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Bangla Hand Written Character Recognition Using Support Vector Machine

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***Abstract*—**Recognizing handwritten character using computer is still consider a strong area of research. A fundamental problem in the field of Bangla character recognition is the lack of availability of Bangla handwritten character data set. In this thesis our main objective is to generate a larger dataset of Bangla character and as well as improving the recognition rate using Support Vector Machine. Support Vector Machines (SVM) is used for classification in pattern recognition widely. In our proposed method we applied support vector machine for increasing the recognition rate. A scanner is used to capture handwritten data sheet written in white paper by various people. After that several approaches used to generate the final data set for training and testing in SVM. A cropped image is scaled into 16*16 pixel matrix and then combing large number of image a dataset is produced. A binary classification technique of Support Vector Machine is implemented and rbf kernel function is used in SVM. This rbf SVM produces 93.43% overall recognition rate which is satisfactory result among all techniques applied on handwritten Bangla handwritten character recognition system.

***Keywords*—** Handwritten character recognition, Support vector machine, LibSVM,rbf,Bangla, Pattern recognition, Pattern Recognition, Supervised Learning.

I. INTRODUCTION

Recognition of characters is an important area in machine learning. Due to the wide acceptance of digital system, now a day's handwritten character recognition becomes more important [1]. However in numerous situations, a pen together with a paper or a small notepad is much more convenient than a keyboard.

With the rapid growth and advancement of the use of computers in Bangladesh, the use of our mother tongue Bangla in computers is being much talked about and much research is being done [2]. As we find in many cases, the problem of input of Bangla characters to computer is time consuming and error prone. Another major problem is that, the Bangla has no rich database for further research. For this reason it is very difficult to develop a system for recognition of Bangla handwritten character.one solution to the problem would be the development of a rich dataset for Bangla and a practical Bangla

Character recognition method towards which the efforts of this thesis is directed. In our thesis we try to demonstrate a process for recognizing offline handwritten Bengali characters using support vector machine (SVM) with more accuracy rate than any other method [3]. Due to different shapes of handwritten of different person it is very tough to gain good accuracy rate form recognition. But if we can make a rich dataset then it is possible to further increase the recognition rate.

Support Vector Machines (SVM) is used for classification in pattern recognition widely. Support Vector Machine (SVM) was first heard in 1992, introduced by Boser, Guyon, and Vapnik in COLT-92 [4]. Our research aims to investigate the usage of support vector machines (SVM) to maximize the recognition rate for Bangla handwritten character.

SVM has been used in recent years as an alternative to popular methods such as neural network. And the higher recognition rate also has been proved for various types of character and shape recognition.

Techincal Terms

The following are the technical terms that we have used.

A. Character Data Set

Generally a collection of related sets information that is composed of separate elements but can be manipulated as a unit by a computer. A dataset (or dataset) is a collection of data, usually presented in tabular form. Each column represents a particular variable. Each row corresponds to a given member of the data set in question. It lists values for each of the variables, such as height and weight of an object. Each value is known as a datum. The data set may comprise data for one or more members, corresponding to the number of rows.

B. Support Vector Machine

A support vector machine (SVM) is a concept in statistics and computer science for a set of related supervised learning methods that analyze data and recognize patterns, used for classification and regression analysis [6], [7]. The standard SVM takes a set of input data and predicts, for each given input, which of two possible classes forms the input, making the SVM a non-probabilistic binary linear classifier. Given a set of training examples, each marked as belonging to one of two categories, an SVM training algorithm builds a model that assigns new examples into one category or the other. An SVM model is a representation of the examples as points in space, mapped so that the examples of the separate categories are divided by a clear gap that is as wide as possible. New examples are then mapped into that same space and predicted to belong to a category based on which side of the gap they fall on.

More formally we can say that, a support vector machine constructs a hyper plane or set of hyper planes in a high- or

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infinite-dimensional space, which can be used for classification, regression, or other tasks. Intuitively, a good separation is achieved by the hyper plane that has the largest distance to the nearest training data point of any class (so-called functional margin), since in general the larger the margin the lower the generalization error of the classifier.

C. SLT and the Optimal Decision Hyper Plane

Recently Support Vector Machine has been used successfully for pattern recognition and regression tasks .It was mainly designed for binary classification, in order to construct an optimal hyper-plane, to maximize the margin of separation between the negative and positive data set [7]. Although, SVM is used for two class pattern classification problem but multi-class problem can also be solved by extend the binary classification to multi class classification. For the Support Vector Machine classifier, an open source software LibSVM tool is used [8]. In general, a classification task usually involves with training and testing data which consist of some data instances. Each instance in the training set contains one "target value" (class labels) and several "attributes" (features). The goal of SVM is to produce a model which predicts target value of data instances in the testing set which are given only the attributes. Before considering the data directly from the linearly scaling each attribute to the range [-1, +1] or [0, 1].

In statistical learning theory (SLT), the problem of classification in supervised learning is formulated as follows:

We are given a set of l training data and its class, {(x_1, y_1)...(x_l, y_l)} in R_(n´) ,R sampled according to unknown joint probability distribution P(x,y) characterizing how the classes are spread in R_(n´) R. To measure the performance of the classifier, a loss function L(y, f(x)) is defined as follows:

$$L(y, f(x)) = \begin{cases} 1, & \text{if } y = f(x) \\ 0, & \text{if } y \neq f(x) \end{cases}$$

L(y, f(x)) is zero if f classifies x correctly, one otherwise. On average, performance can be described by the Risk functional:

$$R(f) = \int L(y, f(x))\, dp(x, y).$$

SVM is realized from the above SLT framework. The simplest formulation of SVM is linear, where the decision hyper plane lies in the space of the input data x [7].

In this case the hypothesis space is a subset of all hyper planes of the form:

$$f(x) = w \times x + b.$$

SVM finds an optimal hyper plane as the solution to the learning problem which is geometrically the furthest from both classes since that will generalize best for future unseen data. There are two ways of finding the optimal decision hyper plane. The first is by finding a plane that bisects the two closest points of the two convex hulls defined by the set of points of each class. The second is by maximizing the margin between two supporting planes. Both methods will produce the same optimal decision plane and the same set of points.

Using the kernel in input space is equivalent to performing the map into feature space and applying dot product in that space. Many kernels can be used in that way as long as they satisfy Mercer's condition. Commonly used kernels are:

- Linear kernel
- Polynomial kernels
- Radial basis function (Gaussian kernel)
- Hyperbolic tangent kernel
- We have used the Gaussian Kernel.

D. Feature

The Feature of an object is the unique attributes which represents the object entirely .The performance of recognition system greatly depends on features that are being extracted.

II. BASIC PHASES OF CHARACTER RECOGNITION

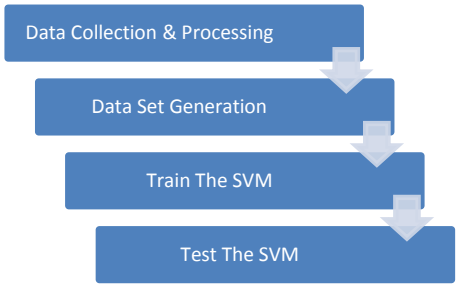

Figure1. Basic phases of character recognition

A. Data Collection & Processing

A.1. Sample Collection

We collect the sample from different group of people. Then scan those characters from white page. It was the very important and time consuming part of our work. Then we crop each character and resize it in 16*16 pixels. The 16*16 resized images we saved in different folder for same character we saved the image in same folder. Details Process is shown in diagram below.

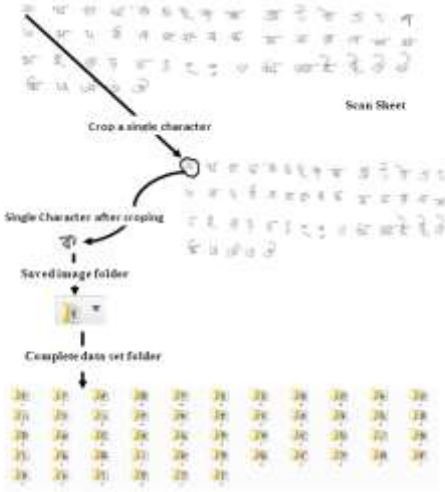

Figure 2.Data Set Organization in File System

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A.2 Data Processing

The basic system architecture of our system is given bellow.

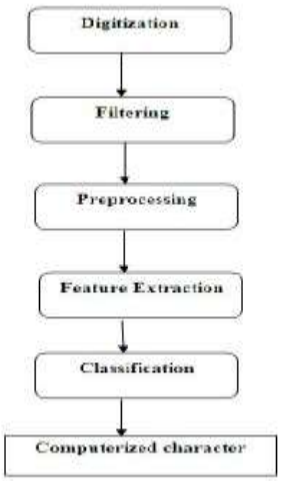

Figure 3.Basic System Architecture

B. Digitization

Each image then is converted into RGB color model and then we got the three channel (red, green and blue) value for each pixel and the image. A gray scale image is shown in the figure bellow. This is the gray level value for Bangla Ka. Digitization also including the handwritten paper copy to be scanned into computerized format. In this step we have scanned the paper and follow some processing to make the final dataset from it. This process is already showed in our proposed method section.

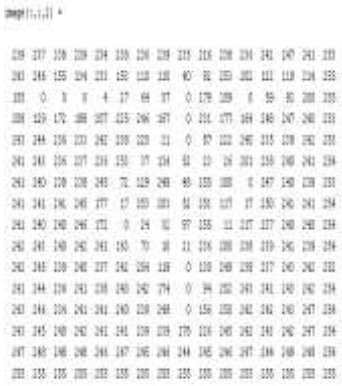

Figure 4.Gray Scale Image

Digitization is the process of converting the paper based handwritten document into electronic form. The electronic conversion is accomplished using a process whereby a document is scanned and an electronic representation of the original document, in the form of a bitmap image, is produced. Digitization produces the digital image, which is fed to the pre-processing phase.

C. Preprocessing

Preprocessing is a series of operations performed on the digital image. Preprocessing is the initial stage of character recognition. In this phase, the character image is normalized into a window ofsize 16×16. After normalization, we produce bitmap image of normalized image. Now, the bitmap image is transformed into a contour image.

D. Filtering

On the time of digitization process, we collect the image and scan it to get the image inside our computer. On the time of scan for different reasons many noise can added with the original image. Now we provide some ways filtering.

E. Noise Removing

Written character may be some connected component, so we have to apply connected components based analysis to remove unwanted objects in the image. Connected components are the rectangular boxes bounding together with connected black pixels. The algorithm used to obtain the connected components is a simple iterative procedure which compares successive vertical scan of an image to determine whether black pixels in any pair of vertical lines are connected together. Bounding rectangles are extended to enclose any groupings of connected black pixels between successive lines.

Ith vertical line and bounding boxes (b) I+1th Vertical line and bounding boxes Figure 5. Connected component analysis process after calculating the bounding boxes in each connected.

Component measure the width and the volume of bounding boxes. If the volume of the bounding box is less than or equal to 5% of the image volume (i.e. image height multiplied by image width) it is assumed as noise object in the image, and removed. If the bounding box width is greater than 25% of the image width, this bounding box is assumed as underline or any other Straight line in the image.

F. Noise Removal and Binarization

From separated 3 channel image we removed the noise and converted it as binary image

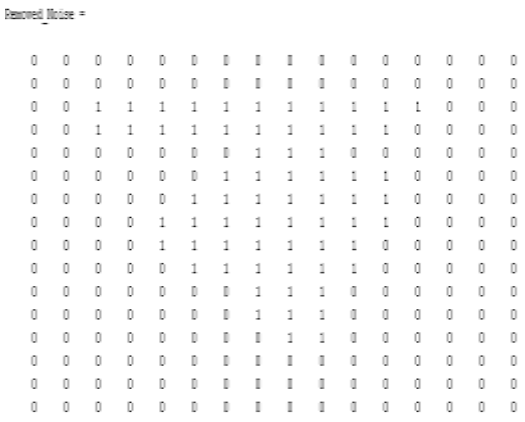

Figure 5.Binary matrix of binary image after noise removal

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Figure 6.Image after noise removal.

G. Skew Detection and Correction

This section describes the skew detection algorithm and the robustness skew correction algorithm. Firstly, the Bengali word image is divided into vertical groups; the width of each group is sixteen pixels. Then the algorithm starts to search black pixel from bottom to top of the image using kernel 16 x 1. If the kernel meets the black pixel it stops moving and then identify at which height the black pixel is found. To further the process set the coordinates (X, Y) in the founded black pixel using equation 1. This process will be continued to other vertical groups in the image as well.

H. Feature Extraction

The feature extraction stage analyzes a handwritten character image and selects a set of features that can be used for uniquely classifying the character. In this phase, the features of input characters are extracted. The performance of recognition system greatly depends on features that are being extracted.

I. Dataset Generation Process

i. At first we collect Bangla hand written Character from different people of different occupation and age to increase the efficiency. Then we scan those characters in jpg format. Then we cut all the character by using photo editing software and resize each character in 16X16.

ii. Convert it in gray scale image

iii. After converting in gray scale image we got the matrix of image. Matrix is usually two dimensional arrays. We separate the row column and then make a single one dimensional array by combining each row one by one. This one dimensional array we set as a single row of a big two dimensional array and at the end of the row we set an identifier by which we can identify which character that is. The following algorithm is used for dataset generation.

Algorithm:

Input: Handwritten character images.

Output: Isolated digit for feature extraction.

Method: Generate Dataset

d=1

for i=1:16

for j=1:16

DataSet(nimage,d)=image(i,j) // DataSet is a big array and nimage is the index of image.

d=d+1;

end

end

Return dataset of n images for feature extraction.

In a single dataset there are four array .First two array(X & Y) for Training the machine. Another two array (tstX&tstY) for testing the recognition rate. For a particular dataset we have put different number of sample for different types of character. We have made lots of different dataset for our experiment. And after that we have also made dataset for neural network. For comparison we have mainly used neural network. So we have also made dataset which is compatible in neural network. Then we use the SVM's datasets for train and test in SVM and the neural networks dataset for train and test in neural network. Then we have put them together to compare with each other and we have found that our proposed method using SVM is better than Neural Network.

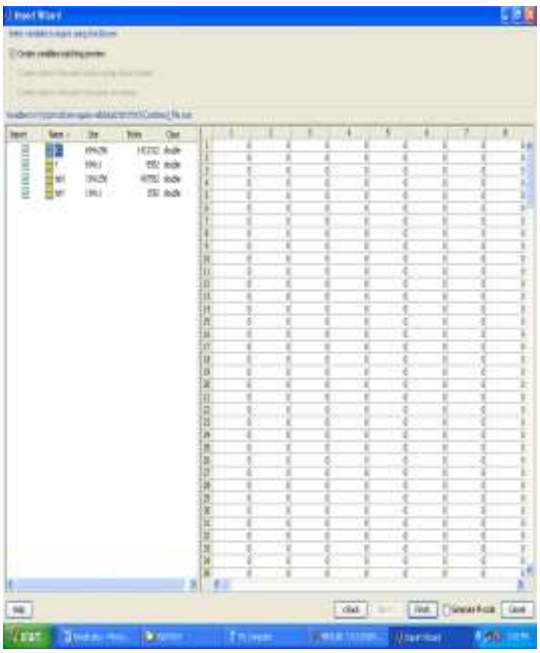

Figure 7.Final Dataset (here X & testX is the data &Y and testY is classifier type of the data)

J. Train Data Set

In a dataset there are two arrays. One is X array which save the two dimensional array into a row of the X array. Another array is Y array which save the identifier of a single row of X array.

We generate two train dataset .One is similar type character dataset here we store Kha and Gha. Kha and Gha are similar with respect to the writer so there are often arise difficulties to recognize which character this is.

There are 700 sample data where Kha is 350 images and Gha is 350 images.

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Another is totally different type of character example ka and ga. There are 700 sample data where Ka is 350 images and Ga is 350 images.

So for training set 1 we arrange 700 samples.

For training set 2 we arrange 700 samples.

Those dataset are used for train the machine.

K. Test Dataset

This dataset is quite similar to training dataset. In a dataset there are two arrays. One is X array which save the two dimensional array into a row of the X array. Another array is Y array whichsave the identifier of a single row of X array.We generate 4 Test dataset .One is similar type character dataset here we store Kha and Gha. Kha and Gha are similar with respect to the writer so there are often arise difficulties to recognize which character is this.

200 sample Test dataset.

400 sample Test dataset.

Another two dataset are totally different type of character example ka and ga.

200 sample Test dataset.

400 sample Test dataset.

Those test dataset are used for testing the success rate to recognition the character.

III. CHARACTER RECOGNITION PROCESS

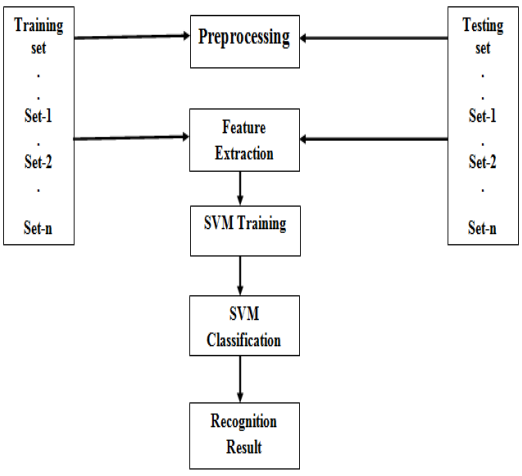

Figure 8.Propossed Architecture

A. A. Support Vector Machine Technique

The concept of support vector machine algorithm was first introduced in 1999 by Vapnik, which is an algorithm to describe special optimization problems and solve quadratic programming to find an optimal hyper plane of maximum separation two types of problems [21]

Given training set

$$T - \{(x_{\mathbf{i}}, y_{\mathbf{i}})\}_{i=1}^{n}$$

Among

$$x_{\mathbf{i}} \epsilon R, y_{\mathbf{i}} \epsilon \{-1,1\}$$

Where support vector machine will find the weight vector w and bias b answered for the following formula:

$$f(x) = \begin{cases} (w.x_{\mathbf{i}}) + b \geq +1, & y_{\mathbf{i}} = +1 \\ (w.x_{\mathbf{i}}) + b \geq -1, & y_{\mathbf{i}} = -1 \end{cases}$$

And the corresponding formula for linear hyper plane is

$$(w.x_{\mathbf{i}}) + b = 0$$

At this point the distance between the two hyper planes:

$$\max_{w,b} \frac{2}{||w||}, s.t. y_{\mathbf{i}}\big((x_{\mathbf{i}}.w) + b\big) \geq 1 \;\; i = 1,2,\dots,n$$

This is obviously a convex quadratic programming problem, and calculates the solution w^*, b^*.

Build separating hyper plane,

$$(w^*.x) + b^* = 0$$

Get decision function:

$$f(x) = sgn((w^*.x) + b^*)$$

B. B. Classification Using Support Vector Machine Technique

Classification phase is the decision making phase of a Handwritten Character Recognition (HCR) engine. This phase uses the features extracted in the previous stage for deciding the class membership.

In this work, we have used Support Vector Machine (SVM) classifier for recognition. The SVM is a very useful technique for data classification. The SVM is a learning machine, which has been widely applied in pattern recognition. SVMs are based on statistical learning theory that uses supervised learning. In supervised learning, a machine is trained instead of programmed to perform a given task on a number of inputs/outputs pairs.

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Basic Steps
Testing Process:

- Extract feature of testing image
- Generate feature vector
- Compare with training feature vector
- If match found image is recognized
- Otherwise not recognized

Training Process:

- Input training dataset
- Using Kernel and Argument and tradeoff value Generate Feature vector
- return feature vector
- Here number of feature is 256

C. Training and Testing

The Statistical Pattern Recognition Toolbox (abbreviated STPRtool) is a collection of pattern recognition methods implemented in Mat lab.

The principal purpose of STPRtool is to provide basic statistical pattern recognition methods.TheSTPRtool is also intended to serve a designer of a new Pattern Recognition method by providing tools for evaluation and comparison of Pattern Recognition methods [8].

In our system we use radial basis kernel function because our feature is 256. By using RBF kernel we get better recognition rate.
Normally a Gaussian will be used as the RBF, the output of the kernel is dependent on the Euclidean distance of from support vector to testing data point.

The equation of RBF kernel

$$K(xi, xj) = exp(-|xi - xj|^2 / \sigma^2)$$

The support vector will be the Centre of the RBF and σ will determine the area of influence this support vector has over the data space.

D. D. Training:

Training examples (x_1', y_1)..... (x_n', y_n). Generate Hypothesis space according to RBF kernel. Parameter *C* for trading-off training error and margin size.

E. E. Testing:

Finds hyper plane in feature space generated by kernel. The hyper plane has maximum margin in feature space with minimal. Training error using given C and the output is the success rate, time consumption for reorganization .we analyze the results in the next section.

IV. Result Analysis

In this research work, each datasheet is written by 1000 people from various fields such as Education, Industry, Service, Business, etc., of different age's ranges from 12 years boy to 50 years gentleman. Three Datasets were constructed namely Set 1, Set 2, Set 3 and Set 4 having 800, 1000, 800 and 1000 sample images image array and identifier of handwritten Bangla character respectively.

Set 1 consists of 200 testing images for handwritten Bangla character was recognized 190 samples and produced recognition rate 95%.
After increasing the test sample into 400 we got 398 recognized character and produce recognition rate 99.50% for Set 2

Set 3 consists of 200 testing images for handwritten Bangla character was recognized 172 samples and produced recognition rate 86%.
After increasing the test sample into 400 we got 373 recognized character and produce recognition rate 93.25% for Set 4.
For Set 3 and Set 4 the recognition rate decreased because Kha and Gha quite similar and some people write Kha as the shape of Gha and also some people some people write Gha as the shape of Kha.
The result of character recognition using support vector machine higher than all other techniques. The result tables showed all the result and all the result bellow is done using RBF kernel.

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A. Result Analysis

We also compare our results with Bangla hand written character recognition using artificial neural network [2]-[10].

TABLE 1.CHARACTER RECOGNITION USING SVM (FOR 5 & 2 CHARACTERS)

Character	No. of class	Training samples	Testing samples	Recognition rate (%)
Ka and Ga	2	600	400	99.5
Kha and Gha	2	600	400	96.3
Ka, Kha, Ga, Gha, Umo	5	694	350	94.29

TABLE 2.CHARACTER RECOGNITION USING NEURAL NETWORK (FOR 5 & 2 CHARACTERS)

No. of class	**No. of data**	**No. of hidden nodes**	**Recognition rate (%)**
5	599	5	59.4
5	599	9	77.6 (High for 5 class)
5	599	10	74.1
5	599	12	52.1
5	599	13	74.0
5	599	15	68.3
5	599	20	69.4
5	599	25	65.1
5	599	30	64.6
2	694	3	83.4
2	694	5	92.2
2	694	8	83.3
2	694	10	73.3
2	694	13	93.2
2	694	15	94.7 (High for 2 class)
2	694	18	93.4
2	694	20	91.8
2	694	23	94.5
2	694	26	92.9
2	694	30	93.7

TABLE 3.CHARACTER RECOGNITION USING SVM (FOR 8 CHARACTERS)

No. of class	**Training samples**	**Testing samples**	**Recognition rate (%)**
9	900	450	86

TABLE 4.CHARACTER RECOGNITION USING NEURAL NETWORK (FOR 5 & 2 CHARACTERS)

No. of class	No. of data	No. of hidden nodes	Recognition rate (%)
9	1350	5	36.5
9	1350	9	53.3
9	1350	10	53.6
9	1350	12	63.8
9	1350	15	54.7
9	1350	19	68.5 (High)
9	1350	20	66.1
9	1350	25	59.8
9	1350	30	41.0

TABLE 5.CHARACTER RECOGNITION RESULTS OF BA & RA

No. of class	Training samples	Testing samples	Recognition rate (%)
2	200	100	95

Unrecognized Characters Index: 17 and 43 number index from Ra test samples.

TABLE 6.CHARACTER RECOGNITION RESULT OF SHA & MA

No. of class	Training samples	Testing samples	Recognition rate (%)
2	200	100	85

Unrecognized Characters Index: 2 and 7-20 number index from Ma test samples.

TABLE 7.CHARACTER RECOGNITION OF 40 CHARACTERS SET.

No. of class	Training samples	Testing samples	Recognition rate (%)
40	4000	2000	85.3

Unrecognized Characters Index: Total 294 index.

TABLE 8.CHARACTER RECOGNITION OF 50 CHARACTERS SET USING SVM.

Character	No. of Training Samples	No. of Testing Samples	No. of Unrecognized Samples	Recognition Rate (%)
অ	100	50	9	82
আ	100	50	5	90
ই	100	50	7	86
ঈ	100	50	6	88
উ	100	50	14	72
ঊ	100	50	12	76
ঋ	100	50	9	82
এ	100	50	5	90
ঐ	100	50	7	86
ও	100	50	5	90
ঔ	100	50	8	84
ক	100	50	4	92
খ	100	50	16	68
গ	100	50	5	90
ঘ	100	50	12	76
ঙ	100	50	4	92
চ	100	50	8	84
ছ	100	50	7	86
জ	100	50	6	88
ঝ	100	50	10	80
ঞ	100	50	3	94
ট	100	50	7	86
ঠ	100	50	6	88
ড	100	50	13	74
ঢ	100	50	11	78
ণ	100	50	9	82
ত	100	50	6	88
থ	100	50	6	88
দ	100	50	9	82
ধ	100	50	8	84
ন	100	50	11	78

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প	100	50	6	88
ফ	100	50	5	90
ব	100	50	17	66
ভ	100	50	15	70
ম	100	50	19	62
য	100	50	13	74
র	100	50	9	82
ল	100	50	8	84
শ	100	50	5	90
ষ	100	50	7	86
স	100	50	8	84
হ	100	50	4	92
ড়	100	50	11	78
ঢ়	100	50	12	76
য়	100	50	7	86
ৎ	100	50	5	90
ং	100	50	4	92
ঃ	100	50	2	96
ঁ	100	50	3	94
Total Character = 50, Total Training Samples = 5000, Total Testing Samples = 2500, Total Unrecognized Samples = 408 , Average Recognition Rate (%) = 83.68				

TABLE 9.CHARACTER RECOGNITION OF 50 CHARACTERS USING NEURAL NETWORK.

No. of class	No. of data	No. of hidden nodes	Recognition rate (%)
50	7500	5	41.3
50	7500	9	37.6
50	7500	10	33.7
50	7500	12	54.2
50	7500	13	55.8
50	7500	15	63.5
50	7500	20	46.2
50	7500	25	56.4

Total Character = 50, Total Training Samples = 5250, Total Samples for Testing = 1125, Total Samples for Validation = 1125, Average Recognition Rate (%) = 63.5

TABLE 10.CHARACTER RECOGNITION USING POLYNOMIAL KERNEL IN SVM

Character	No. of class	Training samples	Testing samples	Recognition rate (%)
Ka and Ga	2	694	400	91
Kha and Gha	2	694	199	87
Ba and Ra	2	200	100	96
Sha and Mo	2	200	100	81
Ka, Kha, Ga, Gha, Umo	5	694	350	82

B. Performance Comparison with Existing Work

Here we compare the Bangla hand written character recognition in two different technique, there are neural network and support vector machine. We got far better recognition in support vector machine using Gaussian kernel.

TABLE 11.COMPARISON TABLE FOR 2 & 5 CLASS.

Method	No. of class	Total no. of samples	Recognition rate (%)
Neural Network	2	694	94.7
Neural Network	5	599	77.4
SVM	2	1000	96.4
SVM	5	1044	94.29

TABLE 12.COMPARISON TABLE FOR 9 CHARACTERS

Method	No. of class	Total no. of samples	Recognition rate (%)
Neural Network	9	1350	68.5
SVM	9	1350	86

TABLE 13.COMPARISON TABLE FOR 50 CHARACTERS

Method	No. of class	Total no. of samples	Recognition rate (%)
Neural Network	50	7500	63.5
SVM	50	7500	83.68

CONCLUSION

This research work deals with the recognition of Handwritten Bangla Character by applying Support Vector Machine technique. Proposed research work provides more efficient and accurate results than any other existing systems.

As a part of future work, recognition rate need to be tested by increasing datasets. This paper implements Radial Basis Function of SVM. By application of other kernel functions such as

Polynomial Kernel function, sigmoid function, this accuracy of Handwritten Bangla Character recognition can be further increased.

Our experimental result shows that for few characters our method results a false detection and that why the recognition rate is reduced a little. This not actually the error of our system, this is due to the unusual shape of a handwritten of peoples. But the overall recognition rate is satisfactory than any other character recognition scheme. And though it is tough to find any good recognition mechanism for Bangla handwritten recognition thus our research provides a good support for the future researcher.

REFERENCE

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