Chapter 8

Conclusion and Future Scope

The primary objective of this work is to develop adaptive inter-point Braille recognition algorithms for Hindi Devanagari Braille which can accommodate the variation in the spatial resolution of the Braille document being scanned. Such an OBR for Hindi language is necessary as Hindi being the national language of India, lacks an efficient OBR system. The existing approaches for OBR are template based approaches, which are non-adaptive in nature. Due to the unavailability of the adaptive algorithm for Braille in any language, herein the adaptive algorithms are designed for Braille dot extraction, inter-point Braille character recognition and for grid construction. Moreover, the developed adaptive recognition algorithms can be extended not only for other Indian languages but also for the rest of the Braille languages in the world by modifying the front end of the developed system. A brief review of the main contributions to the problem of Hindi OBR to speech system is given in Chapter 1.

To develop a Braille recognition system, it is required to have the stored images of Braille sheets. Chapter 2 gives a brief description about the standard database that has been developed which is technically useful for building the OBR system and for evaluating the performance of the proposed system. The developed Hindi Devanagari Braille database- Bharati Braille Bank consists of data pertaining to the Double sided embossed Braille document, Single sided embossed Braille document, Single sided and double sided Hand punched document, skewed documents and documents with varying resolutions which are required to achieve a robust recognition system.

Braille dot extraction is one of the vital steps in OBR as the accuracy of the system depends on the true extraction of the dot components. The existing dot extraction techniques are two stage approaches. The first stage is the Braille image enhancement and the second stage is thresholding. Hence, in chapter 3 frequency domain enhancement techniques using Unsharp masking, High boost filtering and High frequency emphasis filtering using Butterworth and
Gaussian filters are implemented to reduce the computation time involved in Braille dot extraction. As the objective of the proposed work is development of an adaptive algorithm, the proposed techniques are applied for Braille documents with varying resolution namely 2121x1501, 1380x985 and 685x503. The results show that, as the resolution of the Braille document with which it is captured varies, the threshold which is the distance from the centre of the transform required to extract the Braille dots also differs. This limits the use of frequency domain techniques as an adaptive approach to extract the Braille dots from documents with varying resolution. In order to overcome this, adaptive bit-plane slicing approach has been implemented to adaptively extract Braille dots from documents with varying resolution. The experimental results show that the bit-plane 6 and bit-plane 7 carry more information about the Braille dots and superimposing these two planes provides the Braille dot extracted image. This also eliminates all the sources of noise that might have crept in during the Braille image acquisition phase and extracts only the dots.

Many authors have tried to address the issue of inter-point Braille recognition through template-based approach. The fact that the Braille documents can be acquired with varied resolution makes the usual method of template matching to fail. To address this issue, a new system that is capable of differentiating the recto and verso dots from an Inter-point Braille document even with varied resolution has been proposed in chapter 4. The developed adaptive algorithm redesigns the templates by itself based on the changes in the spatial resolution of the Braille document image being scanned. The proposed adaptive template technique efficiently extracts the recto and verso dots from Braille documents with varied resolution with average computation time of 12 seconds per document. The template matching procedure fails to address the issue of deteriorated Braille dots and thus resulting in false recognition of inter-point dots. This is because, if the dots are deteriorated due to several reading, then this will result in aliased gray level values, thereby leading to false recognition of recto dot as verso dot and vice-versa. But for the good quality Braille documents this technique is highly reliable.

A novel dynamic segmentation technique for segmenting the recto dots from verso dots in an inter-point Braille document in case of deteriorated Braille dots is proposed in chapter 5. Herein the performance is enhanced by employing the eight connectivity property of a pixel. The technique proposed here is much reliable and consistent as it is tolerant up to 50% deterioration of dots in a line of character with average computation time being 5.3 seconds.
per document. The limitations being the presence of more number of deteriorated dot patterns in a single row.

A new system for inter-point Braille recognition is presented in chapter 6, which deploys a two-stage highly efficient and an adaptive technique to differentiate the recto and verso dots from an inter-point Braille expending the horizontal and vertical projection profile method to overcome the limitations of the novel dynamic segmentation technique and adaptive template approach. Also in this chapter, a novel adaptive algorithm to convert the recognized Braille dots to Hindi text has been proposed. The results obtained indicate that the proposed method is more accurate and faster than the adaptive template and dynamic segmentation approaches with average computation time being 4 seconds per document and also this system can be extended without any modifications to any Braille document without regard to its grade of writing and the language. The proposed method fails to work if the pre-processing stage fails to extract the dot components from the Braille document image.

The second objective of this work is presented in chapter 7 which is to identify a speech unit for Hindi and use it with a suitable speech synthesis technique to minimize the effects due to Spectral discontinuity and prosody mismatch that occurs during syllable concatenation. This is achieved by building a syllable (C*V) level speech database consisting of 442 syllables in each position of a word namely start, middle and end, thus accounting for 1326 speech units. The effectiveness of the system is demonstrated by synthesizing natural sounding speech for Hindi, national language of India. The most important quality of this system is the improved naturalness in the synthesized speech.

In summary, this work has been carried out to implement and assess a framework for Hindi OBR system that uses an adaptive method to recognize the Braille dots. The system provides promising results for documents with different resolution. The proposed method being adaptive; provides a very well suited approach for Braille documents of all languages irrespective of the resolution with which they are captured. The system performance can be augmented by improving the accuracy of the Braille pre-processing system. Additionally, an extensive work has been carried out to implement and evaluate a framework for Hindi TTS system that uses a syllable based speech unit based on the occurrence of syllable in a word using the concatenative speech synthesis approach. The system provides the required solution both in terms of naturalness and intelligibility as the selected method is concatenative.
method, which is very well suited for Hindi language. Furthermore, an improved system can be developed by enhancing the quality of the speech files recorded.

The major task undergone while building this Hindi Braille to speech system, was to build a unified framework suitable for Hindi Braille document database and a suitable database of speech units that can produce natural speech as output. Braille database was created by using the HP scanner. Sound files in database were created by cutting speech units from continuous speech.

The adaptive techniques which are data inherent are incorporated in to the Hindi Inter-point Braille recognition system. It is observed that the variations in the resolution of the Braille document being scanned have no impact on the performance of the adaptive recognition system. The evaluation of the developed adaptive algorithms is threefold: False Recto Verso Rate (FRVR), False Verso Recto Rate (FVRR) and True Dot Miss-Identification Rate (TDMR). Concretely, these performance factors helped in concluding that the developed two stage histogram based Hindi OBR system is efficacious in its working. The variation in the duration of the syllables with respect to their position of occurrence in a word is incorporated into the developed Hindi TTS system. The assessment process which yields high accuracies both for the naturalness and intelligibility is carried out by using the Mean Opinion Score (MOS) and Diagnostic Rhyme Test (DRT); these techniques are the most widely-employed evaluation approaches in this domain. In addition, these tests helped in concluding that the synthesized speech output of Hindi TTS is almost natural.

**Future Enhancements:***

- The adaptability of Braille image pre-processing techniques can be improvised to overcome deterioration in dots and thereby, increasing the accuracy of the OBR system.
- Incorporating the polysyllable based speech unit with durational knowledge.
- Incorporating emotions and intonations in the synthesized speech.
- Increasing the speed of Braille recognition and speech synthesis.
- Extending the developed system to all the regional languages of India.
- Extending the developed system for real time scenario.