Chapter 7

Conclusion and Future Directions

The aim of our research was to perform experimental study and analysis on online handwriting recognition for Assamese characters. We have developed a dataset for online handwritten Assamese characters. Initial experiments on character recognition are performed using three different quantitative feature vectors for online handwritten Assamese characters. The thesis contributed towards qualitative representation of online handwritten Assamese characters. Two different qualitative feature vectors are formed and character recognition experiments are carried out for Online Handwritten Assamese characters.

7.1   Contributions

This section briefly presents the main contributions to the thesis. We have identified three contributions which are addressed in the thesis: (i) a dataset of online handwritten Assamese characters, (ii) qualitative representations of online handwritten Assamese characters and (iii) Recognition of online handwritten Assamese characters.

7.1.1   A Dataset of Online Handwritten Assamese Characters

The acquisition and distribution of standard datasets have increasingly gained importance. In this direction we have developed a dataset of online handwritten

Assamese characters with an aim to provide samples for research in online handwriting recognition for Assamese characters. The online handwritten Assamese characters dataset reported in this thesis contains a total of 8,235 online handwritten Assamese characters from 183 classes, which consist of Assamese numerals, basic alphabetic characters, and conjunct consonants. The reported dataset of online handwritten Assamese characters is publicly available from UCI Machine Learning Repository. The dataset has already gained importance among various research groups. The dataset is used by a number of researchers for character recognition experiment in online domain [99, 100, 101, 102, 103].

7.1.2 *Qualitative representations of Online Handwritten Assamese Characters*

We have introduced a qualitative representation scheme for online handwritten Assamese characters with an aim to increase the recognition rates of online handwritten Assamese basic alphabetic characters and conjunct consonants (Juktakkhors). We have analyzed the stroke sequences of all the characters taken from the dataset of online handwritten Assamese characters. Based on our analysis, we have introduced a qualitative representation schemes for Online Handwritten Assamese Characters and a qualitative feature set for the same. This representation combines two schemes, namely, qualitative encoding of stroke directions and qualitative curvature component signatures. Stroke directions of the online handwritten Assamese characters are encoded using a qualitative orientation model. Based on our analysis of stroke sequence, we have seen that each class of characters can be represented with a representative character from the class. The strokes of the representative character are assigned qualitative curvature components and the complete character is represented with a sequence of qualitative curvature components termed as the qualitative curvature component signature for the character. The proposed qualitative feature set consists of qualitative orientation symbols and qualitative curvature component signatures.

7.1.3 Online Handwriting Recognition of Assamese Characters

The experiments on the recognition of online handwritten Assamese characters are performed in two stages. We have performed experiments using Quantitative feature vectors in stage 1 and Qualitative feature vectors were used for character recognition experiments in stage 2. The classification of characters was performed using Support Vector Machine (SVM) based classifiers. Several kernel functions of SVM were used for our experiments. We have started with the linear kernel which is the simplest of all and then we have extended our experiments to polynomial kernel and RBF kernel functions of SVM in both the stages. We have formed three quantitative feature vectors, namely FS:1, FS:2 and FS:3. Based on our experiments we have seen that online handwritten Assamese numerals have the highest recognition rate of 99.11% for feature set FS:1 when linear kernel is used. From among the three feature sets FS:1, FS:2 and FS:3, the best recognition rate of 81.15% is obtained for Assamese basic alphabetic characters based on the feature set FS:3 and from among the three feature sets FS:1, FS:2 and FS:3, for Assamese conjunct consonants, the best recognition rate of 69.62% is obtained based on the feature set FS:3. We have introduced two qualitative feature vectors, QFS:1 and QFS:2. Using the qualitative feature set QFS:2, we have obtained recognition rates of 95.00% and 95.13% for online handwritten basic alphabetic characters and conjunct consonants (*Juktakkhors*) respectively. The recognition rates obtained using the proposed qualitative feature set for both online handwritten basic alphabetic characters and conjunct consonants (Juktakkhors) are higher than the previous recognition rates of 81.15% and 69.62% when feature set FS:3 was used. We have also conducted character recognition experiments for the entire character set of 8235 samples of online handwritten Assamese characters considering numerals, basic alphabetic characters and conjunct consonants (Juktakkhors) together using feature sets FS:3 and QFS:2. The experiments demonstrated that for the entire character set the recognition rate (93.93%) obtained using QFS:2 is higher than the recognition rate (73.21%) obtained using FS:3.

7.2   *Future Directions*

The thesis outlines some of the possible future directions of research in the field of online handwriting recognition for Assamese characters.

- There is always a scope for improving the recognition rates. More feature sets of online handwritten Assamese characters can be explored with this objective.

- There is a scope to extend the dataset of online handwritten Assamese characters (TU-OHAC Dataset) by adding more samples to the dataset. Large number of samples will help in training of classifiers.

- An application for recognition of online handwritten Assamese characters can be developed for mobile phone devices. This is left as a future work.

- It is important to recognize characters from online handwritten multi-lingual documents. Therefore, there is a scope for extending this research on the recognition of online handwritten Assamese characters to an online handwritten multi-lingual character recognition system.

- This work is limited to isolated online handwritten Assamese character recognition only. Extending this research to the recognition of online handwritten Assamese word recognition can be a future direction.