Empowering Speech and Hearing Impaired: A Unified Fingerspelling System for Indic Scripts

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Communication in the hearing and speech-impaired community happens through Sign Language (SL). SL is often used to communicate concepts and often falls short when individual words and characters need to be communicated. Fingerspelling is adopted to spell out names of people and places. American Sign Language (ASL) uses a fingerspelling system that mimics the geometry of individual characters and works for Roman scripts like English. However, it is cumbersome to use ASL fingerspelling for Indian languages primarily due to the diversity and the abugida nature of Indic scripts. Indic scripts show a wide variation in the geometry of the individual characters though they have close resemblance phonetically. In this paper, we exploit the phonetic similarity across 10 major Indic scripts to propose a unified fingerspelling system, called Mudrabharati Fingerspelling (MFS). Unlike ASL which signs the shape of a character, MFS signs a character using its phonetic structure. As a consequence, MFS requires the uses of both the hands to distinguish consonants and vowels; Consonant-Vowel combinations, which are very common in Indic scripts are gestured by using both the hands simultaneously.

1 INTRODUCTION

Sign language (SL) allows communication using hand gestures, facial expressions and body language. SL is used by the deaf people to communicate among themselves or with other individuals. One can often see healthy individuals using SL in noisy places [12], [2]. By a rough estimate, there are around 300 distinct SLs used across the world [8], [9]. While American Sign Language (ASL) is the most popular SL, there are some like Indian Sign Language (ISL), and German Sign Language (GSL) [15], [6], [3] which are widely used. According to World Health Organization (WHO) more than 5% of the world's population ($\approx$ 432 million adults and 34 million children) will require SL to address their *disabling* hearing loss. It is estimated that by 2050 this number will raise to 700 million people; one in every ten people, will have disabling hearing loss. The rapid increase in hearing disability is mainly due to current unsafe listening practices [14].

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Most SLs are useful to express a language at conceptual level, and are not equipped to alphabet spell a word. Fingerspelling is a component of SL that uses hand gestures to represent alphabets of a written language. Fingerspelling is commonly used to spell names, places and other proper nouns that cannot be gestured precisely at word level [1]. In ASL, Roman script is represented using 26 gestures corresponding to the 26 distinct alphabets [3].The gestures representing the alphabet are inspired by the geometry of the alphabets and are easy to remember if the signer has prior knowledge of the written script. From the Indian perspective, ASL (a) can only serve English speaking population and is not relevant to the majority, who communicate in Indian languages and (b) requires the explicit knowledge of English language for its usage. As a result, ISL is used by the hearing and speech impaired people in India. Although, ISL has its own vocabulary for 10000 words[5], spread over legal, academic, agriculture, everyday, and technical terms. The vocabulary is at the level of concept signing and lacks a system for fingerspelling of Indian scripts.

India boasts of a large number of languages and there are 10 major scripts (Bengali, Devanagari, Gujarati, Gurumukhi, Kannada, Malayalam, Oriya, Tamil, Telugu, and Urdu) that are used to write most of the major languages of India. Most Indian writing systems are based on a peculiar feature known as the composite character or swarayukta akshara [4] which is formed by a combination of a consonant with a vowel. While Roman script, a linear writing system, used in English, and other Western European languages, consist of a set of characters written horizontally, left to right, the Indian scripts consist of composite characters, which are combinations of smaller units, which have a vertical, multi-tier organization. A single composite character represents either a complete syllable, or the coda of one syllable and the onset of another [4],[7]. Each of the major Indian scripts listed above (except Urdu) are made up of around 16 and 37 vowels and consonants respectively. Tamil language is an exception and has a much smaller number of consonants compared to other Indian languages. A novel and unified Indic script known as Bharati script was recently proposed, that incorporates the above common underlying phonetic organization of most Indic scripts [11].

Fingerspelling convention that is based on the geometry of the Indic scripts would be futile because of the complex construction of Indic characters and more importantly there would be as many fingerspelling schemes as the number of language scripts. Additionally, such a convention can find use *only* in that part of India that uses the script. In order to overcome these problems, we propose, a unified, novel fingerspelling convention suitable for all the 10 major Indian scripts called Mudrabharati fingerspelling (MFS). MFS convention was inspired by Bharati script [11]. As observed on [11] while there is a great diversity in characters used in different Indic scripts, phonetically most major Indic scripts (other than Urdu) have a common organization. MFS exploits the phonetical homology among the Indian scripts and uses two hands to fingerspell a character in any Indian script.

The main contribution of this paper is a refined single fingerspelling convention that cuts across a number of Indian languages called Mudrabharati fingerspelling (MFS), and a machine learning based functional visual detection system for MFS [1].

2   MUDRABHARATI FINGERSPELLING (MFS) CONVENTION

Indic characters are not just vowels and consonants, but are also formed by the combination of these two. A single composite character in Indic scripts can have up to 3 consonants and a vowel. Therefore, the number of characters in a typical Indic script (with the exception of Tamil) is in the range of over 10000 and it is practically impossible to assign a unique gesture to each of the characters based on their geometry. However, based on the phonetic nature of the alphabets, they can be broadly classified into three categories; (a) Consonant Akshara, (b) Vowel Akshara and (c) Swarayukta Akshara in addition to punctuation.

A RIGHT WORKSPACE

1	2	3
4	5	6
7	8	9

LEFT WORKSPACE

| 1 |
| 2 |

B

	CLOSED FIST	THUMB OUT	INDEX OUT	THUMB+ INDEX OUT	NASAL
1	क (க்) (k)	ख (க்) (kh)	ग (க்) (g)	घ (க்) (gh)	ङ (ங்) (ng)
2	च (ச்) (ch)	छ (ச்) (chh)	ज (ஜ்) (j)	झ (ஜ்) (jh)	ञ (ஞ்) (nj)
3	ट (ட்) (T)	ठ (ட்) (Th)	ड (ட்) (D)	ढ (ட்) (Dh)	ण (ண்) (N)
4	त (த்) (t)	थ (த்) (th)	द (த்) (d)	ध (த்) (dh)	न (ன்) (n)
5	प (ப்) (p)	फ (ப்) (ph)	ब (ப்) (b)	भ (ப்) (bh)	म (ம்) (m)
6	य (ய்) (y)	व (வ்) (v)	ह (ஹ்) (h)		ण (ந்) (N)
7	र (ற்) (R)	र (ற்) (r)			
8	ल (ல்) (L)	ल (ன்) (l)	ल (ழ்) (zh)		
9	स (ஸ்) (s)	श (ஷ்) (sh)	ष (ஷ்) (shh)		

C

Dheerga						𝟬
GESTURE								
VOWEL	अ (அ) (a)	इ (இ) (i)	उ (உ) (u)	ऍ (எ) (ae)	ऐ (ஜ) (ai)	ओ (ஒ) (o)	औ (ஒள) (au)	अं (am)	अः (ः) (aha)

D

GESTURE										
PUNCTUATION	Period	Comma	Space	Next line	Question mark	Exclamation	Double quotes	Semi-colon	Delete word	Backspace character
	.	,	_	/n	?	!	"	;		

E

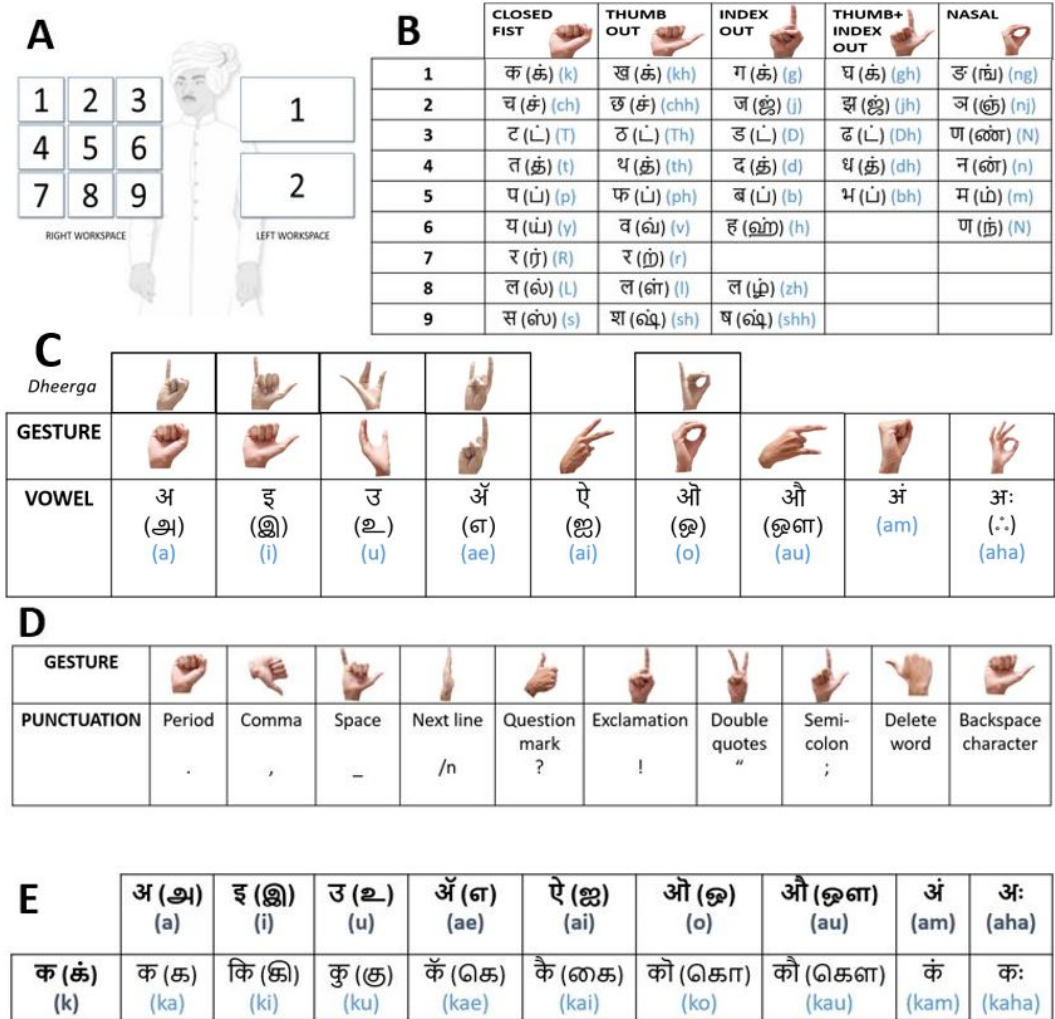| क (க்) (k)	अ (அ) (a)	इ (இ) (i)	उ (உ) (u)	ऍ (எ) (ae)	ऐ (ஜ) (ai)	ओ (ஒ) (o)	औ (ஒள) (au)	अं (am)	अः (aha)
	क (க) (ka)	कि (கி) (ki)	कु (கு) (ku)	कॅ (கெ) (kae)	कै (கை) (kai)	को (கொ) (ko)	कौ (கௌ) (kau)	कं (kam)	कः (kaha)

Fig. 1. (A) Positions used by the signer for the right and the left hand. Right workspace has 9 different positions for the consonants, while the left workspace has 2 positions (1 for vowel and 2 for punctuation), (B) The position (1 to 9) and gesture combination for consonants, (C) the gesture for vowels, (D) gesture for punctuation and (E) formulation of swarayukta akshara by combining consonant and vowel.

(A) **Consonant Akshara:** Phonetically, most consonants are plosives i.e. they are uttered as bursts [13]. In order to mimic the same, consonants are gestured as flashes. Nine positions and 5 different gestures are assigned to the consonant hand (see Fig 1 (B)). As is evident, 45 unique characters can be gestured using the consonant hand. Consonants with similar sounds are grouped together at one position and those with similar vocal chord features are signed using same gestures across the 9 positions.

(B) **Vowel Akshara:** Vowels can be uttered continuously without any pauses. Unique gestures are assigned to each vowel (see Fig 1 (C)) because the total number of vowels is much smaller than the number of consonants in all Indic scripts. Dheergas, the longer duration vowels, are signed by sticking the little finger out along with the corresponding gesture corresponding
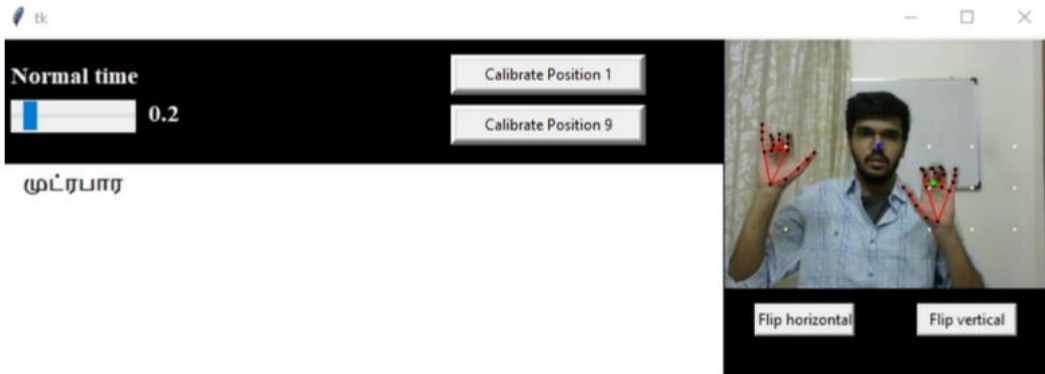
Fig. 2. User signing (right) in Mudrabharati fingerspelling (MFS) convention and the system returns the output in Tamil (left). Please see [10] for a sample video demonstration.

to the shorter duration vowel. The choice of gestures are motivated by the geometrical representation of vowels in Bharati script [11].

(C) **Swarayukta Akshara:** These sounds are produced by the combination of a consonant and a vowel akshara. Since the right hand is used to gesture consonants and the left hand is used to gesture vowels, the convention permits the signer to represent the swarayukta akshara without any difficulty by simultaneously gesturing the consonant akshara using the right hand and the vowel akshara using the left hand (see Fig 1 (E)).

(D) **Punctuation:** MFS accommodates punctuation as well. The lower workspace of the vowel hand (see Fig 1(A)) is used to represent 10 punctuation's (see Fig 1(D)). MFS uses the geometry of the punctuation, to assign a closely resembling gesture.

The complete alphabet set of Indic script, in MFS, can be gestured using both the left and the right hand. Unlike other fingerspelling system, where the gestures are based on the shape (or geometry) of the alphabets, the gestures in MFS are based on the articulation (or phonetic structure) of the alphabets. This, deviation from shape to represent an alphabet, not only makes it possible to gesture a large number of alphabet shapes, as is common in Indic scripts, but also makes the Mudrabharati fingerspelling (MFS) system independent of the language script (unified across most Indic languages). Thus, gestures in MFS are such that it is easy for people to recall the gesture-alphabet association and potentially gesture the large number of alphabets in Indic scripts with ease. Another important feature of MFS is the uniformity of the gestures across several Indic languages. This is important because a single fingerspelling system can be used across all the different language speaking regions in India.

The initial formulation of MFS presented in [1] did not have specific gestures to represent longish vowels, namely dheerga (see Fig 1(B)). A dheerga, in [1], was gestured using the corresponding short vowel gesture held for a *longer* duration. The dependence of MFS on the duration of a gesture to gesture a dheerga was seen as a limiting factor because it was dependent on the signer to differentiate between a short and a long vowel. In this version, additional gestures were introduced to represent dheergas (5 additional gestures) to eliminate signer dependency. These additional gestures, while requiring the signer to recall 5 additional gestures, made the overall MFS system robust and independent of the signer. A snapshot of a functional MFS system being used by one of the authors is shown in Fig 2 (see [10] for a sample video demonstration).

3 CONCLUSION

A large population in India do not speak English language and use their mother tongue to communicate. Today, because of lack of an alternative, the speaking and hearing impaired community, is forced to use ASL-based fingerspelling to spell Indic words. Indic characters are by design highly complex and ASL fails to do justice to gesture Indic characters. The only reason ASL is used, despite of it falling short of being able to gesture Indic alphabets, is because of its wide acceptance across different regions in India.

Mudrabharati fingerspelling (MFS) system overcomes all the aforementioned hurdles. MFS is a single fingerspelling system that can be used across most Indian languages. MFS can be used by the deaf people to communicate words, especially names of people or places, written in Indic scripts. From the point of view of Indian users, MFS removes the constraint on the vernacular user to be aware of English language to spell Indic words. This novel convention adopted in MFS is easy to remember and recall because it is based on the phonetic structure and not the geometric structure of the alphabet or character. The use of a single MFS across different Indian languages cuts down the need to learn an additional *language specific SL* to spell words (particularly proper nouns) in their native tongue.

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