Chapter 6

Conclusions and Future Directions

6.1 Conclusions

A novel approach on a template-based on-line writer independent Nepali handwritten character recognition by using both structural and spatial information is conducted through a series of experiments.

Firstly, only the structural approach is utilized along with the use of Dynamic Programming (DP) for classification of alphanumeric character. The proposed template-based on-line Nepalese natural handwritten alphanumeric character recognition is demonstrated through a series of experiments manipulating two factors in 2×2 design. The first evaluation factor is the inclusion of a pre-processing step incorporating specific knowledge about the Nepalese alphanumeric characters. The second factor is the set of features used for stroke identification. It means, a separate classifier is built for original and pre-processed writing samples in both features: $f_t = (\theta_t)$−one dimensional and $f_t = (x_t, y_t, \theta_t)$−two dimensional. The highest recognition rates are 88.37% and 89.79% for pre-processing samples from the systems using feature events: $f_t = (\theta_t)$ and $f_t = (x_t, y_t, \theta_t)$ along the stroke's sequence respectively. The question of which feature is the best feature is answered by the help of five-fold cross validation. The inclusion of pen-tip's positions with the slopes of consecutive coordinates as a feature along the trajectory of the user's drawing provides much information in stroke classification than from only the sequence of slopes. Therefore, the system combining stroke pre-processing with the position and direction at every point in each stroke as a feature performed better than other systems having different combinations. Hereby, a conclusion has been made that significant places are required for pre-processing and feature selection blocks in character classification engine.

Secondly, a novel idea is explored based on the number of strokes and their spatial relation with each other within a character. Interestingly, the unique feature of Nepali character: the 'shirorekha' is used as the reference feature sequence in order to determine the spatial relation, which helps to achieve the accuracy more than 95%. One of the biggest problems is the similarity in structures between the classes of characters (similarity pairs: (भ, म), (थ, य) and (ध, घ) etc.) is reduced significantly by the use of spatial information about the strokes within a character.

Beside the recognition rate of the classifier, the recognition speed is to be taken under the classifier's performance. As the classifiers use matching procedure for identification of test strokes, the speed is variably determined from one stroke to another. The number and size of strokes in the test letter and templates affect the recognition speed. In addition, de-

gree of dimension in feature vector sequence plays a crucial role. Alignment is faster in a one-dimensional feature than in a two dimensional. Hence, different recognition speed is achieved. However, 12 seconds per character is the fastest average speed of the classifier from the entire experiments.

The superiority of the present work over several related works on Devanagari script is the recognition of writer independent natural handwritten alphanumeric characters, which are stroke number and stroke order free. The methodology used in this classification engine is general and hence flexible in adding extra symbols in Nepali and can be extended to other scripts as well.

6.2 Future Directions

Most of the problems faced during the system design are related to the cursive nature of the scripts and natural writing styles too. It not only brings the problems but also gives a birth of solution techniques. We proposed few extra contributions in this script as future plans by looking into the performance of recognition system based not only on the recognition accuracy but also on the computational complexity and speed. Pre-processing is applied on those characters, which do not have high recognition confidence such that it will enhance the speed. Improvement will be achieved by extracting structural features of all loops, curves, hooks/cusps and intersections etc.

In the first step, building a syllable level recognition in Nepali is the aim to reach. The existing methodologies will work better, once the segmentation of a complete syllable into a character and modifier(s). A concrete technique is needed for segmenting the syllable. As we believe that this methodology is general and can be extended to many of the scripts and symbols, a multilingual recognition system is the plan to build in the second step. How good it will be for those, who are non-natives to English, computer novices and feel inconvenient in using keyboard and keypad (old people), if a system (multi-lingual) having the intelligence in recognizing the natural handwriting for all possible scripts around the world exists.