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AN ACCURATE AND ROBUST HANDWRITTEN NANDINAGARI RECOGNITION SYSTEM

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Abstract
This paper is one of the early attempts for the recognition of Nandinagari handwritten characters. Good literature for finding specific types of key interest points using single approach is available for manuscripts. However, careful analysis indicate that a combinatorial approach is needed to be used in a collaborative manner for achieving good accuracy. On a variant data set of over 1000 Handwritten Nandinagari characters having different size, rotation, translation and image format, we subject them to an approach at every stage where their recognition is effective. In the first stage, the key interest points on the images which are invariant to Scale, rotation, translation, illumination and occlusion are identified by choosing Scale Invariant Feature Transform method. These points are then used to compute dissimilarity value with respect to every other image. Subsequently we subject these to Hierarchical Agglomerative cluster analysis for classification without supervision. Finally, for a query image, the same steps are followed and cluster mapping is analyzed. The result shows over 99% recognition, thus achieving a robust and accurate manuscript character recognition system.

Keywords:
Invariant Features, Scale Invariant Feature Transform, Nandinagari Handwritten Character Recognition, Hierarchical Agglomerative Clustering, Dissimilarity Matrix

1. INTRODUCTION

The understanding of the technique of writing might be one of the greatest wisdom towards the human civilization. Writing is the graphic representation of a language. It is based on a script that is distinctively developed for the language. With time, script undergo modifications due to various linguistic, political and socio-cultural factors. A prevalent script may even be discarded as a whole and could be replaced by a new one. Nandinagari handwritten script is one of its kind. This is the earlier version of Devanagari scripts which is widely used currently in India and in some parts of the world [1] [18].

Written records are the most authentic source of information for understanding the history and culture of a society. Sri Anandathirtha, also named as Acharya Madhwa of the 13th century, who founded the Dvaita school of Vedanta has hundreds of manuscripts written in Nandinagari. Nandinagari manuscripts cover ancient research on different disciplines like Ayurveda, Jyotisha, Nyaya, Vyakarana, Itihasa, Kavya, Mantra, Tantra, Vedanta, Natyasatra and Shiplashastra to name a few. This invaluable information needs to be preserved and interpreted for passing across generations. Hence, there is a compelling reason to convert these handwritten characters to a standard format which can then be indexed and searched.

1.1 NANDINAGARI CHARACTER SET

Nandinagari character set has 52 characters out of which 15 are vowels and 37 are consonants as shown in Table.1. Handwritten scripts pose significant challenges, and sufficient work needs to be done in each step for their identification.

To perform reliable recognition, it is important that the features extracted from the image be detectable even under changes in image scale, noise and illumination. Such points usually lie on high-contrast regions of the image. Another important characteristic of these features is that they should be such that their relative positions between them in the original scene should not change to another variant of the same image.

Image Matching is a technique used to find the differences or similarities between two or more images and aids to measure these differences. For the purpose of matching, the interest points are identified in an Image from which relevant features can be extracted. In many computer vision applications image matching is one of the most important problems. Matching schemes have been popularly used in document image retrieval such as in accessing historic handwritten manuscripts and searching documents in a collection of printed documents.

In this paper we focus on extracting robust invariant features for the identification of handwritten Nandinagari characters. The features of similar characters are grouped together using Agglomerative clustering technique. Then the query image is mapped to the appropriate clusters.

For processing historic handwritten Nandinagari characters we use Scale Invariant Feature Transform (SIFT). The detection and description of local image features can help in object recognition. The SIFT features are local and based on the appearance of the object at particular interest points, and are invariant to different sizes and orientations. They are also robust to changes in illumination, noise, and minor changes in viewpoint. In addition to these properties, they are highly distinctive, relatively easy to extract and allow for correct object identification with low probability of mismatch.

Table.1. Nandinagari Vowels and Consonants

Consonants	

SIFT transforms image data into scale-invariant co-ordinates relative to local features. SIFT-based descriptors outperform other contemporary local descriptors on recognition accuracy. We have used the concept proposed by David Lowe [2] for extracting the SIFT features in finding the distinct Image Features from Scale-Invariant Key points and apply a transformation model to identify the landmark correspondences of these features as per the Random Sample Consensus (RANSAC) approach proposed by Fischer and Bolles [3].

2. LITERATURE REVIEW

An attempt to identify scale invariant features of the handwritten Nandinagari vowels using structural feature extraction techniques has been done using SVM and a recognition accuracy of about 94.45% has been achieved [4]. The recognition of Handwritten Nandinagari characters using SIFT approach is not available till date. This is the first attempt to recognize these rare scripts. The recognition of multiple type of words including Devanagari using Visual bag of words is discussed [5] using SIFT algorithm [6].

The robustness of SIFT for handwritten Devanagari word Identification is indicated [7] and its comparison with SURF algorithm is discussed [8]. These papers indicate varying types of occlusions amidst which SIFT performs better than SURF as its descriptors are double the size. Thus, SIFT is one of the most important robust algorithm for extracting key features of an image accurately and identify even the scripts that are in deformed state.

An attempt to classify human faces using SIFT and hierarchical clustering approach is also introduced [9]. The scale and variety of applications using this SIFT is discussed in many papers on pattern recognition [10] - [16].

3. METHODOLOGY

The proposed model architecture is as shown in Fig.1. There are two major parts in the proposed recognition rostrum.

Part 1: The offline part consists of the following steps:

Step 1: Scan distinct handwritten manuscript character and its variants: Characters from the writer of a handwritten manuscript are collected in the image form. Variants for these characters are manually prepared with different size, orientation, and occlusion. For a set of 52 vowels and consonants in Nandinagari, with an average of 5 different variations over the format of representation (jpg or png), size (256×56, 384×384, 512×512, 640×640), degree of rotation (0°, 45°, 90°, 135° and 180°) and translation (positive or negative offset of 15 pixels), we prepare a database of 1040 characters.

Step 2: In this approach, the preprocessing is kept to the minimal by just converting the images to grey-scale. We need not apply a threshold on this. This saves the overall time of processing.

Step 3: Candidate points from the input image are extracted using the Scale Invariant Feature Transform (SIFT) technique. From each candidate point 128 feature descriptors are extracted which are invariant to scale, rotation and illumination.

Step 4: For each image i out of N images, match points are found with every other image and the number of match points from image A to image B and vice versa are written to form an $N \times N$ matrix.

Step 5: If the number of match points from A to B is ($n_A \rightarrow B$) and B to A is ($n_B \rightarrow A$), the maximum number of match points is computed as n_{Max} and the same is used to replace the smaller of the two match points to obtain the match point matrix. i.e.,

if ($n_{A\rightarrow B} > n_{B\rightarrow A}$)

{

$n_{Max} = n_{A\rightarrow B}$;

}

else

{

$n_{Max} = n_{B\rightarrow A}$;

}

Step 6: The dissimilarity ratio is now computed as follows: Let n_A and n_B be the number of candidate points for Images A and B respectively.

We compute n_{Min} such that:

if ($n_A < n_B$)

{

$n_{Min} = n_A$;

}

else

{

$n_{Min} = n_B$;

}

The dissimilarity ratio for element at i_{th} row and j_{th} column is:

$$E_{ij} = E_{ji} = \{100\times(1-n_{Max}/n_{Min})\};$$

These values are stored in the database at the end of offline part in the recognition system.

Part 2: The online part consists of the following steps:

Step 1: The client provides a query image which is a character.

Step 2: Steps 1 through 6 are repeated here similar to those in part 1 for the query image of character.

Step 3: The dissimilarity matrix consists of N+1 rows/columns and can now be used for clustering which is part of the comparison and matching step 7.

Step 4: The results are displayed in step 8 as indicated in Fig.1.

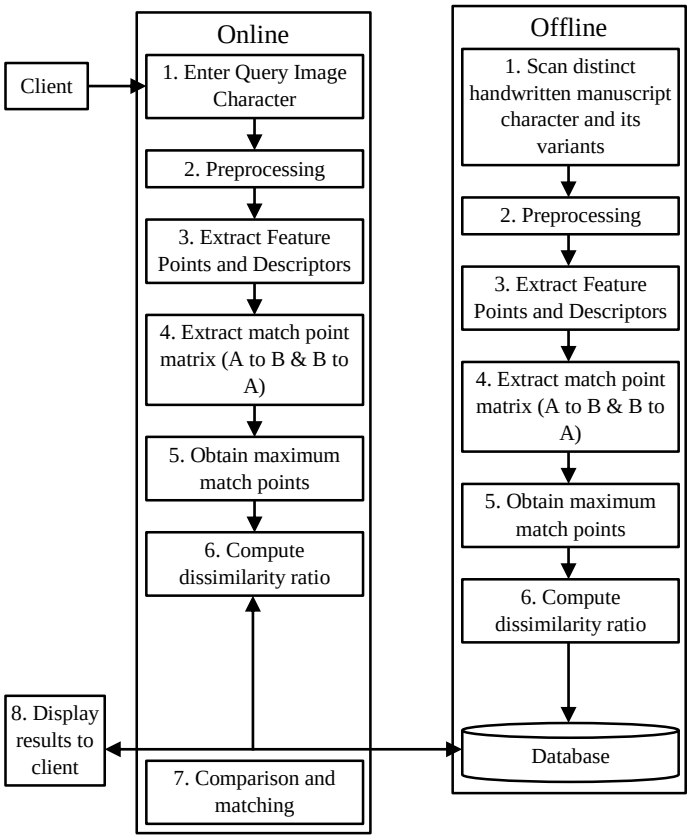

Fig.1. Proposed Model Architecture

3.1 CLUSTERING

Clustering is a process of grouping similar objects into distinct groups according to predefined distance measure. Agglomerative Hierarchical Clustering is a bottom up approach where each observation starts in its own cluster, and pairs of clusters merged as one moves up the hierarchy. There are different methods for agglomeration which could "ward.D2" [17], "single", "complete", "average", "mcquitty", "median" or "centroid". The minimum variance of ward's helps to get compact, spherical clusters while the complete linkage method gets similar clusters.

The single linkage method is similar to the minimal spanning tree algorithm and other methods adopt strategies in between the single and complete linkage approaches. All approaches give a similar pattern of results and we have used average linkage algorithm. This is better than the K-means approach since it automatically detects the 52 clusters.

4. EXPERIMENTAL RESULTS

SIFT interest points are extracted from the base images at a given scale with no rotation. The Table.3 indicates a sample of 16 characters taken from the Nandinagari character set. The SIFT match points with metrics for a typical character pair "Ha" are indicated in Table.2.

Table.2. SIFT Match Points with Metrics (A to B and B to A)

Image Name	**A: 11D7F_HA000_0006_0.jpg**	**B: 11D7E_HA000_0006_min90.jpg**
Interest Points	$n_{A=}$ 60	n_B =56
Match Points	$n_{A \to B}$ = 51	$n_{B \to A}$ = 54
Dissimilarity	n_{Max} = 54	n_{Min} = 56

Table.3. Sample Nandinagari Character Set with SIFT points

Cluster No.	**Nandinagari Character**	**Unicode**	**Variant Size**	**Variant Types**	**SIFT interest points**
1		11D50_A0000_37	5	0°, 45°, 90°, 135°, 180°	
2		11D52_I0000_37	5	0°, 45°, 90°, 135°, 180°	
3		11D56_RE000_37	5	0°, 45°, 90°, 135°, 180°	
4		11D61_GHA00_0006	5	0°, 45°, 90°, 135°, 180°	
5		11D62_NGA00_0006	5	0°, 45°, 90°, 135°, 180°	
6		11D63_CA000_37	5	0°, 45°, 90°, 135°, 180°	
7		11D64_CHA00_0006	5	0°, 45°, 90°, 135°, 180°	
8		11D65_JA000_0006	5	0°, 45°, 90°, 135°, 180°	
9		11D66_JHA00_0006	5	0°, 45°, 90°, 135°, 180°	
10		11D50_AA0000_37	5	0°, 45°, 90°, 135°, 180°	
11		11D55_UU000_0006	5	0°, 45°, 90°, 135°, 180°	
12		11D57_REE00_0006	5	0°, 45°, 90°, 135°, 180°	

13		11D5B_AI000_0006	5	0°, 45°, 90°, 135°, 180°	
14		11D5C_O0000_0006	5	0°, 45°, 90°, 135°, 180°	
15		11D5D_AU000_0006	5	0°, 45°, 90°, 135°, 180°	
16		11D60_GA000_0006	5	0°, 45°, 90°, 135°, 180°	

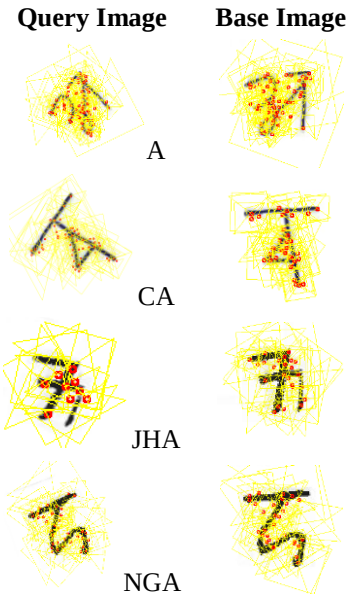

Fig.2. SIFT Interest points for query Images and Base images

The metrics indicate a pair of images considered for comparison with the following attributes:

- Unicode names having their suffixed variations,
- Maximum number of SIFT interest points extracted from the given image in isolation,
- Match points from one image to the other and vice versa,
- Dissimilarity value for each pair of images.

A polygon is drawn around each interest point based on the scale and orientation of the SIFT points extracted. To evaluate the performance, different query images are generated with a random size, character and inclination, which are not present in the input samples.

The dendogram after hierarchical clustering for sample characters partitioned by clusters with query and training images is shown in Fig.3 and Fig.5 and the 16 clusters are as shown here. The graph of Dissimilarity Matrix is indicated as a radar plot for query image JHA with rest of the characters below in Fig.4.

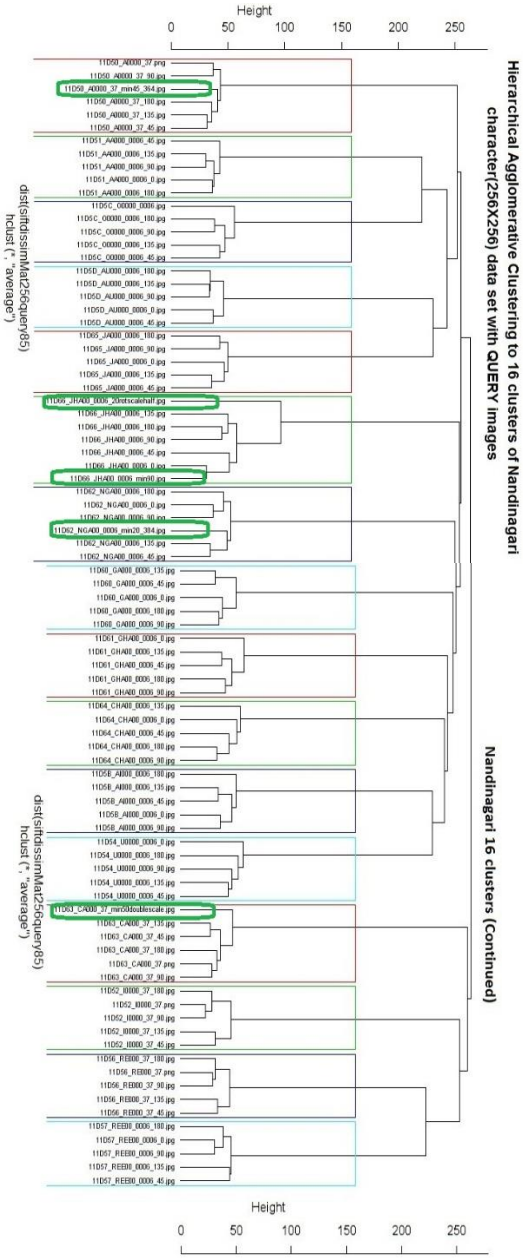

Fig.3. Dendogram after Hierarchical clustering for sample characters (16 clusters are shown here) with Query Image

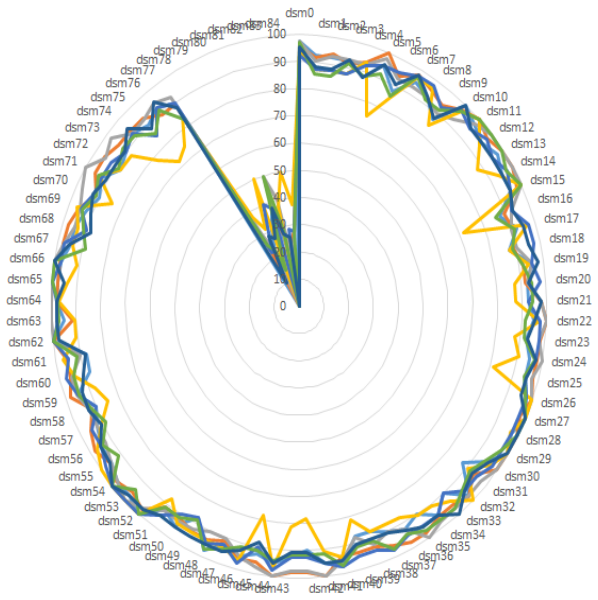

Fig.4. Radar plot of dissimilarity Matrix for sample characters and Query Image (85)

The Table.4 shows list of handwritten Nandinagari images retrieved from the database with metrics. The results indicate a representative sample of image recognition irrespective of variations to scale, orientation, translation and illumination. The Fig.5 shows the dendogram of sample training character set after Hierarchical clustering with 16 clusters.

Table.4. Query and Retrieved Images with Metrics

Test Cases	Query Image	Retrieved Images from the Data Base				
A						
Size	364×363	256×256	256×256	256×256	256×256	256×256
Degree	-45	0	45	90	135	180
Features Matched	53	46	50	62	51	52
B						
Size	384×384	256×256	256×256	256×256	256×256	256×256
Degree	-20	0	45	90	135	180
Features Matched	71	45	46	44	47	37
C						
Size	512×512	256×256	256×256	256×256	256×256	256×256
Degree	-50	0	45	90	135	180
Features Matched	79	49	42	41	37	42
D						
Size	128×128	256×256	256×256	256×256	256×256	256×256
Degree	20	0	45	90	135	180

Features Matched	32	20	20	16	22	16
E						
Size	256×256	256×256	256×256	256×256	256×256	256×256
Degree	-90	0	45	90	135	180
Features Matched	42	36	29	26	30	30

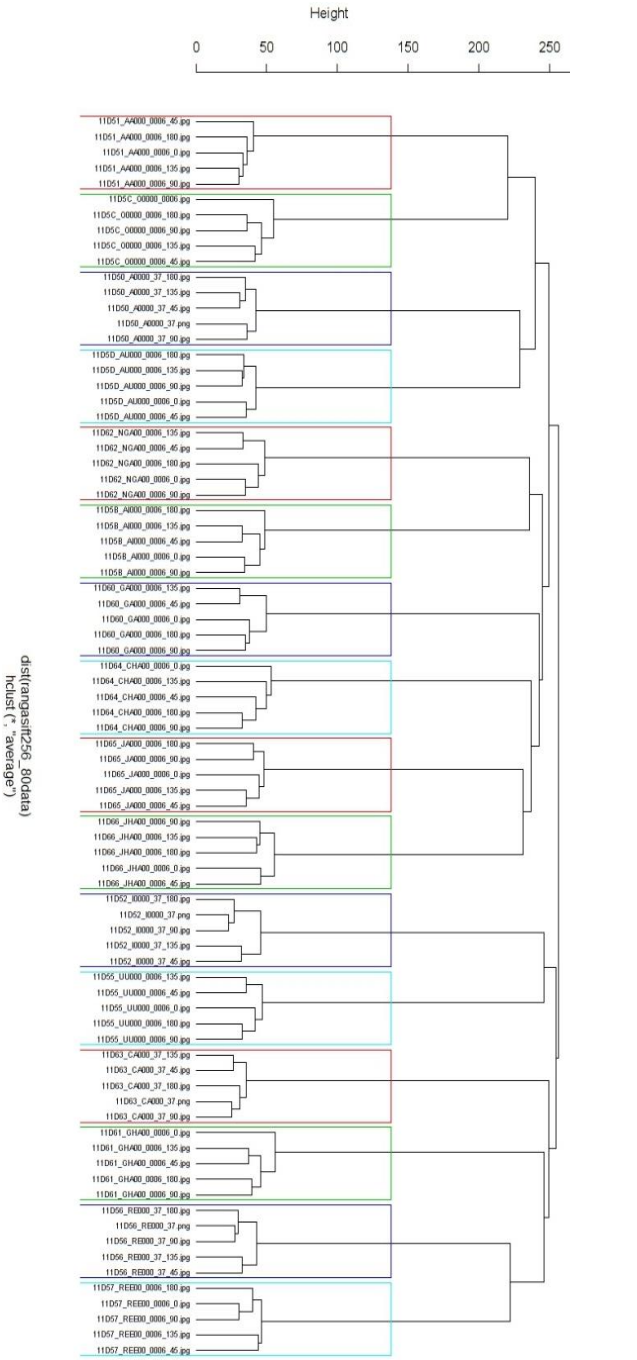

Fig.5. Dendogram after Hierarchical Clustering for sample training 256×256 set characters (16 clusters)

5. CONCLUSION

The proposed Nandinagari character retrieval system is based on data visualization method and is scalable. The Scale-Invariant Feature Transform (SIFT) detects the interest points and derives feature-descriptors. This approach requires no or minimal pre-processing of images and still can identify images in varying states of occlusion. Our main aim is to provide efficient and robust descriptors which are then used to compute dissimilarity matrix. They are then subjected to hierarchical clustering approach which filters the characters that typically tend to get misclassified thereby improving the recognition accuracy of over 99%.

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