Chapter 6

Conclusions

The primary objective of the dissertation “Development of a Novel Dactylology and Human-Computer Interface Design for Visually Impaired” is to enable blind and visually impaired users to interact with computers. Computers have become an essential part of our daily life. Due to its widespread use, it is expected that everyone—sighted or visually impaired—should be able to interact with computers without hesitation. Usage of a computer requires visual presentation of information for the input—hand-eye coordination in using computer mouse/keyboard—as well as the output—seeing the information on a computer screen. Hence, visually impaired users are unable to interact with computers by conventional means of Human-Computer Interaction (HCI). Braille and other conventional methods have limitations while entering data in the computer. The proposed dissertation is focused on solving this problem.

The recent aim of the HCI system is to build an interactive system which uses a natural way of interaction between human and computer as this will help sighted as well as visually impaired. A hand is an attractive input means which could help them to express added information by itself in comparison to the keyboard, joysticks, etc.

The recent advancement in gesture recognition algorithms and low-cost hardware development has made the use of gesture as a popular choice of interaction. They provide this capability in a more flexible, natural and expressive form. Research has also confirmed that vision is not responsible for the production of gestures. Every human being—even those who are blind from birth—produces hand gesture during the interaction. The gestures produce by the blinds are almost similar to the gestures produced by sighted users. However, their gestures are limited and less detailed. Additionally, till date, no study has been performed to understand these facts and considered their preference towards hand gesture posing. In this dissertation, an attempt is made to investigate whether a gesture-based interaction is possible with them or not. If yes, what shall be their performance to the gestures?

Chapter 1 dealt with the introduction of the dissertation. The problems faced by visually impaired users while interacting with computers was presented. Some technological solutions to these problems and their feasibility were discussed. Further, motivation, challenges and research problems were presented in this chapter.

Chapter 2 presented the preliminaries and system overview in detail. The definition of visual impairment and blindness were introduced. Next, a preliminary study with visually impaired was performed. In this study, we investigated the hurdles faced by them in HCI. Based on this, design considerations necessary for the development of special interfaces were presented. Specific issues faced by visually impaired users in using a conventional gesture-based interaction were considered and a table-top arrangement was proposed as one of the solutions to it. Further, the framework of the proposed interactive system was also discussed in this chapter.

Chapter 3 presented a user evaluation study with visually impaired users. Through this user evaluation study, we made an attempt to devise an optimal gesture set so that the painful gestures could be eliminated. In this user evaluation study, finger-based gestures were studied. These gestures were evaluated on the basis of quantitative rating analysis. More than 12,400 questions were asked and analysed in this quantitative rating analysis. This rating analysis indirectly gives an indication of complexity levels of gestures and their suitability for the users.

Optimal gestures are selected based on performance and preference measure metrics. Performance measure included rating of gestures on four subjective criteria—easiness, naturalness, ease of learning, and reproducibility. A Likert scale (1=strongly disagree to 5=strongly agree) was used to rate gestures on the basis of questions related to these four criteria. The proposed questionnaires included a mix of 'positively-keyed' and 'negatively-keyed' items. In preference measure, use of relative preference was proposed, and we formulated a new parameter, preference index, to explicitly consider the popularity and preference of a gesture among blind users. Results of the performance measure entail that although several gestures can be formed using fingers, only a few of them were optimal for posing. Rest of the gestures cause fatigue due to the constrained relationship between individual joints within the finger as well as between adjacent fingers. It was also observed that the ratings of the left and the right hand were different. This difference in the performance measure indirectly tells us that the constrained relationships between joints and fingers were different in both hands of the same participant as well as among participants. The findings are in agreement with the other studies.

The result of the preference measure clearly shows that participants had a preference towards simpler gestures. The findings of preference measure were in positive correlation with performance measure. Based on performance and preference measure, optimal gestures with lower biomechanical and ergonomics risk were devised. Finally, dactylology was proposed by mapping the obtained optimal gestures by a visualisation matrix which is obtained by modifying Polybius square. Through this visualisation mapping, we reduced the cognitive load incurred in remembering and recalling the commands as compared to Braille. Further, reduction in cognitive load was achieved by reusing similar gestures under a different context. The reuse of gestures permitted to form a larger set of commands with less number of gestures.

In **Chapter 4**, we presented a new shape signature—Reduced Shape Signature (RSS)—for hand gesture classification. The proposed method processes only finger boundary instead of entire hand gesture boundary. Consequently, it reduced the number of feature sets essential to describe a hand gesture. Additionally, this method was rotation, translation and scale invariant as well as simple, compact, computationally efficient and robust to irregularities around the wrist region. Use of differential angle and polygonal area was proposed to discriminate intra-class gestures. The proposed algorithm was able to recognise 98.57% of the symbols accurately.

In **Chapter 4**, we assumed that the user had worn a hand band while performing gestures. This restriction was removed and a robust wrist point detection algorithm was proposed in **Chapter 5** for automatic hand-forearm segmentation. The underlying idea behind the proposed algorithm was inspired by the facts and observations of human hand anatomy. Circular and elliptical shapes were used to approximate the palm region. Next, a wrist point detection algorithm was proposed using geometric features of the binary hand mask. Almost 84% (753 out of 899) of the wrist points were detected accurately with an acceptable error $e < 0.5$ for ground truth skin mask of HGR1 database. Among these correctly detected wrist points, the majority (480 out of 753) belonged to error bin $e < 0.2$. Apart from this, the performance of the proposed algorithm was also tested on the real-life scenario—skin masks obtained from different skin detection algorithms—and results comparable to ground-truth skin mask were obtained.

The original contributions of this dissertation are

- A novel method and assistive system for blind and visually impaired is proposed to interact with the computer. The issues faced by them in a conventional gesture-based system are taken into account and a tabletop setup is proposed as one of the solutions.
- A dactylology is developed based on the user-evaluation study performed with 25 blind and visually impaired users. Optimal gesture set is proposed based on the performance and preference measure.
- A robust shape signature, RSS technique is proposed to classify hand gestures. Two additional features—difference angle and polygonal area—have been proposed. The proposed RSS is compact as it reduces the number of feature-sets by 35%. Additionally, this technique is rotation, translation and scale invariant as well as simple, compact, computationally efficient and robust to irregularities around the wrist region.
- A new method for hand-forearm segmentation is proposed. Circular and elliptical shapes are used to approximate the hand palm. Next, a wrist point detection method is proposed which is inspired and based on the observations of human hand anatomy. The proposed algorithms are tested on HGR1 database. The experimental results prove that the proposed elliptical method is accurate and more effective as compared to the other existing methods. The proposed methods are also tested in the real-life scenario and results comparable to ground-truth skin mask are obtained.

Several problems were encountered during this user evaluation study. Few of them are discussed below.

- Some participants were unable to complete the study in one session. The remaining part of the study was done in the subsequent session. This may affect the ratings by the users. However, we have ignored this factor in the present study.

- Apart from this, all the participants in the user evaluation study were male with an average age of $\simeq$22 years. School children and female participants were not considered in this study as there were issues while obtaining ethical approvals for them. It will be useful to incorporate their view on an optimal gesture selection.

- While analysing the questionnaires response, we came across the problem of treating the Likert scale as either ordinal or interval. It is a long-running dispute. We have treated it as ordinal scale and computed the median of the overall score obtained as the sum of all criteria.

In this dissertation, an attempt has been made to develop an assistive system for visually impaired to interact with the computer. But, several issues need to be dealt in future in continuation of this work. Some of those are:

- Mapping of additional symbols: In Chapter 3, we proposed a dactylology which matches tier-1 gestures to alphabets and numbers using a visualization matrix. Mapping of remaining tier-2 gestures should also be done based on certain technique to increase the usability of the system. The rule of association, chunking should be considered while mapping the rest of the gestures to a command.

- In Chapter 4, we presented a new feature extraction method for gesture classification. Recently, convolutional neural networks (CNNs) have achieved significantly good recognition accuracy in object detection and classification. The detection of the fingertip(s) in a hand gesture is challenging due to the nature of hand movement and its varying articulation. Also, the finger being a relatively smallest object in the whole image affects the robustness of the fingertip detection algorithm. Works [165–167] gives a good viewpoint of the challenges faced. Recent work [168] given a clear insight on how various CNN architectures can be used for hand pose estimation.

- Performance comparison: The performance of the proposed dactylology should be tested in comparison to the QWERTY keyboard and Brailler. The study should analyse the cognitive load and performance parameters in the typing task on these devices/techniques.

- Understand the effect of handedness: It will be interesting to find the effect of handedness while posing gestures.

- Addition of dynamic gestures: Usage of dynamic gestures for various intuitive onboard commands like delete, rotate right, rotate left, next, previous etc. will improve the speed of tasks.

So, in a nutshell, this is the first step to build such an assistive system for blind and visually impaired to interact with the computers. The author will consider his modest effort a success if it proves to be useful to the visually impaired people of the society.