Chapter 1

Introduction

In the early days, only people who were technology enthusiast used to interact with computers. With the evolution of personal computing, the number of users and its applications have grown significantly. According to the current population survey [1] conducted by the United States Census Bureau, usage of computer has increased almost tenfold in the past three decades. Nowadays, Human-Computer Interaction (HCI) has become unavoidable due to the massive use of computers in each dimension of society. Some of the applications of computer in today's arena are shown in Figure 1.1. Their widespread usage suggests that the ability to handle computers is perhaps equally essential for visually impaired as well as sighted persons. The National Policy of India on Universal Electronic Accessibility also suggests that differently abled persons should be facilitated with equal and unhindered access to electronics, information and communication technologies (ICTs) products and services.

According to the World Health Organization (WHO) over 253 million people in the world are visually impaired, of whom 36 million are blind and 217 million have moderate to severe visual impairment [2]. These facts are presented in Figure 1.2. An

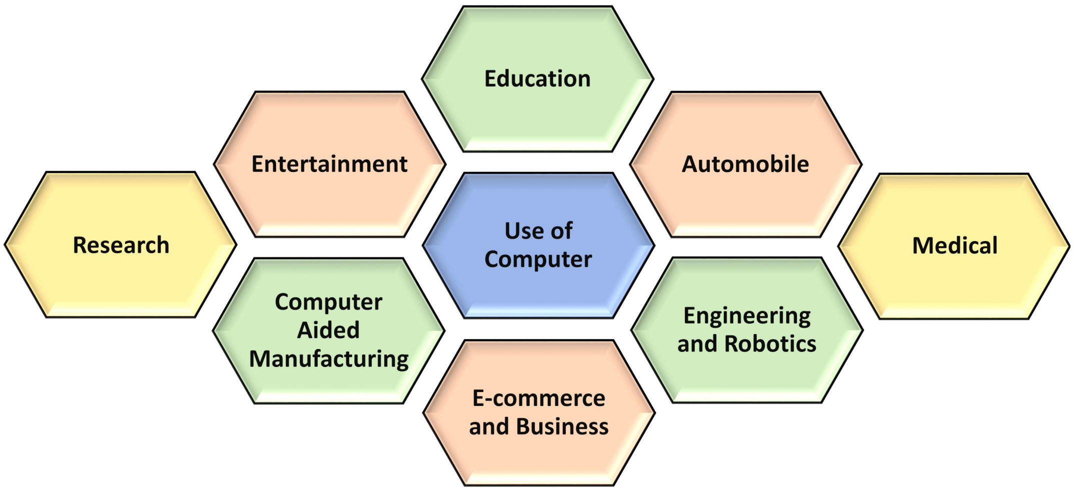

Figure 1.1: Use of computer

infographic released by the International Agency for the Prevention of Blindness is shown in Figure 1.3. It is predicted that these numbers are expected to triple by the year 2050 [3]. Majority of visually impaired people ($\approx$ 90%) reside in developing countries and they fall under the low-income group. According to the Blind Foundation for India, nearly 30% of the global blind population belongs to India.

Computers during its infancy were entirely inaccessible to the users with visual impairment. If we browse through the evolution of the computer, it has witnessed a series of research, development and innovation through the generations. Among

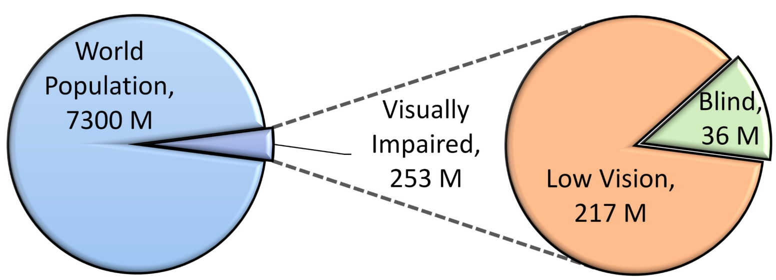

Figure 1.2: Some interesting facts about blind population [2]

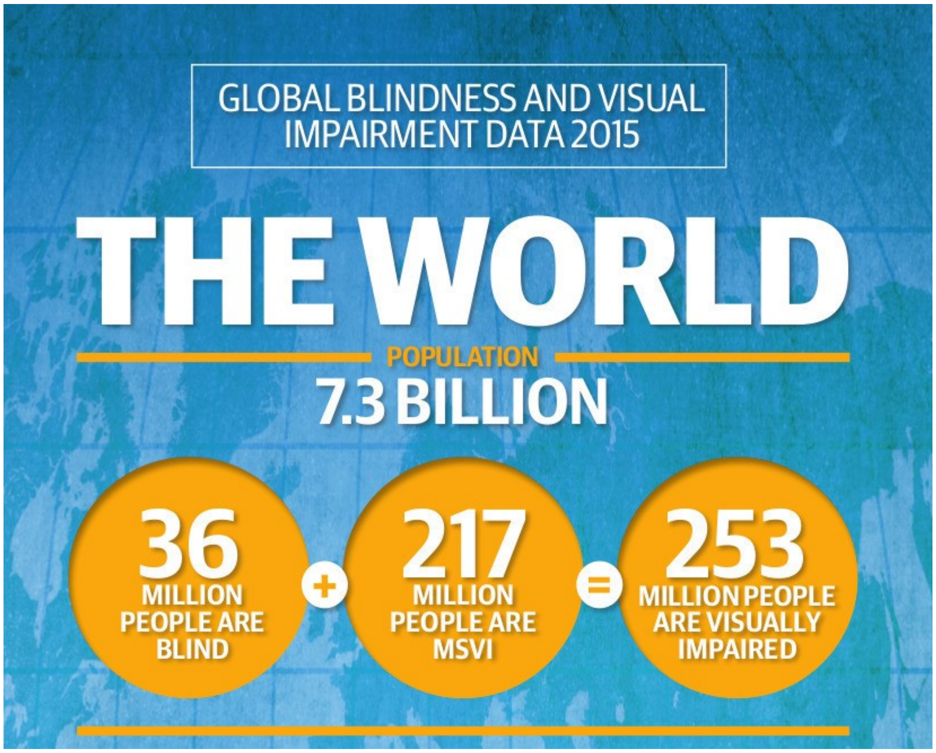

FIGURE 1.3: Infographic released by the International Agency for the Prevention of Blindness

them, the development of Graphical User Interface (GUI) was one of the remarkable landmarks in the history of HCI. During the initial days of batch processing, the user interface was a set of cards with holes (punch cards) and perhaps an operating console. The users were unable to interact with the computer in real time. Further, with the increase in processing power, people started using a computer in real-time and command-line interface was introduced. In the command-line interface, the user could interact with the computer by typing commands using keyboards. The development of display terminals facilitated users to watch the commands entered by them and prompt response to those by the computer.

Entering lines of text on these command line interface was tiring and error-prone.

Additionally, the keyboard was problematic or inadequate for some of the applications. For example, a user wanted to select and delete one of the items on the screen. If each item had a label, it could be deleted through command line by referring to the corresponding label. The same action could be performed hassle-free just by pointing the item on the screen. This eliminated the extra jumble of labels. Similarly, if a user wanted to add a line/item to the application on the screen, it was necessary to provide the exact position of the same. Estimating exact position was difficult for the users while it was easy to perform the same action accurately by just pointing on the screen. This untidy approach has motivated the use of a pointing device. Various devices like light pen, trackball were introduced but were phased out after the development of mouse [4, 5].

It was apparent till then that having a user interface and pointing device like a mouse could provide a compelling user experience. The first GUI was developed by researchers at Xerox Palo Research Center (PARC) in the 1970s. It was the dawn of innovations in computer graphic which has led us to where we are today. GUI created a comfortable interaction environment that made personal computer appealing to the sighted users. However, for a visually impaired user, GUI has introduced additional difficulties. Visually impaired users are unable to locate the pointing device on the screen due to lack of visual feedback and hence, they face difficulty in using GUI.

During these evolutions, no attention was paid to visually impaired users. The importance of computer for visually impaired was first realized by Scadden [6] in 1984. As a far-sighted view, he realised the issues and warned to take suitable remedial action to include them otherwise they will be left behind in the coming digital age. In 1990, Boyd raised the issues faced by visually impaired users in accessing GUI [7].

Later in 1998, Seale [8] re-emphasised the importance of microcomputers for disabled people.

She believed that the if programmed appropriately, a computer is capable enough to correct and help disabled people to do what they are unable to do. Since then, a lot of efforts have been made to make the computer accessible to visually impaired users. Still, visually impaired community face difficulty in handling computers.

1.1 Human-Computer Interaction

Human-Computer Interaction (HCI) is defined as "A discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and study of phenomena surrounding them" [9]. The interaction between human and computer can be viewed as the exchange of information between two powerful information processors [10]. However, this exchange of information is limited due to human capabilities. Most of the research in this domain is trying to speed up and ease the interaction. This is achieved by adopting convenient means to transmit information to computers. Additionally, providing efficient, salient, and pleasant feedback mechanisms to the users [11].

Figure 1.4 depicts the human-computer interaction framework [12]. It has four major components—the system, the user, the input and the output. Each of the components has its own language. Input and output together form an interface. The interface is the boundary across which both—users and system—exchange information with each other [13]. There are four steps in the interactive cycle, each corresponds translation from one component to another, as shown by the labelled arcs in Figure 1.4. The user starts the interaction cycle with the set-up of a goal and a task to accomplish that goal. The user provides the input by articulating

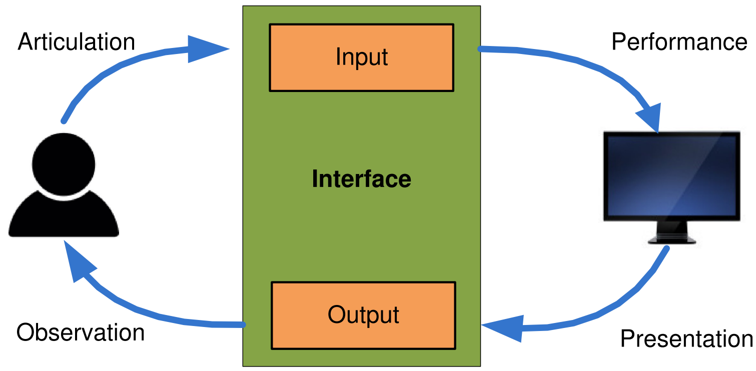

FIGURE 1.4: Human-Computer interaction framework

the task using the specified language. User's input language is translated into the system's core language as operations in performance step. The system executes and transforms itself as described by the operations. Once execution is done, its response must be communicated to the users. It is presented to the user taking care of the limited expressiveness of the output devices. The user observes the output and assesses the results of the interaction relative to the original goal and this ends the interactive cycle.

Interaction of user with the outside world happens through the information being sent or received (i.e. input or output). Looking specifically towards the input and output channels with reference to the users. Senses—vision, hearing, touch, taste and smell—are considered as users input channels [14]. Users receive the processed information from the computer through these input channels only. Among these five senses, vision, hearing and touch are of great importance to HCI. Recently, HCI researchers have also started exploring touch, taste, and smell interface for gaming, multimedia, and art environments [15]. In user output channel (i.e. input to the computer) the information is provided via the movement of the human body such as fingers, eyes, head, limbs and the vocal system etc. Among these output channels, finger, eye and vocal system are of great importance. The exchange of information is constrained by users and the computer's capability. On the user's side, interaction is constrained by various factors such as the nature of human attention, cognition, and perceptual-motor abilities while the computer side of the interaction is constrained by the technologies and methods [11]. However, the exchange of information from the computer to the user is far greater than that from the user to the computer.

QWERTY keyboard and mouse are the most popular and conventional means of intercommunication between human and computer. They provide familiarity in interaction for a sighted person but, these devices also cap the speed as well as naturalness. However, in the case of visually impaired, they find it difficult to use computer with the help of these means of HCI. Despite the difficulty, most of the visually impaired users use keyboard along with the screen reader software. This software reads aloud the contents displayed on the screen. After listening to it carefully, they provide appropriate input to the system through the keyboard. This action requires hand-eye coordination which makes it difficult for them to use the computer fluently. Braille-based devices are also available for such users.

Braille is a globally accepted reading and writing system invented by Louis Braille in 1824. It is universally acknowledged and used by sightless persons. It consists of a distinct code for sixty-three characters which is made by raised dots arranged in a cell or a matrix (containing three rows of two dots each). The braille alphabets and their raised dots arrangement are shown in Figure 1.5. These Braille characters are embossed on Braille transcribing paper and this embossment is then read by passing the fingers gently over the manuscript. A six-key entry device called brailler is used for the writing purpose. This brailler can be either mechanical or electronic. A braille character is formed using six-keys, where each key corresponds to a distinct dot position in a Braille cell. A Braille cell or matrix is made by simultaneously pressing keys corresponding to the desired cell dots. A various advance

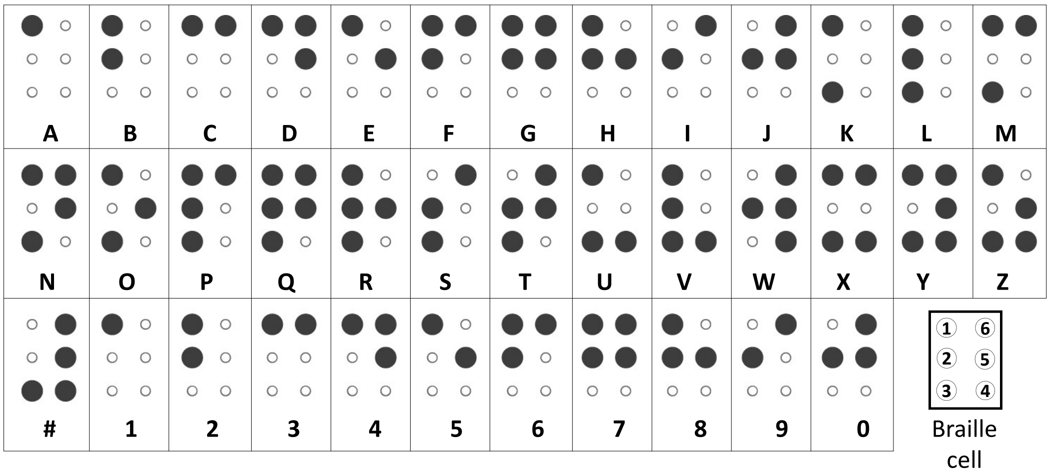

Figure 1.5: Raised dots arrangement in Braille alphabets

form of brailler—e-brailler, electronic notetakers etc.—are available in the market with computer support. These specialised devices provide input using a conventional Braille keyboard and output is provided through a refreshable Braille display (some model contains speech synthesiser and a display too). These advance braillers are clunky, inconvenient and cost up to \$5,000 ($\approx$ 3.5 lakh).

Some of the suggested solutions to interact with the computer are illustrated in Figure 1.6. The most straightforward solution is to use Braille stickers above the conventional QWERTY keyboard. However, a six dots matrix forms a maximum of sixty-three unique patterns. A standard QWERTY keyboard generally has 47 keys and by using the Shift key, 94 distinct character codes can be produced. All of the computer keyboard characters cannot be mapped to the sixty-three unique cells of the six-dot Braille alphabets. Even if some are mapped, a novice blind user needs to search for a character on the entire keyboard. This is time-consuming and lowers productivity.

Additionally, according to the annual report by American Printing House for the

FIGURE 1.6: Various solutions suggested to interact with computer

Blind [16] only 7.80% blind students in the United States use Braille as primary reading medium and merely 10% of the blind children are learning it. This situation is the worst in the developing countries wherein 90% of the global blind population reside and their literacy rate is almost 3%. These facts are illustrated in Figure 1.7. Due to these reasons, Braille-based solutions are not popular for interacting with computers.

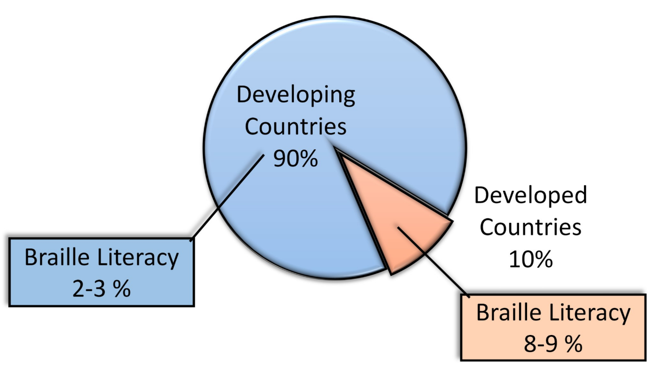

FIGURE 1.7: Some facts about Braille literacy rate

The aim of the recent HCI systems is to build an interactive system that uses a natural way of interaction between human and computer. Human being uses various modalities like hand gesture, speech, facial expression, etc. to express information and convey their cognitive processes [17]. The forthcoming innovative technologies are trying to incorporate these new modalities of communication because these will help sightless persons as well as a sighted person.

Speech recognition technology can be used by visually impaired for providing input to the computers. Though speech recognition has been available for several years, its use as an input to the computer was always an issue due to low recognition accuracy. Additionally, it depends on gender bias, regional accents, dialects and mannerisms make its usage even more difficult [18]. Recent advancement in deep learning approaches and its remarkable performance in improving speech recognition accuracy have drawn a lot of attention. Recently, a comparison of speech and keyboard text entry was presented in [19]. This study was performed under ideal laboratory conditions. It was found that the mean recognition accuracy drops considerably in realistic usage conditions [20]. It would be interesting to see the performance of speech recognition in non-laboratory settings and how it deals with gender bias, regional accents, dialects and mannerisms. This entails, there is a need to develop an assistive system based on non verbal communication viz. electroencephalogram (EEG), hand gesture, etc. Building a robust and practical system using EEG is a challenging problem because the recorded signals are feeble and noisy [21]. On the contrary, hand gesture shows potential to be used as the powerful means of conveying information.

1.1.1 Hand Gesture

Hand gestures help us to express our thoughts and make it understandable to others in an effective way. Psychological studies have already revealed that babies use a certain form of gestures to convey and communicate before they learn to speak [22]. Gesturing is a natural phenomenon that is found even in individuals who are congenital blind [23, 24]. Gestures are deeply embedded in communication between individuals from different cultures. Interaction using gesture is becoming more and more popular day by day as it provides a more natural and comfortable means of interaction. They are capable of providing control through symbolic commands (similar to keyboard) and pointing commands (similar to a mouse) [25]. The highlighting feature is that they provide these capabilities in a more flexible, natural and expressive form. Recent advancement in gesture recognition algorithms and low-cost hardware development had made it possible to use gesture commands to interact with the computer and other consumer electronics. Apart from all kinds of input and output technologies, usage of hand gesture is in demand to make interaction more comfortable.

The theory of using hand gestures, as a means of interacting with computers, actually originates from a multidisciplinary research domain. This domain involves human gesturing, anthropology, cognitive science and psychology etc. Different taxonomy of gestures exists in literature [26]. Some of them relevant to human-computer interaction are discussed below. According to the psycholinguistic point of view, each hand gesture has four essential attributes—hand shape (configuration), position, orientation, and movement [27]. These attributes act as distinguishable features in gesture recognition. Static gesture or posture are those gesture whose position, orientation and configuration remain fixed over time. In contrast dynamic gestures exhibit variation in position, configuration, or orientation over time [28]. According to [25], hand gestures are also categorised based on the purpose of usage, such as communicative, control, conversational, and manipulative gestures [29].

Sign language is an example of a communicative gesture. It is a method of communication used by hearing-impaired people which use gestures and signs. In fact, it is the only mode of communication for the deaf and mute people. Sign language provides a substitution for dialogue among hearing impaired and mute people. Examples of some sign languages are the American Sign Language (ASL) used among deaf communities of United States, the British Sign Language (BSL) is used in the United Kingdom, South African Sign Language (SASL) is used in South Africa, and the Indian Sign Language is used in South Asia. It is a living language with several facets, dialogue which keeps on changing as per the need. In a sign language, finger-spelling is usually used for those words for which there is not any sign. Those words are spelt out with the help of certain hand shapes (gestures) and their movement. However, Sign Language is not based on English. It is a distinct language with signs, movements and facial grammar. Here, a predefined hand shape (gesture) represents an alphabet in English.

Use of gestures on touch screens, i.e. handwriting recognition via smartpens seems to be a possible technique. However, the letters like f, i, j, t, x, consists of two strokes. As we can see that the second stroke is referential to the first stroke (dotting the i's and crossing the t's). Further, locating precise spots on the touch screen surface can be very difficult for visually impaired users. Research confirms that visually impaired users are able to draw and make gestures on touchscreens with more or less difficulty [30]. They face serious issues with form closure, line steadiness, location accuracy while drawing gestures [31]. Consequently, it is difficult for them to learn and use handwriting.

Efforts are also going on to assist visually impaired users by understanding their performance on providing input over tablet PC. The touchscreen-based device provides text entry using VoiceOver and Talkback [32]. Users put their finger above the key and the key is read aloud once it is touched. The text entry rate on a virtual keyboard is still very low.

1.1.2 Gesture Recognition Techniques

Numerous hand gesture recognition techniques are available. A few of them are discussed in this section. In the primitive technique, user wear a special type of data-glove [33–35] using which hand movement information is acquired. These data gloves provide the location of the hand, as well as the position of the different fingers. A special sensor is embedded in the gloves to record these spatial information. In this approaches, the glove sensor is interfaced to the computer system through wires and it limits the user mobility. Data gloves are also recognized as Electronics or Instrumented gloves.

Sayre Glove was the first glove prototypes which came into existence in 1977 [33]. A few years later, the Massachusetts Institute of Technology (MIT) developed a LED glove in the early 1980s. The Bell Telephone Laboratories developed and patented a digital entry data glove in 1983. Apart from these some other data gloves developed were dexterous hand master power glove, cyberGlove etc. For further details, please refer to [33].

The Sayre Glove make use of bendable tubes. It contains a laser and detector at both ends of each finger. Flexion of fingers causes bending of the tube which reduces the amount of light reaching to the detector. The voltage developed at each finger is directly related to the bent of the finger. The MIT-LED glove used

LEDs studded on a cloth. While the digital entry data glove uses different sensors such as proximity sensors, knuckle-bend sensors, tilt sensors and inertial sensors for different purposes [34]. These sensors were fixed on a cloth. This glove was planned for creating alphanumeric characters based on hand positions [35]. The main advantage with data gloves technique is that it provides excellent results, but it is quite expensive as well as cumbersome. Size of gloves is dependent on user age and cannot be used for a wide range of common application. Instrumented data gloves were supplanted by markers (optical based) which project infra-red light. The markers fixed on the hand reflect this infra-red light on the screen. This reflected light provides data related to the position of the hand and fingertip. Optical markers also provide very good result but the method is quite cumbersome as very complex and sophisticated arrangement is required.

Currently, vision-based hand gesture recognition systems are used for the recognition of hand gestures. Vision-based techniques have advantages over the data gloves and optical markers. This technique provides obstruction-free interaction and obviates the need to wear any external hardware. This technique requires a camera(s) and an algorithm which translates hand posture into some command. The recent development of robust algorithms and accessibility of fast processing devices has made vision-based gesture interaction a favourable choice.

1.1.3 Previous Research Work

In this Section, we present an overview of the work done in the field of hand gesture. Most of the study in this field is focused on either technical design and implementation or usability and human factors. Only a few researchers [36–48] have considered the usability and human factors related aspects of hand gestures. Majority of the research concentrates on the technical design and implementation aspects [49–90]. In this dissertation, we are dealing with both the aspects.

In the initial days of HCI using gestures, system designers have selected only those gestures which were simple to recognise [44]. User comfort and preference were not given priority. It is essential to consider their preference and comfort because if gestures are painful, users will not enjoy the experience of using it. Hence, the gestures in a vocabulary should be simple, easy to use, and with better learnability and recall. The recent advancement in image acquisition technology and recognition algorithm, have increased the desire of universal gesture set. The growing demand has encouraged researchers to develop gesture set based on user evaluation study.

An attempt to develop a gesture vocabulary by considering user view was made in [36]. The authors have considered several factors like intuition, learning rate, ergonomics. Later, work by Wobbrock et al. [37] introduced the concept of guessability and agreement score. Guessability is defined by Wobbrock et al. as "That quality of symbols which allows a user to access intended referents via those symbols despite a lack of knowledge of those symbols." This work proposed the agreement score formula also. It indicates the consensus of referent proposal among the participants. Many works [40–42, 44] have adopted this agreement score. A meta-heuristic approach of selecting gestures was presented by Stern et al. [38]. In this work initially, criteria of minimal recognition accuracy were used to selected gestures and further, the selected gestures were matched to referents considering human factors. Later, Morris et al. [43] presented a study on the selection of gestures for web browsing for TV interface. He used max-consensus and consensus-distinct ratio to select gestures. Table 1.1 presents some of the key works which performed a user evaluation study to select hand gestures. Apart from these, some researcher performed studies with disable/old users [39, 47, 48] and proposed gesture set for them. Open gestures

Table 1.1: Previous gesture selection methods

Ref.	N_p †	Visually impaired	N_r ‡	Selection criteria	Purpose
[38]	35	No	8	Intuitiveness, comfort and gesture recognition accuracy	Car game
[42]	12	No	12	User agreement analysis	TV interfaces
[43]	25	No	15	Max-consensus and consensus-distinct ratio	Web browser in TV
[40]	6	No	22	User agreement analysis	Object manipulation, navigation-based tasks, and spatial interaction
[41]	20	No	40	Agreement analysis	Augmented reality
[44]	20	No	12	User agreement and memorability	Smart TV interfaces
[46]	15	No	-	Experimental observation of users and survey questionnaire	Computer aided sketching and modelling
[45]	30	No	34	Usability and effort rating	Human-computer interaction
[48]	-	No	-	Borg scale to rank the difficulty	Human-computer interaction

† N_p Number of participants
‡ N_r Number of referents/commands

and their usability for older people are investigated by Bhuiyan and Picking [39]. A gesture set especially aimed for people with cognitive disabilities is developed by Gomez-Donoso et al. in [47]. Jiang et al. performed similar study with upper limb motor impaired users to make gesture interfaces usable by them [48]. However, no work has been performed with visually impaired users. It would be interesting to find and understand their preference toward the selection of hand gesture.

Research work dealing with the various aspects of hand gesture recognition has been introduced in the literature. These works are broadly categorised as pre-processing, feature extraction, and classification. In pre-processing block, several work [49–53] dealing with illumination compensation are proposed in the literature. The most used approach to deal with illumination compensation is based on retinex

TABLE 1.2: Previous feature extraction and classification methods

Ref.	N_s†	Features/techniques used	Classification techniques
[78]	10	Multi-feature fusion and template matching	Euclidean distance
[79]	10	Multiple shape-based feature (Area, perimeter, radial profile etc.)	Rule-based
[80]	10	Geometry based normalizations and Krawtchouk moments	Minimum distance
[81]	32	Locality preserving projections	Support vector machine
[82]	10	Thresholding decomposition and finger earth mover's distance	-
	10	Near-convex decomposition and finger earth mover's distance	-
[83]	10	Elastic bunch graph and adaptive boosting	Weighted elastic graph matching
[84]	24	Scale-invariant feature transform, bag-of-visual-words	Support vector machine
[85]	12	Multiple feature descriptors such as distance, elevation, curvature and palm area	Support vector machine
[86]	10	Histogram of oriented gradient features	Hierarchical elastic graph matching
[87]	6	Combinatorial approach recognizer	Support vector machine
[88]	10	Random forests	Binary decision tree
[89]	16	Run-length algorithm	Multi-layer feed-forward neural networks
[90]	14	Multi-scale weighted histogram of contour direction	Support vector machine

† N_s Number of symbols/ gestures

algorithms presented by Land and McCann [49] and its variants [50–53]. Recently, Vonikakis et al. [54] proposed a framework to evaluate the performance of some illumination compensation algorithms.

Skin-segmentation and binarization is another important step in pre-processing. Many boundary based skin color models have been proposed in literature. These include RGB [55], HSV [56], YCbCr [57], etc. These work determine the boundary by empirically analysing skin, non-skin pixels. Apart from these methods, other skin color based methods [58–62] have been proposed in literature. Some probabilistic approaches have been presented in [63–67]. Some methods [65–67] use additional features like the texture and spatial information to improve the skin segmentation results.

Literature on feature extraction shows a variety of approaches to recognise static hand gestures. Some of these include use of features like geometrical moments [68], orthogonal moments [69–71], shape signatures [72, 73], Fourier descriptor [74], wavelet descriptors [75], curvature scale space [76], chain code [77] etc. In the recent years, numerous other feature extraction techniques [78–89] were reported in the literature. The overview of these techniques is presented in the Table 1.2. Similarly, various classification techniques have been proposed in the literature to classify hand gestures. These work includes methods like distance based classifier [78, 80], decision tree [88], k-nearest neighbor, support vector machine [81, 84, 85, 87], graph matching techniques [83, 86], neural network [89] etc.

After studying all these methods, we found that no study has performed user evaluation study with blinds and visually impaired so far. Further, very limited number of gestures were used in such studies. *Detailed discussion on these works is provided in the related literature of each Chapter (refer Section 3.2.1, Section 4.2, Section 5.2).*

1.2 Motivation

The primary motivation comes from the intuition about the way visually impaired produce gesture while communicating. Gestures have the capability of providing a natural means of interaction. Research has already confirmed that vision is not responsible for the production of gesture [91]. Every human being—even those who blind from birth—produces hand gesture during their interaction [24]. Blinds produce gestures almost similar to the gestures produced by sighted users. But, their gestures are limited and less detailed.

In most of the HCI applications, researchers have used fingerspelling of American Sign Language (ASL) or its subset. These shape standards were result of gesture elicitation study performed on mute and deaf people. Blind people feel awkward to adopt this shape standard because it requires fingers to be posed properly, and their orientation should also be correct. Previous studies have also suggested that user-design approach with targeted user community is likely to produce more usable gestures than just adopting sign language gestures [92]. However, no study has included visually impaired users in their study. So, there is a requirement of a user evaluation study with visually impaired users which should investigate whether a gesture-based interaction is possible with them. Can it be used to interact with computers? If yes, which type of gestures are suitable for them? How should these gestures be matched to the keys on the computer keyboard? Which algorithm should be used to recognise these gesture? In order to answer the above questions, we faced the same challenges discussed in the next section.

1.3 Challenges

As discussed before, every human being—even those who are blind from birth—produces hand gesture during the interaction [24]. Gestures produced by blinds are almost similar to the gestures produced by sighted users. However, their gestures are limited and less detailed. Unfortunately, no work has explored and investigated the usefulness of hand gesture for them. A need, therefore, arises to investigate the efficacy of hand gestures for visually impaired to interact with the computer. In order to develop such a gesture-based human-computer interface for visually impaired, the following challenges are observed.

- Selection and usability analysis of hand gesture: Selection of hand gesture is a crucial aspect in the design of a gesture-based interface. It must consider learnability, usability, ergonomic design, and comfort aspects [93]. Unfortunately, the majority of work has selected hand gestures based on technical feasibility instead of user-centred aspects. This often causes frustration among users. The fingers of the hand do not move independently unlike a robotic hand. Performing various task like grasping, pinching, typing etc. involves the movement of more than one fingers. Further investigation by Häger-Ross et al. [94] shows that each finger has an interdependency causing simultaneous motion. The interdependence between fingers causes fatigue in posing certain gestures. Hence, the effect of the interrelation between fingers and fatigue caused by them must be considered while selecting optimal gestures.

- Mapping of gestures to the commands: One of the challenges in the design of gesture-based interfaces is the association between gestures and commands [95]. There is no standard practice that formally reports the method of mapping commands to gestures. A standard QWERTY keyboard contains a large number of keys (e.g. alphabet, number as well as special keys). In order to perform one-to-one mapping of its functionality, large numbers of gestures are required. Additionally, remembering such a large gesture-command pairs will be difficult to learn at the same time it will be difficult to recall too!

- Recognition of gestures: Recognition of gesture is a highly complex problem. The human hand is highly articulated and deformable due to which it can form various hand poses/gestures. Differences in physical capabilities and environmental condition also causes high variability in users pose. These substantial

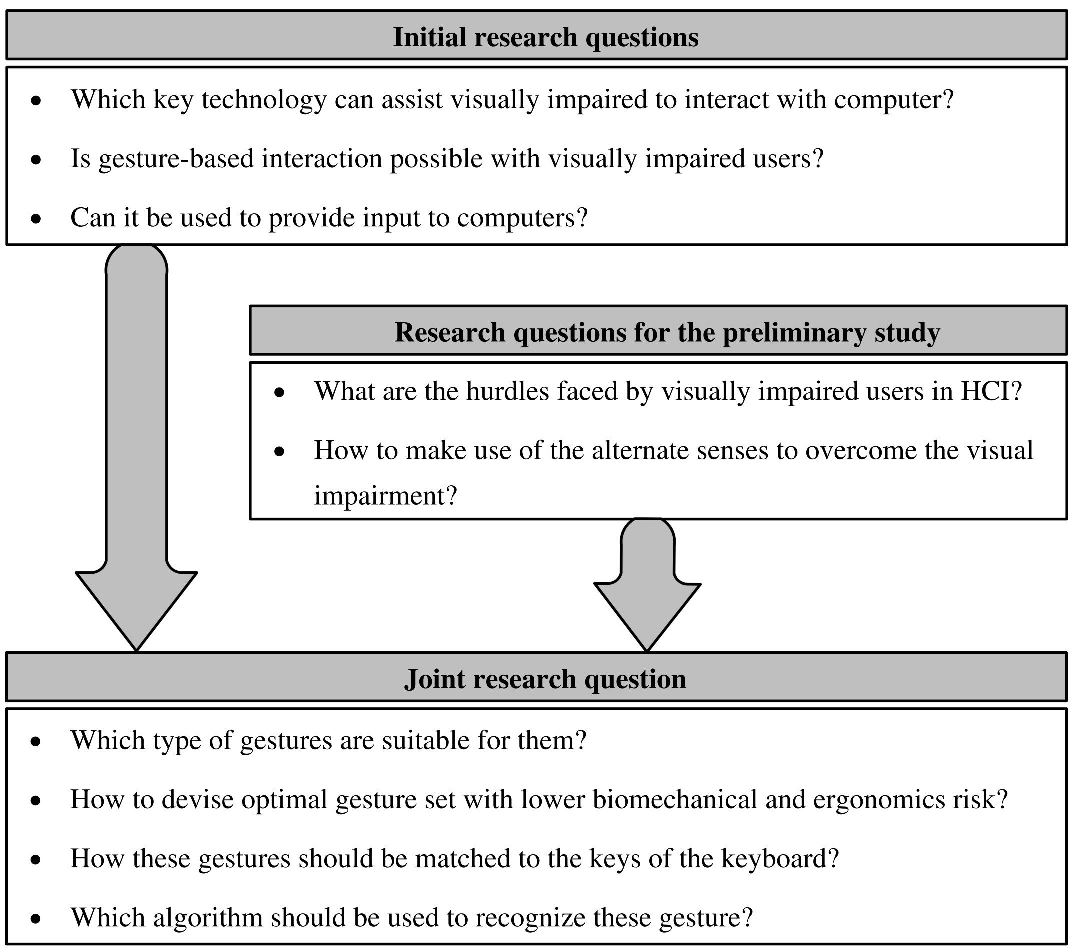

Figure 1.8: Research questions evolution

variations in the pose of users often make recognition a more difficult task. Recognition of gestures also gets affected by geometric changes—pose, scale etc.—and photometric factors—illumination, appearance etc.

The evolution of research questions is illustrated in Figure 1.8. We started with some initial research questions, discussed in this chapter. We also performed a preliminary study to find the hurdles faced by visually impaired users and understand the design considerations which are necessary for the development of a special interface for them. Finally, joint research questions are formalized and presented.

1.4 Contributions of the Dissertation

The original contributions in the presented dissertation are listed below:

- 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 user-evaluation study is performed with 25 blind and visually impaired users and a novel dactylology is proposed as an outcome of it. Optimal gestures in the dactylology are devised based on performance and preference measure metrics.
- A robust shape signature technique called Reduced Shape Signature (RSS) is proposed to classify hand gestures. Two additional features—difference angle and polygonal area—have been proposed to recognize gestures precisely. 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 algorithm 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 observation of human hand anatomy. The proposed algorithms are tested on HGR1 database. The experimental results prove that the proposed elliptical method is accurate and effective compared to the other existing methods. They work very well with real-life scenario too!

1.5 Organisation of the Dissertation

The organisation of the dissertation is outlined in Figure 1.9. The remainder of the Chapters are organised as follows. Chapter 2 introduces the preliminaries and system overview in detail. The definition of visual impairment and blindness are introduced. Next, hurdles faced by visually impaired while interacting with computers using assistive devices are discussed. Important blocks of the proposed system and framework of the proposed interactive system are also discussed in this chapter.

Chapter 3 presents the user evaluation study performed with 25 visually impaired users. In this chapter, two measure metrics—performance and preference—measure are proposed to select optimal gestures. Further, a novel dactylology is proposed based on the optimal gestures. The last section of this chapter is devoted to the result and discussion of the user evaluation study.

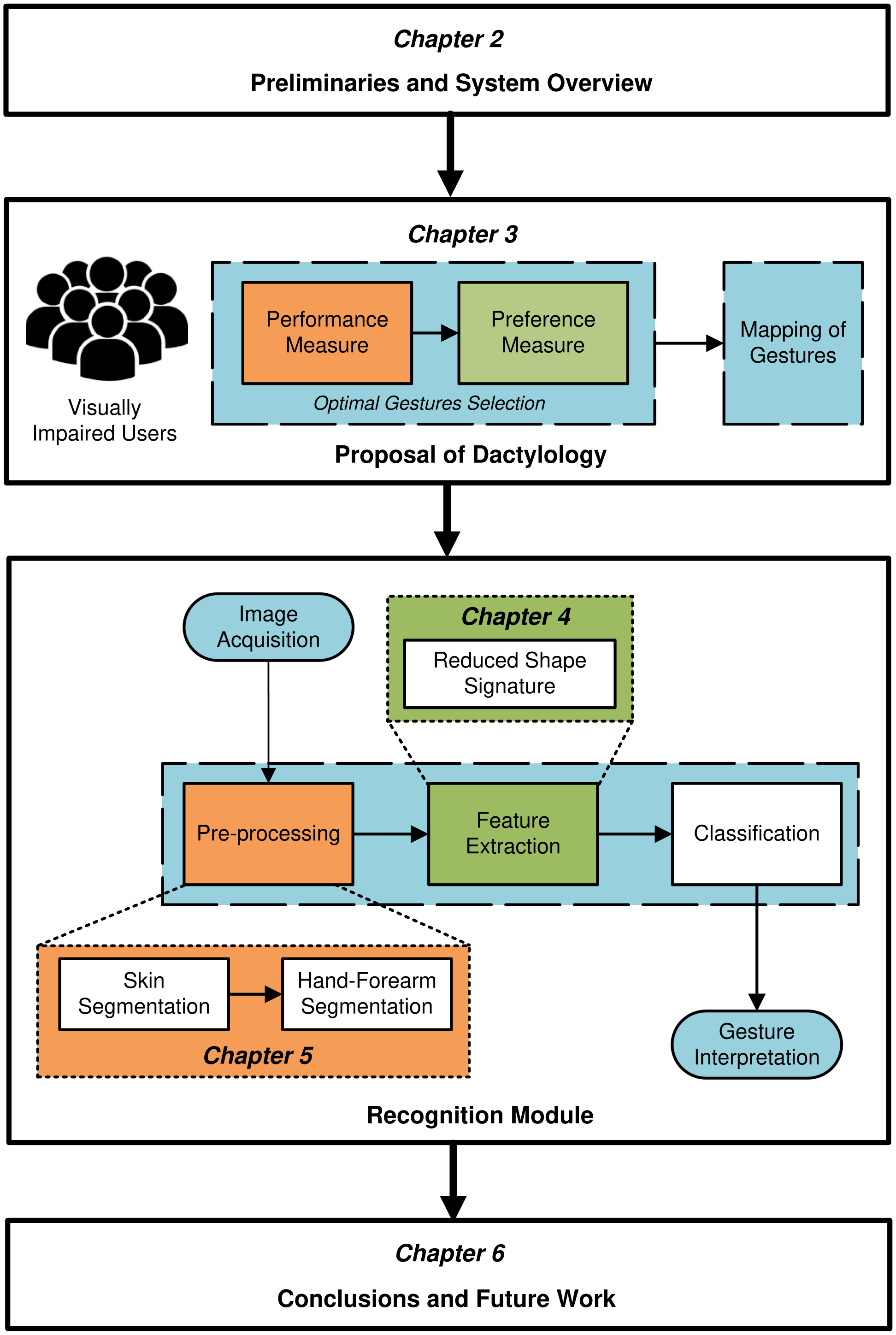

FIGURE 1.9: Organisation of dissertation

In Chapter 4, we present a new shape signature—reduced shape signature—for hand gesture classification. Two additional features—difference angle and polygonal area—are also discussed here. The proposed method is rotation, translation and scale invariant as well as simple, compact, computationally efficient and robust to irregularities around the wrist region.

In Chapter 5, we removed the constraint of using a band while posing. This chapter presents a robust wrist point detection algorithm for hand-forearm segmentation. The underlying idea behind the proposed algorithm is 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 is proposed using geometric features of the binary hand mask.

Chapter 6 presents a summary and conclusions of this dissertation. Future research directions and challenges faced are also discussed in this chapter. Last but not the least, Appendix A contains the Snellen chart used to measure the visual acuity. Appendix B contains the questionnaires data record form used in the user evaluation study.