**Related Work:**

To deal with the above mentioned challenges, a number of effective and comprehensive techniques have been put forward by many research groups around the world. Based on the properties of the features used, the proposed methods are predominantly divided into two groups – structure based features and texture based features. Structure based features mainly focus on structural and topological properties of a numeral image either taken from the entire image shape or after subdividing the image into different sized zones or sub images. Basu et al. in their paper [1] have proposed a 76-element feature vector containing 16 centroid feature, 36 longest run feature and 24 shadow feature for recognition of handwritten Bangla numerals. Thereafter Multi-Layer Perceptron (MLP) is used for classification purpose. In another version of their work [2], Basu et al. have come up with an application of Dempster-Shafer (DS) method for combination of classification decisions obtained from two MLP classifiers using two feature vectors providing complement information. In [3] Das et al. have used a feature vector of length of 88 comprising 16 octant and 72 shadow features followed by MLP classifier to recognize Arabic numerals. In the paper [4] Das et al. have designed a novel convex hull based feature set calculated over various bays characteristics of the convex hull of a pattern, for effective recognition of isolated handwritten Bangla characters and numerals. Dongre et al. in their paper [5] have used geometric and structural features to recognize handwritten Devanagari numerals and characters. In this method, every image is divided into nine partitions. To combine both local and global effects, eight structural features are computed from each partitions and from entire image. The classification is carried out using Multi-Layer Perceptron Neural Network (MLP-NN). In [6] Lehal et al. have proposed a system to recognize Devanagari and English numerals using a set of global and local features, obtained from the right and left projection profiles of the numeral images. The primary flaw of structure based features is that it falters in case of similar structure of two different images. Besides, predominant structure based methods use local information from subdivided images which make it computationally inefficient especially in case of repetitive subdivision. On the other hand, texture based features intent to calculate the data pixel density or statistical measures from a group of pixels. The process of calculating features is divided into two types – spatial and spectral based feature extraction approaches. For the former approach, the texture features are extracted by computing the pixel statistics or finding the local pixel structures in the original image, whereas the latter transforms an image into frequency domain and then calculates feature from the transformed image. In the paper [7], Hassan et al. have introduced an approach for handwritten Bangla numeral recognition using three different variations of Local Binary Pattern (LBP) - the basic LBP, the uniform LBP and the simplified LBP followed by a K-NN classifier. In the paper [8] Karthik et al. have put forward a technique based on HOG (Histogram of Oriented Gradients) for the recognition of handwritten Kannada numerals. HOG descriptors are invariant to geometric transformation and hence they are regarded as one among the best descriptors for numeral recognition. Multi-class Support Vector Machine (SVM) is used for the classification purpose. In the paper [9], Singh et al. have suggested a novel Mojette transform (also called projection histograms features) based feature vector to recognize handwritten numerals of four major Indic scripts namely, Bangla, Devanagari, Arabic and Telugu. After that principal component analysis (PCA) is accomplished to reduce the feature dimension, and then this reduced feature vector is fed to MLP for classification of the handwritten numeral images. The main drawback of texture based feature is that it is very sensitive towards the orientation of the numeral image as the texture feature extraction is highly influenced the spatial position of a pixel. It becomes inefficient in the cases of poor handwriting, rotation of the images while scanning etc. Singh et al. in their paper [10] have proposed a 130-element feature set for efficient handwritten numeral recognition. The proposed feature descriptor is essentially a combination of six different types of moments which are geometric moment, moment invariant, affine moment invariant, Legendre moment, Zernike moment and complex moment. Ashiquzzaman et al. in their paper [11] proposed a deep learning based novel approach for recognition of Arabic numeral recognition. The key idea behind the method is to use a suitable activation function and a regularization layer in the neural network. In another work [12], Ahmed et al. have used a LSTM (Long short-term memory) architecture for Bangla handwritten numeral recognition. The suggested LSTM methodology in [12] first normalizes the images and then two-layer LSTM is employed to classify the numeral. Many alternative approaches have been performed by other researchers to deal with handwritten numeral recognition; some of those can be found in the recent survey paper [13] by Singh et al.

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