

# Convolutional Neural Network Assisted Off-line Handwritten Character Recognition of Meitei Mayek

*A thesis submitted in partial fulfilment of the requirements for the degree of*  
**Doctor of Philosophy**

by

**Deena Hijam**

Enrollment No. CSP16102

Registration No. TZ189821 of 2018



**Department of Computer Science and Engineering**

**School of Engineering, Tezpur University**

**Tezpur, Assam, India - 784028**

**February, 2022**

# Chapter 7

## Conclusion & Future Direction

### 7.1 Conclusion

In this thesis, HCR of a new script called Meitei Mayek is studied. A handwritten character dataset of the complete character set of Meitei Mayek script is created. The dataset is named Tezpur University Meitei Mayek Handwritten Character Dataset (TUMMHCD). It contains 55 classes with a total of 85,124 images, training set containing 72,330 and test set containing 12,794 images. The steps followed for the dataset creation is described in Chapter 2. This chapter also presents a performance analysis against TUMMHCD using state-of-the-art classifiers with existing handcrafted features and image pixel intensity (IPI) values. Four classifiers viz. Support Vector Machine (SVM), K-Nearest Neighbour (KNN), Random Forest (RF) and Multi-Level Perceptron (MLP) are tested with Histogram of Gradients (HOG) and Discrete Wavelet Transform (DWT) and IPI as features. It is observed that for all the classifier-feature combinations, the classification rates of certain character classes are low compared to the rest of the classes. The overall recognition accuracies achieved using the mentioned traditional machine learning techniques are low. Therefore, with an aim to improve the recognition accuracy, CNN is adopted due to its recent success in image classification tasks.

In Chapter 3, performance analysis of five recent state-of-the-art pre-trained CNN models against TUMMHCD is carried out. Observing the disadvantages of such deep models, a shallower CNN model is built from scratch for recognition of TUMMHCD. With the proposed CNN model, better recognition is achieved with less resource requirements. Even though better recognition accuracy is achieved, the misclassification rates of some character classes are still low

as was the case in Chapter 2.

In Chapter 4, a multilevel recognition of TUMMHCD using fusion of features is proposed. There are two levels of recognition. First-level recognition is achieved by the proposed CNN. The proposed methodology achieves a more discriminative feature set in the second level recognition by using a fusion of features technique and making the recognizers more specific by only considering three character classes for each recognizer. The method is based on the idea that when a character image is misrecognized, it is highly possible that its true class is one of the classes with higher softmax values. The second-level recognizer carries out recognition of the misrecognized image in a smaller space by considering only the three classes with highest softmax values. A filtering module decides which of the test images will be forwarded for second-level recognition. The multilevel system shows an improvement in recognition accuracy compared to the single-level system.

In Chapter 5, a recognition methodology based on script-specific features is presented. The work is based on the finding that most of the misrecognitions occur in between two character classes. Images belonging to each pair of these classes are structurally very similar and hence are called confusing pairs. The proposed method identifies the confusing pairs and employs script-specific features of Meitei Mayek such as division of a word into zones, identification of vowels and non-vowels based on the zones and orthographic rules to distinguish the characters in the confusing pairs from each other. The recognition takes place in two stages. First-stage is a CNN-based recognition. Second-stage narrows down the recognition to only the identified confusing pairs. Correct recognition by the second stage enhances the system recognition accuracy significantly.

Chapter 6 presents an approach for incorporating language model with the proposed CNN for achieving a better recognition accuracy on the Meitei Mayek handwritten characters. The approach combines the class probabilities and the conditional probabilities generated by the CNN and the LM respectively, thereby leveraging the strengths of both the models. The method gives higher weightage to the CNN model and lower weightage to the LM and achieves a better recognition accuracy.

## 7.2 Future Work

- More datasets of Meitei Mayek could be developed such as word dataset, document dataset which are essential for the study of other pattern recognition tasks like word recognition and writer identification.
- The use of Bangla is gradually being replaced by Meitei Mayek and many people are not familiar with the new script. Therefore, we believe that development of transliteration systems which convert Meitei Mayek to Bangla script will be very beneficial for the majority of Manipuri speaking people. Such works could be taken up in future.
- More features and more deep learning techniques could be explored to achieve better recognition accuracy on TUMMHCD.
- The incorporation of LM in the overall handwriting recognition of the script could be studied by developing the appropriate datasets.