Offline Handwritten Gurmukhi Character Recognition using Particle Swarm Optimized Neural Network

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ABSTRACT
The offline handwritten character recognition is the frontier area of research from last few decades in pattern recognition. It is difficult to recognize handwritten characters as compared to printed characters because of the varying writing styles of individuals. The massive work has been done in languages like Devnagri and Chinese character recognition. The area of Gurmukhi character recognition is even though not new but the problem lies when it comes to look alike and unique characters where the system lacks. In this proposed work, 35 different character samples are used for recognition. The samples have been taken on a plain paper in an isolated manner. After the pre-processing of particular character feature extraction technique is applied. The technique used for feature extraction is Gabor filter. Then ANN is applied for character recognition and if ANN fails to recognize, then character is recognized with the help of PSONN. This improves the overall efficiency of the character recognition system. By training the classifier with whole dataset we obtained 100% accuracy for the given samples.

Keywords
Optical character recognition, Particle swarm optimization, Handwriting recognition, Gurmukhi characters, Artificial Neural Network, Handwritten Character Recognition.

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1. INTRODUCTION
Handwritten character recognition, abbreviated as HCR has been studied from the last forty years. This problem is quit complex because of unique writing styles of individuals. Many approaches have been proposed for handwritten character recognition (HCR) but there is no single approach which can solve it both completely and efficiently [1]. HCR is the process of converting handwritten text into computer operateable format [2].HCR is the field of research in pattern recognition and is categorized as online and offline character recognition. In online character recognition, the data is captured during the writing process. The samples are taken on digital tablets which are then converted into a series of electronic signal according to the movement of pen. On the other hand, in offline character recognition data is captured after the writing process is finished. The HCR consist of steps namely, Digitization, Pre-processing, Feature extraction and Classification. The offline handwritten character recognition is more difficult than online handwritten character recognition because stroke information is not available [2]. HCR is used in wide verity of areas like engineering, business, commercial applications, banking and medical etc. [3]. The most of the work has been already done in the field of printed character recognition but the HCR area is still new and complicated [2]. The languages on which massive work has been done are Devnagri and Chinese character recognition. So one thing which need to pursue is to improve the recognition quality or we can say efficiency of recognition and apply this concept on various other scripts around the world.

Gurmukhi script is primarily used to write Punjabi language. This is the 14th most widely spoken languages in the world. Gurmukhi consist of 35 basic characters in which there are 3 vowel bearers and 32 consonants. In addition to this, Gurmukhi script includes 6 additional consonants, 9 vowel modifiers and three half characters. The 35 basic Gurmukhi characters are mentioned below in Table 1 showing basic 35 characters.

Table 1: Gurmukhi Characters

Vowel Bearers				
ੳ	ਅ		ੲ	
Consonants				
			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 Consonants				
ਸ਼	ਖ਼	ਗ਼	ਜ਼	.ਫ਼	ਲ਼

The writing style of Gurmukhi is from left to right and top to bottom. There is no case sensitivity in this script. This work is an attempt towards the development of the system that could recognize handwritten Gurmukhi characters.

This paper is organized as follows: Section 2 covers the literature review, section 3 covers the proposed work and Section 4 covers results and discussion followed by the conclusion in section 5.

2. LITERATURE REVIEW

The recognition of handwritten Gurmukhi character is most challenging because of the different writing styles of the users, different shapes of characters, look alike characters and different size and writing style. Some writers use cursive writing which also makes the system more complicated [4]. The presence of background noise and low quality of the characters also put the challenge in recognition. Many researchers have worked on HCR with different scripts like Devnagri, Chinese, Arabic and also on Gurmukhi [1-3]. A brief survey of research work on various scripts is presented below:

Kumar et al. developed a model on Gurmukhi script based on Hidden Markov model and Bayesain decision making classifier. They extracted zonal, diagonal and directional features [2].

Garg and Verma [4] in their manuscript proposed a system which can work like biological human neural network.The features of particular character were extracted and for handwritten Gurmukhi character recognition each character was stored as 32*32 matrix size. After classification the different efficiency for different characters has been achieved.

Singh and Budhiraja [5] proposed a system on numeral recognition. They used wavelet transform for feature extraction and classification was done with back propagation neural network. The accuracy achieved was 88.83% .

Lehal and Singh [6] developed a system for recognition of machine printed Gurumukhi words. The segmentation breaks the word into sub-characters and recognition phase classifying these sub characters and combining them to form Gurumukhi characters. A set of very simple and easy to computer features is used and a hybrid classification scheme consisting of binary decision trees and nearest neighbors is employed.

Sahu and Kubde [7] have proposed an OCR system for handwritten English characters in capital and small case. The feature extraction methods used are Zoning, characteristic loci, crossing and feature and structural features. For classification, template matching statistical purpose and neural network is used.

Siddharth et al. [4] proposed a model for handwritten character recognition and applied it on 200 samples from different writers. The K-nearest neighbor, Support vector machine and Probalistic neural network are used as classifier.

Abed [8] presented an overview on handwritten character recognition system using diagonal feature extraction and particle swarm optimization as a classifier.

From above discussion it is clear that feature extraction and classification both are important equally to produce a good system. Due to involvement of these steps no method can be quoted as best method as some researchers emphasize on feature extraction and some on classification.

3. PROPOSED MODEL

As already discussed that the main problems in recognition of handwritten Gurmukhi characters are the different writing styles of the user and resemblance of one character with other characters of Gurmukhi script. In addition, character recognition process involves various steps like image acquisition, pre-processing, feature extraction and classification. The Artificial Neural Network (ANN) gives good results in local optimization but it terminates pre-maturely when it comes to global optimization, Particle Swarm Optimization (PSO) technique is good in global optimization. To produce a good optimistic system and to solve the above mentioned problems Gabor filter is used for feature extraction and ANN and PSO techniques are combined to develop an algorithm which will be good in local as well as in global optimization. The proposed recognition system involves steps namely, Digitization of input samples, Feature extraction, Training of NN, Development of PSONN algorithm and testing of data. The flow diagram of above mentioned steps is as shown in figure 1.

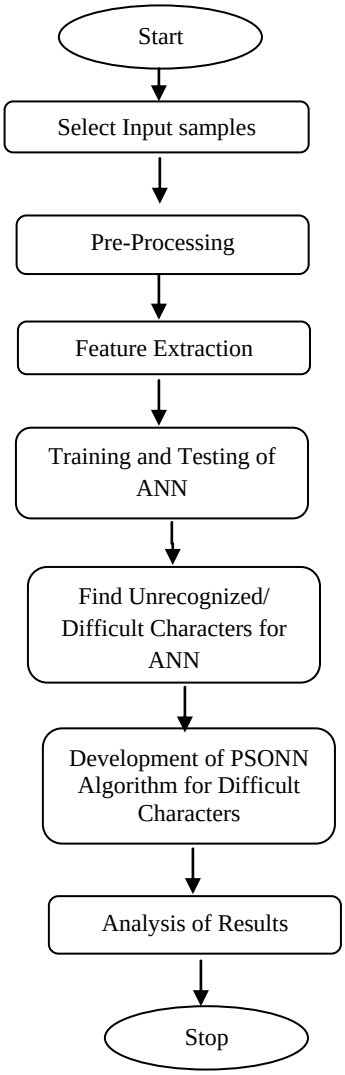

Figure 1: Flow diagram of proposed offline HCR system

3.1 Selection of input samples

In this proposed work, the input samples are taken on plain paper in an isolated manner. The samples are then converted to a digital form with the help of camera. The digitization is a process of converting handwritten document into electronic form that electronic representation of the original document is then fed to the pre-processing phase. From the data set the desired character is cropped and preprocessed.Figure 2 is showing the data set for character recognition.

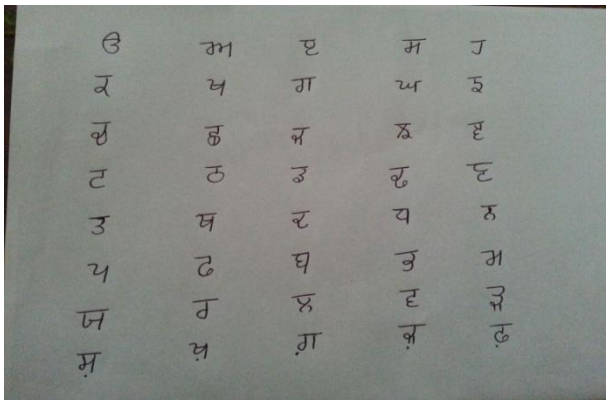

Figure 2: Data Set for Character Recognition

3.2 Pre-Processing

The digital form of input fed to the pre-processing block may contain some noise which should to be removed in this phase. In pre-processing, the cropped RGB (red green blue) image is converted into binary form and then cropped to the edges to remove the white area around the character. After that the image is resized to the size 5*7 to avoid the minor holes and noise. The resulting noise free image is then used for feature extraction.

3.3 Feature Extraction

The feature extraction step is used to extract the useful features from the character which will be able to represent the character back. The aim of feature extraction is to describe the pattern by mean of minimum number of features that are efficient to describe pattern classes. The extracted features should be able to classify each character uniquely. During recognition the extracted features of particular character are matched with the previously stored features to produce the output. Feature extraction is the integral part of any recognition system. The Gabor filter is used in this proposed work because it works well on edges and is less sensitive to noise. The modulation of Harmonic function by Gaussian distribution defines the Gabor filter. Gabor filters are used for various applications like texture segmentation and classification, texture analysis and edge detection. The features extracted from Gabor filter have been successfully applied to many pattern recognition applications for example finger print recognition, IRIS pattern recognition and face recognition [11]. It is interesting to know that the Gabor features are not popular in the field of OCR system. Gabor features are easy to understand and features produced by Gabor filter are less sensitive to noise.

The Gabor filter impulse response is defined by harmonic function multiplied by Gaussian function.

$$h(x,y) = g(x,y)\, s(x,y) \qquad (1)$$

Where g (x,y) = Gaussian shape function.

s (x,y) = complex sinusoidal function.

The Gabor filters are self-similar that means they are generated from one mother by little dilation and rotation [10].Gabor filters are used for face recognition as feature generator. In the spatial domain, a two dimensional Gabor filter is a Gaussian kernel function modulated by a complex sinusoidal plane wave, defined as:[11]

$$G(x,y) = \frac{f2}{\pi\gamma\eta} \exp\left[\frac{-x'2 + \gamma 2\, y'2}{2\,\sigma 2}\right] \exp(j2\pi f\, x' + \Phi) \qquad (2)$$

$$x' = x\cos\theta + y\sin\theta \qquad (3)$$

$$y' = -x\sin\theta + y\cos\theta \qquad (4)$$

Where f is the frequency of the sinusoidal factor, θ represents the angle, Φ is the phase offset, σ is the standard deviation and γ is the spatial aspect ratio. Figure 3 is showing the magnitudes of Gabor function for 5 different scales and 8 different orientations and Figure 4 is showing the real parts of Gabor function.

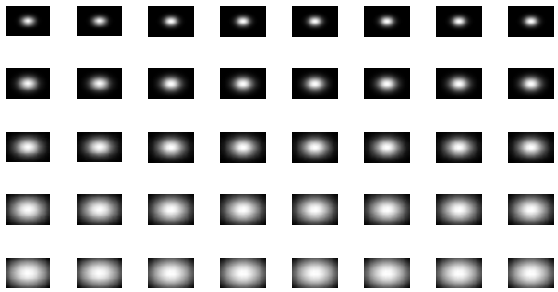

Figure3: Magnitude of Gabor filter bank

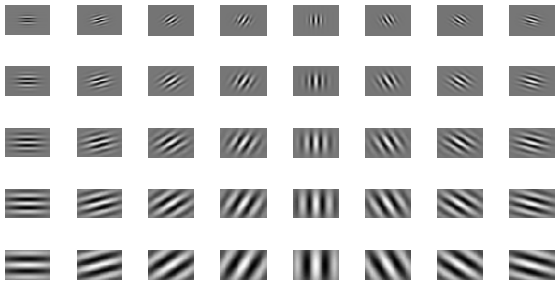

Figure4: Real Part of Gabor filter bank

3.4 Training and Testing of ANN

To work with ANN, it should be trained with appropriate data set which is generated with the extraction of features from standard Gurmukhi characters with Gabor filter. The ANN used is loaded with the possible trial inputs. Once the ANN is trained it is ready to test on the input samples. In proposed work, the data base used is generated from standard Gurmukhi characters. This phase is the decision making phase for ANN. Once the training of ANN is done it is tested for the given samples. ANN recognizes most of the Gurmukhi character but it fails to recognize some look alike characters. Where ANN fails the PSONN algorithm is used there to improve the efficiency of the system.

3.5 Find Unrecognized/ Difficult Characters for ANN

The algorithm is applied on all the basic 35 characters and it is observed that ANN fails to recognize some difficult characters. The Characters which resembles with other characters and are having complicated shape produced some error. For example, ਲ, ਹ and ਝ etc.

3.6 Development of PSONN for Difficult Characters

The PSONN is the combination of two algorithms PSO and ANN. PSO algorithm is a global optimization algorithm like genetic algorithm, however it is weak in local optimization [1]. On the other hand artificial ANN is good enough in producing local optimistic results but ANN is weak in global optimization. By combining PSO and ANN a good system can be produced which is good in local optimization as well as in global optimization. After the training of ANN with PSO the PSONN algorithm is developed which uses the same data set as used in ANN.

Following is the step by step procedure of PSONN algorithm:

Step 1: Initialize the positions (weights and biases) and velocities of group of particles randomly.

Step 2: PSONN is trained using the initial particle positions.

Step 3: The learning error produced by ANN is treated as particle fitness value according to initial weight and bias.

Step 4: The learning error at current epoch can be reduced by changing the particle position which will update the weights and biases bias of the network.

Step 5: The new set of positions (ANN weight and bias) are produced by adding the calculated velocity value to the current position value with movement equation (eq. 5) of PSO. The new sets of values are used to produce new learning error in ANN.

$$V_{id}(t+1) = W\Delta V_i(t) + C_1R_1(P_{id}(t) - X_{id}(t)) + C_1R_1(P_{id}(t) - X_{id}(t)) \quad (5)$$

$$Xid(t+1) = Xid(t) + Vid(t+1) \quad (6)$$

Where

Vid= Velocity of particle I along dimension d

Xid= Position of particle I in dimension d

c1, c2= Weighing factors

W= Inertia weight

R1, R2= Random numbers in range of 0 to 1

Step 6: This process is repeated till the mean square error (MSE) is reduced or maximum numbers of iterations are met.

Step 7: The optimization process terminates and the final positions are used as weights.

These steps are represented in the form of flow diagram as shown in the figure 5.

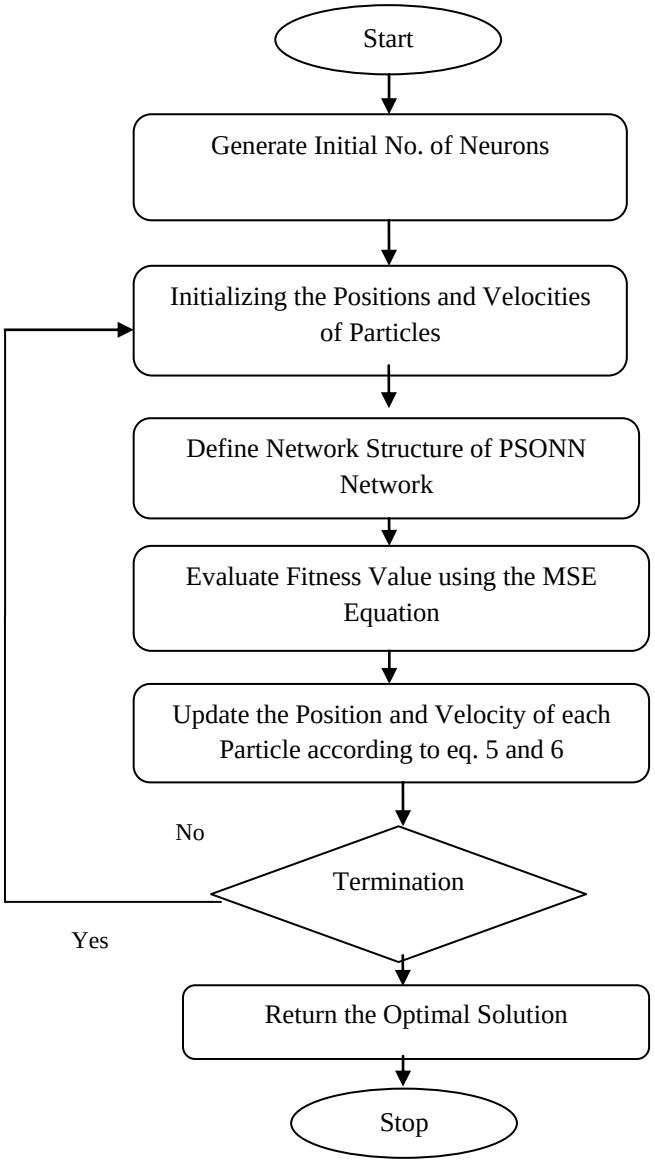

Figure 5: Flowchart for Hybrid PSONN Algorithm

3.7 Testing of Data

Testing phase is the decision making phase. The input samples are tested to produce the desired output. In the proposed work input sample's features are first tested using ANN if the ANN is unable to generate the output then PSONN is used to give correct output. This makes the system highly efficient. The input image can be of any size. Figure 6 is showing the designed graphical user interface (GUI) which makes this system easy to access. The GUI is showing various push buttons to perform different functions.

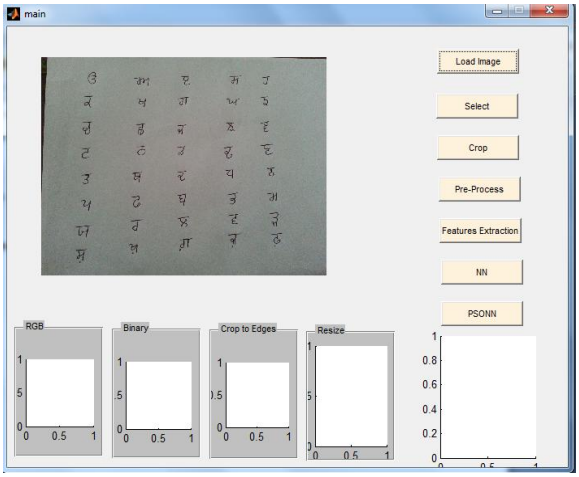

Figure 6: Screen shot of uploaded sample image on GUI

4 RESULTS AND DISCUSSION

To examine the functioning of proposed system, the program is executed a number of times. The inputs are given as Gurmukhi characters in handwritten form on a plain paper. That handwritten document is converted into digital form with the help of camera. The test data is stored in the form of images. This algorithm is applied on 35 characters of Gurmukhi script. For test samples also, the feature vector is generated and then the classification of given sample is done using this feature vector.

First the recognition is done using only the ANN system and results of the recognition are shown in Table 2. As it is clear from Table 2, ANN sometimes lacks to recognize some characters which resemble with some other characters. In case of ANN failure, PSONN is used and gives good results and recognize all characters correctly.

Table 2: Results of ANN

Character	No. of Trails	Misclassification	Accuracy
ਉ	25	0	100%
ਅ	25	0	100%
ਏ	25	0	100%
ਸ	25	2	92%
ਹ	25	24	4%
ਕ	25	0	100%
ਖ	25	1	96%
ਗ	25	0	100%
ਘ	25	0	100%
ਝ	25	0	100%
ਚ	25	0	100%
ਛ	25	0	100%
ਜ	25	0	100%
ਝ	25	24	4%
ਞ	25	0	100%
ਟ	25	0	100%
ਠ	25	0	100%
ਡ	25	0	100%
ਢ	25	0	100%
ਣ	25	2	92%
ਤ	25	2	92%
ਥ	25	0	96%
ਦ	25	0	100%
ਧ	25	0	100%
ਨ	25	1	98%
ਪ	25	0	100%
ਫ	25	0	100%
ਬ	25	0	100%
ਭ	25	1	96%
ਮ	25	0	100%
ਯ	25	0	100%
ਰ	25	24	4%
ਲ	25	25	0%
ਵ	25	0	100%
ੜ	25	0	100%
		Average	87.8%

Table 3: Results of PSONN

Character	No. of trails	Accuracy
ਉ	25	100%
ਅ	25	100%
ਏ	25	100%
ਸ	25	100%
ਹ	25	100%
ਕ	25	100%
ਖ	25	100%
ਗ	25	100%
ਘ	25	100%
ਝ	25	100%
ਚ	25	100%
ਛ	25	100%
ਜ	25	100%
ਝ	25	100%
ਞ	25	100%
ਟ	25	100%
ਠ	25	100%
ਡ	25	100%
ਢ	25	100%
ਣ	25	100%

ਤ	25	100%
ਥ	25	100%
ਦ	25	100%
ਧ	25	100%
ਨ	25	100%
ਪ	25	100%
ਫ	25	100%
ਬ	25	100%
ਭ	25	100%
ਮ	25	100%
ਯ	25	100%
ਰ	25	100%
ਲ	25	100%
ਵ	25	100%
ੜ	25	100%

The comparison of different approaches with different classifiers is mentioned in Table 4 and it has been observed that the ANN system accuracy is less as compared to earlier published results but proposed PSONN algorithm has 100% accuracy and hence superior performance.

Table 4: Comparison of Different Approaches

S. No.	Reference Paper	Feature Extraction	Classifier	Recognition Accuracy
1	Sharma et al. (2009)	Loop crossing, Straight & Headline, Curliness	Elastic Matching	81.02
2	Kumar et al. (2011)	Diagonal and Transition	KNN	94.12%
3	Singh et al. (2011)	Zone & Background Directional Distribution	SVM	95.04%
4	Singh et al. (2012)	Wavelet	Back Propagation NN	90.40%
5	Singh et al. (2012)	Gabor Filter	SVM	94.29%
6	Rekha (2012)	Zonal	kNN	95.02%
7	Sinha et al. (2012)	Zone based	SVM	95.11%
8	Abed et al. (2013)	Diagonal Zonal Feature Extraction	PSO	93.39%
9	Proposed Approach	Gabor Filter	ANN	87.84%
			PSONN	100%

5 CONCLUSION

The main focus of this work is on improving the recognition rate of handwritten Gurmukhi character. In this work, ANN and PSONN techniques are used to recognize the handwritten Gurmukhi characters. The pre-processing is done over the scanned input image which is digitized with the help of camera after that preprocessing of scanned image is done. The Gabor filter bank is applied for feature extraction and the feature vector produced is used to design the ANN but, the appropriate recognition of some characters cannot be achieved by ANN because of their similar shapes, so PSO trained ANN is proposed.It has been observed that PSONN read all characters correctly. A GUI (Graphical user interface) is constructed to make the designed system more users friendly. The proposed work recognizes each Gurmukhi character which has been loaded and whose target feature vector was created in ANN. The training of ANN Could be based on more than one sample of handwriting which would definitely improve results. The additional characters were not included in the proposed work so one can also involve the vowels and Gurmukhi numerals. The writing style can also reflects the mood of writer so work can also be done towards this side.

6 REFERENCES

[1] S. Lagudu, C. V. sarma (2013) "Handwriting Recognition using Handwriting PSO and BP", IJAIEM, vol. 2, No. 1, pp. 75-81

[2] M. kumar,M. K. Jindal and R.K. Sharma (2011)"Classifications of Characters and Grading Writers in Offline Handwritten Gurmukhi Script", IEEE International Conference on Image Information Processing, pp. 1-4.

[3] K.S. Siddharth, M. Jangid, R. Dhir, and R. Rani (2011) "Handwritten Gurmukhi Character Recognition Using Statistical and Background Directional Distribution Features", International Journal of Computational Science and Engineering, vol. 6, No. 3, pp. 2332-2345.

[4] N. Gargand K. Verma (2009) "Handwritten Gurmukhi Character Recognition Using Neural Network", M.Tech. Thesis, Thapar University.

[5] P. Singh, S. Budhiraja (2012) "Offline Handwritten Gurmukhi Numeral Recognition using WaveletTransforms", IJMECS, No.8,pp. 34-39.

[6] G.S lehal, C. singh (2000)"A Gurmukhi Script Recognition System", Proceeding of IEEE International Conference, vol.2, pp. 557-560.

[7] V. L. Sahu, B. Kubde(2011) "Offline Handwritten Character Recognition Techniques using Neural Network: A Review" IJSR, No. 2, pp 87-94.

[8] M. A. Abed (2013)"Simplifying Handwritten Character Recognition using PSO", European academic research,No. 1.

[9] U. pal, B.B Chaudhary, (2004) "Indian script character recognition: A survey", Pattern recognition society.

[10] S. Singh, A. Aggarwal and R. Dhir, (2012) "Use of Gabor Filters for Recognition of Handwritten Gurmukhi Character" International Journal of Advanced Research in Computer Science and Software Engineering, No.2, pp. 234-240.

[11] B. S. Bargavi and C. Santhi, (2014) "Global and Local Facial Extraction using Gabor Filter" ", International Journal of Advanced Research in Computer Science and Software Engineering, vol. 4, No4, pp 29-34.

[12] R. Kumar, R.K Sharma(2009) " Rearrangements of Recognized Stocks in Online Handwritten Gurmukhi Words Recognition", IEEE International Conference on Digital Object Identifiers, pp. 1241-1245.

[13] K. S. Siddharth, M. Jangid, R. Dhir and R. Rani (2011) "Handwritten Gurmukhi Character Recognition Using Statistical and Background Directional Distribution Features" International Journal of Computational Science and Engineering, 3, No. 6, pp. 2332-2345.

[14] M. Kumar, M. K. Jindal, and R. K. Sharma(2013) "PCA-based Offline Handwritten Character Recognition System" Smart Computing Review, vol. 3,No. 5,

[15] V.J Dungre and Mankar V. H.(2010) "A review of Research on Devnagri Character Recognition", International Journal of Computer Applications, No.12.

[16] Sinha, G., Rani, A., Dhir, R. and Rani, R. (2012) "Zone Based Feature Extraction Techniques and SVM for Handwritten Gurmukhi Character Recognition", International Journal of Advanced Research in Computer Science and Software Engineering, vol. 2, No.6, pp. 106-111.

[17] Sharma, D. and Jhajj, P. (2010) "Recognition of Isolated Handwritten Characters in Gurmukhi Script", International Journal of Computer Applications, vol. 4, No. 8, pp. 9-17.

[18] Plamondon, R. and Srihari, S. N. (2000) "Online and Offline Handwritten Character Recognition: A Comprehensive Survey", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 22, No. 1, pp. 63-84.

[19] Patel, D. K., Som, T., Yadav, S.K., and Singh, M. K. (2012) "Handwritten Character Recognition Using Multiresolution Technique and Euclidean Distance Metric", Journal of Signal and Information Processing, vol. 3, pp. 208-214