Pattern Recognition 57 (2016) 50–60

Contents lists available at ScienceDirect

Pattern Recognition

journal homepage: www.elsevier.com/locate/pr

Towards hand gesture based writing support system for blinds

Gourav Modanwal *,1, Kishor Sarawadekar

Indian Institute of Technology (BHU), Varanasi, India

ARTICLE INFO

Article history:
Received 24 June 2015
Received in revised form
15 March 2016
Accepted 19 March 2016
Available online 1 April 2016

Keywords:
HCI
Reduced shape signature
Gesture recognition
Dactylology and rule based classifier

ABSTRACT

In this digital age, personal computers are widely used. But the blind people cannot handle it easily. Human–computer interaction (HCI) may play vital role in overcoming this obstacle. Computer keyboard contains about 104 keys, whereas six-dot Braille keyboard supports only 63 symbols. To bridge this gap, a new dactylology is proposed in this article. Additionally, a new feature extraction technique, Reduced Shape Signature (RSS), is introduced in this article which is rotation, translation and scale invariant. Further, RSS is compact as it reduces the number of feature-sets by 35%. To discriminate intra-class gestures difference angle and polygonal area are computed along with RSS. The symbols recognition rate of the proposed algorithm is 97.53%.

1. Introduction

Since personal computers play vital role in human life, human–computer interaction (HCI) is unavoidable. Further, the widespread use of personal computers suggests that the ability to interact with them is equally essential for both visually impaired and sighted person. Mouse and keyboard are the basic units of interaction between humans and computers [1,2]. Generally, these units are intended to be used by sighted users. Hence, sightless users face difficulty while interacting with computers by these means of HCI [3]. Braille based devices are available in market for such users.

Findings in the annual report by American Printing House for the Blind [4] show that only 8.64% of blind students in the United States use braille as primary reading medium and mere 10% of blind children are learning it. This situation is worst in the developing countries wherein 90% of the global blind population resides and where their literacy rate is only 3%. Moreover, a large population of blind people belongs to low-income group and braille based devices available in the market may not be affordable/accessible to them. The recent aim of HCI systems is to build interactive systems, which uses a natural way of interaction between human and computer. The forthcoming innovative technologies are also trying to incorporate different communication modalities with HCI, e.g. speech, hand gesture [5,6]. Human computer interaction has improved with these modalities, and they help sightless as well as sighted person.

Generally, a standard PC keyboard has 104 keys and with the help of modifier keys additional symbols are produced. It is not possible to map all these symbols on the sixty-three unique cells of six-dot braille alphabets. Even if it is possible, a novice blind user needs to search characters on the entire keyboard. This is time consuming and less productive. Speech processing may solve this problem, but it depends on accents, dialects and mannerisms. Moreover, it is ineffective in crowded environment and symbol recognition rate is small [7]. Therefore, this technique is unsuitable for writing support application. This entails that there is a strong need to develop assistive technology based on non-verbal communication such as hand gesture, electroencephalogram (EEG) which will help sightless person to interact with the computer. Non-invasive EEG based computer interaction is safe and easy to use, but the recorded signals are noisy. Hence, building a robust and real time system using EEG signals is still a challenging task [8].

A lot of complexity is involved in hand-posture recognition because of dissimilarity in hand size, rotation of the hand gesture, differences in skin color and viewpoint angle. Hand gesture recognition based on modeling of the hand in 2D and 3D are proposed in [3,9,10,11], respectively. The computational time required in 3D modeling is quite large and even slight variation in hand shape affects the accuracy of the system [12]. Consequently, it is unsuitable for real time applications. Most of the researchers used limited number of hand gestures and performed their study [13–27]. Hence, they are not suitable for the writing support applications. Further, some of the HCI applications [24–27] have used American Sign Language (ASL) shape standard or its sub-sets which are originally intended to be used by mute and deaf people.

* Corresponding author.
E-mail addresses: gmodanwal.rs.ece@iitbhu.ac.in (G. Modanwal), skishor.ece@iitbhu.ac.in (K. Sarawadekar).
[1] **Present/permanent address:** PG research lab, Electronics department, IIT (BHU), Varanasi, Uttar Pradesh, India, 221005.

http://dx.doi.org/10.1016/j.patcog.2016.03.026
0031-3203/

For a blind user posing different hand shapes as in ASL is difficult because many symbols are quite similar. Additionally, posing style of each human being is different. This increases the chance of misinterpretation among similar symbols when used in real time applications. Due to this, the blind finds it difficult to adopt this shape standard. Development of a writing support system requires large numbers of symbols which must be mapped to a standard QWERTY keyboard to provide similar functionality. It means there is a need to develop a new dactylology with which blinds will interact with computers. This article presents a new dactylology, an algorithm for its recognition and an experimental setup to capture and recognize these symbols in real-time.

The rest of the paper is organized as follows. Section 2 presents the proposed dactylology for different alphabets, numbers and symbols. The proposed algorithm is detailed in Section 3. Database creation, experimental setup and results are discussed in Section 4. Finally, Section 5 concludes the article with future research direction.

2. Proposed dactylology

American Sign Language (ASL) is a language of hand gestures and symbols. It is originally devised to be used by mute and hearing-impaired people for communication. Fingerspelling is used in ASL to spell the name of a person, place or organization, which does not have a designated ASL sign. It is also used to spell out words for which the ASL sign is unknown to the user. Many gestures in fingerspelling are quite similar and complex. Moreover, fingers must be posed with appropriate orientation. Due to these requirements, the blind find fingerspelling difficult to use.

Gestures in any vocabulary must be simple, intuitive, easy to reproduce, and different from each other [28]. The proposed dactylology uses combination of gestures to form a symbol. The least complex hand shapes are used as gestures and those are chosen from the American manual alphabet [29]. This reduces the chance of misinterpretation, which consequently increases the recognition rate.

The proposed dactylology can be easily visualized in terms of a matrix. Table 1 depicts alphabets ‘A–Y’ as a 5 × 5 matrix. Here, the element of the first row and first column represent ‘A.’ If left hand fingers represent row and right hand fingers represent columns, gesture for ‘A’ can be visualized as one finger of both hands. Similarly, other symbols such as ‘I’ can be represented by the combination of two fingers of left hand and four fingers of right hand as shown in Fig. 1(a).

If we do not pose a hand, i.e. zero fingers of a hand, ten more symbols can be added in the set. Column-0 means, symbol is posed using left hand only. Here, finger number of the left hand corresponds to the number. It means ‘1’ and ‘4’ are represented by the left hand with one and four fingers, respectively. Fig. 1 (b) depicts this fact. Similarly, row-0 means only right hand is posed and symbol is obtained. Here, ‘6’ is represented by one finger and ‘7’ by two fingers, respectively. Five fingers are used to represent ‘0’.

Use of special hand gesture is proposed to incorporate more symbols, refer Fig. 1(c) and Fig. 1(d). A gesture is treated as a special gesture, if it is posed using thumb and any other finger of the same hand. From the user's perspective, gestures must be simple and easy to reproduce. To ensure this, a pilot study with 10 sighted (6 male and 4 female) and 10 blind (7 male and 3 female) users was performed. First, we explained to them the purpose of the study and asked them to pose special gestures. Next, they rated it according to their level of easiness and relaxation. Rating was given on a scale of 10 where 10 stand for easy and relax gesture. Fig. 2 presents ratings obtained during this phase of the pilot study. Fig. 2(a) shows special hand gestures with left hand and their ratings. It is clear from this figure that the rating for gesture L2(A) and L2(B) is much higher than that of L2(C) and L2 (D). For special gestures posed with right hand, observations are similar and Fig. 2(b) represents these details. Finally, the four special gestures with higher rating - L2(A), L2(B), R2(A) and R2(B)- were selected and included in the proposed dactylology. Symbols formed using special gestures are depicted in Fig. 1(c) and Fig. 1 (d) along with their meanings.

3. Proposed algorithm

An outline of the proposed system is depicted in Fig. 3. It has three major steps namely image acquisition, processing, and gesture interpretation. Image acquisition is the first stage where optical flow method is used to obtain displacement vector between two consecutive frames. Based on this, frames which seem to be static are captured and processed further. The processing unit extracts distinctive features and performs

Table 1
Visualization matrix for alphabets and number.

Column / Row (Number of left hand fingers ↓; Number of right hand fingers →)	Column-0	Column-1	Column-2	Column-3	Column-4	Column-5
Row-0	*Ready*	*6*	*7*	*8*	*9*	*0*
Row-1	*1*	A	B	C	D	E
Row-2	*2*	F	G	H	I	J
Row-3	*3*	K	L	M	N	O
Row-4	*4*	P	Q	R	S	T
Row-5	*5*	U	V	W	X	Y