnitudes of output of Gabor Filters. In this the output of Gabor Features is divided into 3 parts.

1) One part corresponds to the Real part (**Re**) of the Output,
2) Other one corresponds to the Imaginary (**Im**) part of output,
3) The last one corresponds to Absolute $(\sqrt{(\boldsymbol{Re^2 + Im^2})})$ of Complex Output of the Gaussian Gabor Filter.

After obtaining the required three forms of output, Energy magnitudes of these outputs are calculated. Energy magnitude of any output is nothing but square of that output.

In the proposed system, multi-bank Gabor filters having five different values for Spatial frequency (f = 0.0625, 0.125, 0.25, 0.5, 1.0) and seven different values for orientation θ = (0, 30, 60, 90,120, 150, 180) are chosen thus giving total of 35 combinations of Gabor filters. From the output of each Gabor filter Real, Imaginary and Absolute part of output are calculated and then for each part mean and standard deviation are computed, which serves as Gabor features. Thus for each character image we get a feature vector of dimensionality 210.

5.3 Gabor Features-GABN

This set of features is based on extracting features from real parts and imaginary parts of output of Gabor Filters. In this also the output of Gabor Features is divided into 2 parts, Real part and Imaginary part. For this set of features we don't process the outputs further as we did in earlier technique rather we use the outputs as it is, as our feature extracted. One thing to note is that whenever the Image is convolved with Gabor Filter the size of output is similar to size of input image we have taken. Since size of image being 32x32 the output of convolution is also 32x32 thus making the feature extracted with dimensionality of 1024. The processing time and storage increases proportionally with increase in dimensionality of feature vector. Since the size of feature is very high, the required processing time and storage can be reduced by the dimension reduction employing the principal component analysis (PCA transform). The principal component analysis is a typical dimension reduction procedure based on the orthonormal transformation which maximizes the total variances, and minimizes the mean square error due to the dimension reduction. It is shown that the dimensionality can be reduced to 1/5 without sacrificing the recognition accuracy. Thus by applying PCA we have reduced the dimensionality of feature vector from 1024 to 200.

For this set of features we have to determine the optimum combination of **θ & f** out of the above mentioned ranges of θ and f. Along with varying values of both θ & f we also need to determine right pair of values of (σ_x,σ_y) to obtain the most suitable result as feature extracted. For our approach $\boldsymbol{\sigma_x}$**=4,** $\boldsymbol{\sigma_y}$**=5**, **θ=pi/6, f=0.0625** serves as the optimum set of values.

VI. CLASSIFICATION

Support Vector Machines (SVM) classifier

Support vector machines (SVM) are a group of supervised learning methods that can be applied to classification or regression. The standard SVM classifier takes the set of input data and predicts to classify them in one of the only two distinct classes. SVM classifier is trained by a given set of training data and a model is prepared to classify test data based upon this model. For multiclass classification problem, we decompose multiclass problem into multiple binary class problems, and we design suitable combined multiple binary SVM classifiers. Our problem also needs to classify the characters into 35 different classes of Gurmukhi characters. We obtained such multiclass SVM classifier tool LIBSVM available at [25].

According to how all the samples can be classified in different classes with appropriate margin, different types of kernel in SVM classifier are used. Commonly used kernels are: *Linear kernel*, *Polynomial kernel*, Gaussian *Radial Basis Function* (RBF) and *Sigmoid* (*hyperbolic tangent*). The effectiveness of SVM depends on kernel used, kernel parameters and soft margin or penalty parameter C.

The common choice is RBF kernel, which has a single parameter *gamma* (g or γ). We also have selected RBF kernel for our experiment. Best combination of C and γ for optimal result is obtained by grid search by exponentially growing sequence of C and γ and each combination is cross validated and parameters in Combination giving highest cross validation accuracy is selected as optimal.

In *N*-fold cross validation we first divide the training set into N equal subsets. Then one subset is used to test by classifier trained by other remaining N-1 subsets. By cross validation each sample of train data is predicted and it gives the percentage of correctly recognized dataset.

VII. RESULTS AND ANALYSIS

5-fold Cross Validation

In our implementation we have used 5-fold cross validation. First we created randomly generated 5-fold cross-validation index of the length of size of dataset. This index contains equal proportions of the integers 1 through 5. These integers are used to define a partition of whole dataset into 5 disjoint subsets. We used one division for testing and remaining divisions for training. We did so 5 times, each time changing the testing dataset to different division and considering remaining divisions for training. Thus we got 5 sets of feature vectors containing training and testing dataset in the size ratio of 4:1.

The average recognition accuracy of these randomly generated 5 sets of training and testing is referred as cross validation accuracy. For selection of these parameters to obtain optimized results, first we used small sample of whole dataset and observed the parameters giving highest results. Later we refined this optimization by cross validation of whole dataset.
In SVM classifier, the results vary significantly on small values of C. These results are more sensitive to change with parameter g of RBF kernel comparative to C. At larger values of C results are stable and variation is negligible. Most of the results of SVM listed are observed at larger range of C tested upto 500, while the values of kernel parameter used varies from (0.01 to 2). As the value is increased beyond this range accuracy decreases gradually.

Table 2 depicts the optimized results obtained with different features set at optimized parameters.

Table 2: Parameters Used For Feature Set

Feature Set	Recognition Rate	Parameters
Gabor Feature GABM(210)	88.271%	C=512; γ = 4-32
Gabor Feature GABN(200)	94.29%	C=512; γ = 0.64-1.28

While observing the results at other values of parameter C, it is analysed that decreasing the value of C irrespective of any change in γ slightly decreases the recognition rate, but on increasing the value of C and after a certain increment normally after 64 i.e. at higher values of C the recognition rate becomes stable. In contrast, the recognition rate always changes with the change in γ.

Table 3 illustrates past work done in the recognition of Handwritten Gurmukhi Characters and comparison of our approach with all of them.

Table 3: Comparison of accuracy with different methods

S. No.	Method	Accuracy (%)
1	Puneet Jhajj et al. [17]	72.83
2	Ubeeka Jain et al. [18]	92.78
3	Anuj Sharma et al. [19]	90.08
4	Dharam Veer Sharma et al. [20]	92.6
5	Anuj Sharma et al. [22]	91.95
6	Our Approach	94.29

VIII. CONCLUSION

Thus we can conclude that we have obtained the maximum recognition rate as 94.29% by using GABN one of variant of Gabor Filter output as a Feature Extractor of dimensionality 200. The purpose of using Gabor Filters as mode of feature extractor is to promote its utility as major feature extraction technique in field of character recognition of Indian Scripts especially Gurmukhi. Very less literature is available on utilization of Gabor Filters for character Recognition.

The work can be extended to increase the results by using or adding some more relevant features along with Gabor features. We can determine optimum combinations of σ_x, σ_y, θ, f which would yield higher recognition accuracies**.** We can use some features specific to the mostly confusing characters, to increase the recognition rate. We can divide the entire character set to apply specific and relevant features differently. More advanced classifiers as MQDF or MIL can be used and multiple classifiers can be combined to get better results.

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