Sarala - సరళ

An Ergonomic Keyboard Layout for Telugu Script

Krishna Dhullipalla
Chapel Hill, North Carolina, USA
krishnadvr@gmail.com
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***Abstract*—The sole purpose of a keyboard layout should be to minimize stress on the fingers. However, none of the keyboard layouts for typing Telugu script that are in use today, including the ISCII-91 Inscript Keyboard, are optimized for reducing stress on the fingers. This paper outlines certain principles and a methodology for creating a keyboard layout. It proposes a new keyboard layout called *Sarala* for the Telugu script which is based on those principles and the methodology. An optimized keyboard layout for Telugu script is essential at this historical juncture of exploding use of computers by Telugu people.**

I. Introduction

The era of writing by hand is drawing to a close and the era of typing on a computer keyboard is emerging at a blazing speed. We are going to spend increasingly more time typing on the keyboards and hence we are bound to experience stress on our fingers. The stress cannot be completely eliminated but can be significantly reduced with an ergonomically designed keyboard layout. An ergonomic keyboard layout maps the letters to the keys on the keyboard according to the frequency of use of the letters.

Currently, there is no keyboard layout that is specifically optimized for the Telugu Script. The most popular keyboard layouts supported by Anu Fonts [10], the popular desktop publishing software or the IME transliteration sequence used by Baraha [11] and Google[14] or the ISCII-91 Inscript Keyboard Overlay [1-3], which has become the de-facto standard are not optimized for Telugu script. These layouts are either adoptions of keyboard layouts of other languages or based on clustering letters based on phonetic or alphabetical affinities.

It is surprising that the need for an optimized keyboard layout for typing Telugu script did not get enough attention from agencies like Department of Electronics (DOE), Center for Development of Advanced Computing, Andhra Pradesh Official Language Commission, or Telugu university; or from computer operating system manufacturers like Microsoft, Sun Microsystems, Apple and IBM. Even if there were efforts by these agencies, they are certainly not available readily.

In this paper, we will present a keyboard layout optimized for Telugu script with ergonomic considerations to reduce stress on fingers.

II. Definitions

Let us begin with defining certain terms, phrases and concepts related to keyboards and language scripts.

Unicode Consortium decomposes [12] Telugu script into various categories. They identify Signs like *sunna* (ం), Independent Vowels like *aa* (ఆ), Consonants like cha (చ), Dependant Vowel Signs like *aa* (ా), Digits like 2 (౨), Historic Variants like *tsa* (ఀ) and additions for Sanskrit like *avagraha* (ఽ). We will use the collective word '*letter*' to refer to all of them.

The Dependant vowel signs are known as *gunintam* or *matras.* We will use the word *matra* in this paper for the dependant vowel signs. Unicode does not have separate codes for free-standing *vattulu* , since they were achieved by the fonts at the time of rendering the glyphs.

Keyboards are generally equipped with two states. Each key in the keyboard can represent two different letters, one for each of the two states. One of the states is the default or normal state. We will refer to this as the BASE State. The other state of the keyboard, which we will refer to as SHIFT State, is achieved by depressing a key while the key labeled 'SHIFT' is in the depressed position.

We will refer to a key on the keyboard by prefixing 'Key_' to the English letter or other special character that it represents on the standard English keyboard. As an example, 'Key_L' is used to refer to the key labeled with 'L' on the Standard English keyboard.

We will refer to the row of keys containing the keys, Key_A, Key_F, Key_L, etc., as the *Home Row*, because fingers are traditionally rested on the keys in this row.

We will use the phrase 'ease of use rating' or *EOU rating* to denote the ease with which a key on the keyboard can be reached and depressed by the fingers.

We will use the phrase ' frequency of use' or *FOU* to denote the frequency with which a letter is used in writing a book or an article or a document.

III. Usage Frequency of Telugu Letters

It is necessary to understand the frequency of use of Telugu letters before designing the keyboard layout for Telugu script.

For this purpose, a large sample of Telugu text in Unicode was collected from various websites [7-9] consisting of more than 3,00,000 letters, equivalent to more than 150 A4 size pages in print. This sample consisted of various types of contemporary writings such as fictional prose, poetry, news items, movie reviews, essays on computer technology, articles about business, letters and opinions, astrology, *vasstu* and classic literature. The sample also included non-Telugu (e.g. English and Hindi) words that are often written in Telugu script.

A Java program was developed to profile the number of occurrences of each Telugu letter and punctuation marks such as period, comma and quotation marks in the sample text. Table 1 shows the results of the profile:

TABLE I

USAGE FREQUENCY OF THE LETTERS

ి	్	ా	ు	న
7.85%	7.81%	6.86%	6.27%	6.00%
ర	ం	క	ల	త
5.10%	4.69%	4.35%	4.29%	3.63%
వ	ప	ద	మ	స
3.01%	2.95%	2.70%	2.58%	2.51%
చ	ే	య	గ	ో
2.26%	2.11%	2.09%	1.99%	1.96%
ట	డ	.	ీ	అ
1.88%	1.86%	1.57%	1.18%	1.17%
ె	ూ	,	శ	జ
1.00%	0.92%	0.79%	0.62%	0.61%
బ	ొ	హ	ష	ధ
0.60%	0.51%	0.49%	0.46%	0.45%
ళ	భ	ణ	ై	ఆ
0.44%	0.43%	0.42%	0.41%	0.40%
ఇ	ఉ	థ	ఎ	ఈ
0.34%	0.33%	0.24%	0.24%	0.20%
ృ	"	ఒ	ఏ	ఖ
0.20%	0.18%	0.18%	0.13%	0.13%
'	ఫ	?	ఓ	ౌ
0.13%	0.09%	0.08%	0.05%	0.04%
ఁ	ఘ	ఠ	ఇ	ఊ
0.03%	0.03%	0.03%	0.02%	0.02%
ఐ	అ	ఛ	ఢ	ః
0.02%	0.02%	0.01%	0.01%	0.01%
ఋ	ఙ	ఝ	ఔ	ఒ
0.00%	0.00%	0.00%	0.00%	0.00%
్యా	ఱూ	ఴ	ఄ	
0.00%	0.00%	0.00%	0.00%	

The percentage below each letter in Table 1 indicates the frequency of the usage (FOU) of the letter or punctuation mark in the sample text. The table shows the letters in the decreasing order of frequency of use (FOU). The letters towards the end of the table show a frequency of 0.00%, even though there are few occurrences of those letters, because the results were truncated to two decimal points of precision in this table.

The profile in the above table gives the following insight into the usage frequency of Telugu letters in contemporary writing:

a) No letter is used more than 8% of the time.
b) Only 11 letters are used more than 3% of the time.
c) The top four letters used are the *matras* ి, ా, ు, and the '*pollu*', ్, which is used for joining two consonants. These four letters account for almost a third of the usage time, 31.02%, to be precise.
d) The combined usage of all the other *matras*, other than the ా, ి, ు, is less than 9%.
e) Only thirteen letters, ి, ్, ా, ు, న, ర, ం, క, ల, త, వ, ప, ద are used for two-thirds of the time, 65.51% to be precise.
f) The long *matra* ీ at 2.11% is used more than twice as many times as the corresponding short *matra* ి, which is used only 1.00% of the time. The long *matra* ో at 1.96% is used almost four times as often as the short *matra* ొ, which is used only 0.51% of the time,
g) The nasal consonant ఞ and the vowels ఊ, ఐ are used at a very low and equal frequency of 0.02%,
h) The combined usage of the letters ఒ, ఏ, ఓ, ఊ, ఐ, ఔ, ౌ, ఁ, ః, ఖ, ఫ, ఱ, ఛ, ఢ, ఘ, ఠ, ఞ, ఙ, ఝ, ఴ, is less than 1%.

It is clear from this profile that very few letters have high FOU, a small number of letters have medium FOU and a large number of letters have low or very low FOU. This pattern is specific to Telugu script and the pattern could vary for other language scripts.

IV. Ease of Use Rating

Ease of use rating for any given key should be assigned based on the effort needed to *reach* the key and the effort needed to *depress* the key. The combined effort is directly proportional to the finger movement required to reach the key and indirectly proportional to the strength of the specific finger. We will examine these factors in detail below in order to assign ease of use rating for each key.

First, let us note that there is a difference between the mechanical keyboards of the typewriter era and electronic keyboards of the computer era. The rows of keys are at different elevation on the typewriter keyboards while they are at almost the same elevation on the computer keyboards. Keys on computer keyboards need lighter touch than their counter parts on the mechanical typewriters. Keeping the fingers in the air and depressing the keys vertically is a common practice with the typewriter keyboards. Resting the fingers on a pad or on a flat surface and tapping the keys at an angle is the common practice with the computer keyboards. Because of these differences, the ease of use ratings for keys may differ between typewriter keyboards and computer keyboards. Our focus here is on the ease of use ratings for computer keyboards only. Hence the observations below are pertinent to computer keyboards only.

Fingers can be moved in certain directions easier than in certain other directions. The middle finger, for example, being the longest one, can more easily stretch upwards to reach the Key_I, than it can bend itself to reach the Key_M. This argues for a higher ease of use rating for Key_I compared to Key_M. Similarly the index finger can move downward to reach to the key Key_N easier than it can move upward to reach the key Key_U because of the natural curved resting position of the fingers. This argues for a higher ease of use rating for Key_N compared to Key_U. However, the finger is in stretched position to tap Key_U and is in a bent position to depress the Key_N, which argues for higher ease of use for Key_U than Key_N. On the whole the ease of use for Key_U and Key_N can be considered the same.

If we agree that tapping at an angle is a more natural activity for fingers than depressing vertically, especially, when they are rested in a horizontal position, we could argue that Key_O would cause less or same stress on the ring finger as does Key_L. Similar observations can be made about keys reached by other fingers.

Index and middle fingers tend to have more strength than ring and little fingers. This argues, as an example, for higher ease of use rating for Key_D compared to Key_A.

The distances that a finger needs to move in order to reach various keys are not identical. Index finger, for example, has to stretch farther to reach Key_Y than to reach Key_U. Tapping Key_Y causes more stress than tapping Key_U, not only because of the stretching distance, but also because the finger would be weaker in the too outstretched position. This argues for higher ease of use for Key_U compared to the Key_Y.

Table 2 below, gives the Ease of use ratings (EOU rating) for each key based on the observations above.

TABLE II

EASE OF USE RATING

Keys	Ease of Use Rating
Key_F, Key_J, Key_D, Key_K,	11
Key_U, Key_R, Key_V, Key_N	10
Key_T, Key_S, Key_L	9
Key_E, Key_I, Key_ W, Key_O	8
Key_ G, Key_H	7
Key_ A, Key_;	6
Key_M, Key_B, Key_P	5
Key_C, Key_,	4
Key_Q, Key_Y	3
Key_X, Key_.	2
Key_Z, Key_/	1
All other keys	0

Higher ease of use (EOU) rating implies lower stress on the fingers and lower ease of use (EOU) rating implies higher stress on the fingers.

The rating in the above table has ordinal value, but has no cardinal value. In other words, higher rating implies higher ease of use, but not necessarily in proportion to the number. For example Key_U has a rating of 1o and KEY_M has a rating of 5. That does not mean Key_F is twice as easy to use compared to Key_F. It simply means Key_F is easier to use than Key_T.

The ratings given to the keys in Table 2 are based on the above mentioned common sense observations. Hence, some one other than the author might assign slightly different ratings for the keys, but it is difficult to conceive that they will be drastically different from the ratings in the table.

V. ISCII-91 Inscript Keyboard Layout

We noted earlier that the keyboards that are not currently in use are not optimized for minimizing the stress on fingers. We will now take Inscript keyboard as an example and discuss why it is not optimized for minimizing the stress on fingers.

The Inscript keyboard overlay was standardized by Department of Electronics (DOE) in 1986 and was revised in 1988 [1]. This Keyboard overlay became the de-facto standard since then. It has been included by all the major computer manufacturers including Microsoft [4], Sun Microsystems [5] and IBM [6], as the default Keyboard layout for Indian languages in their respective operating systems. The Inscript Keyboard layout [2] for Telugu is shown below in Fig 1. for easy reference.

Fig 1. Inscript Keyboard Layout

The primary design factors of this keyboard layout seem to be two fold: first, maintaining similarity with the Hindi Keyboard and second, assigning related letters to a cluster of keys. We will now analyze the consequences of this approach in detail.

The Inscript keyboard layout assigns all the *matras* and vowels to the left side keys and the consonants to the right side keys. It places vowels according to their phonetic affinities (such as long matras above the short matras) with in their cluster and consonants according their *varga* affinities (such as placing గ above క) with in their cluster [1-3]. This assignment appeals to the instinct of orderly arrangement of letters. It makes it possible for the eyes to locate the letters easily on the keyboard.

If this principle of 'clustering related letters' had been followed by the creators of QWERTY keyboard, there would have never been a key board called QWERTY keyboard! All vowels of the Roman alphabet would have been clustered together in one area of the keyboard and all the consonants would have been clustered in another area of the keyboard, perhaps, in a neat alphabetical order!

The inscript layout also fails to balance the use of fingers of left hand side and right hand side. For example, the *matra ai* (ై) and the consonant *da* (ద) are assigned to keys Key_W and Key_O, which correspond to the ring fingers on the left and right. With this mapping the right hand ring finger, corresponding to the letter ద, is used 6.5 times more than the left hand ring finger, corresponding to the matra, ై. Similar imbalances can be observed between several keys on the left and right sides of the keyboard by comparing the FOU ratings from Table 1.

The Inscript keyboard layout is uniform across all Indian languages, but it is only optimized for the frequency of usage of letters in Hindi. For example, the letter *ha* (హ), with high frequency of use in Hindi, is rightly assigned to the high ease of use Key_U. But the corresponding letter in Telugu (హ) is used with a very, very low frequency of 0.49% and it is not optimal to assign it to the high ease of use Key_U. Similarly, the *matra ai* is used in Hindi (ै) with a very high frequency and is rightly assigned to the high ease of use Key_E. But the corresponding *matra* in Telugu (ై) is used at a very, very low frequency of 0.41% and it is not optimal to assign it to the high ease of use Key_W.

There are more examples of less than optimal use in the Inscript keyboard. *Sunna* (ం), which is the 9th most used letter with a frequency of 4.72%, is assigned to a very low Ease Of Use Key_X. The letter *ya* (య) which is in the top 18 most used letters with a frequency of 2.09% is assigned to a low ease of use Key_/. The *matra* au (ౌ) which is almost unused in Telugu at 0.04% is assigned to a relatively high ease of use Key_Q. The frequently used punctuation mark such as quotation mark is replaced with the letter *Ta* (ట) making the quotation marks unavailable for easy use, even though the frequency of quotation marks surpasses 16 other Telugu letters.

If the principle of creating identical keyboard layouts for related languages were followed, there would have been no such thing as a French keyboard. They would have used English keyboard because they share the same alphabet.

A common keyboard layout for multiple languages or scripts is viable only if the frequencies of the use of the letters in all the languages are similar. Otherwise, the keyboard will minimize the stress for the users of one language only and creates additional stress for users of all other languages.

Inscript is a suitable standard for Hindi language only, as it is tuned for that language and independent effort is required to create standard layouts for each of the other Indian Languages including Telugu. Said in other words, with the Inscript keyboard, the work is done for Hindi, the work is yet to be done for other Indian Languages like Telugu.

VI. *Sarala* Keyboard Layout

The author designed the *Sarala* keyboard layout ground up, without the influence of other existing keyboard layouts, by

following clearly defined principles of design and using a clearly defined methodology for assigning letters to the keys.

A. Design Principles

The following design principles were followed in the design of *Sarala* layout, which could be generically used in the design of a keyboard for any language or script:

a) Assign letters with higher frequency of use (FOU) to keys with higher ease of use (EOU) rating and letters with lower frequency of use (FOU) to keys with lower ease of use (EOU) rating. This is the primary design principle, directly aimed at minimizing stress on the fingers.

b) Assign the frequently used punctuation marks and numerals to their standard keys as far as possible.

c) Do not force a group of letters with phonetic, alphabetical or linguistic affinities to a cluster of keys artificially. Keyboard layout need not appeal to the instincts of orderly arrangement or to the eyes. Fingers, with sufficient practice, can 'remember' any letter at any position of the keyboard. The ability of large numbers of the world population to use the QWERTY standard keyboard layout without any problem, even though the letters are in no particular order, speaks for the importance of this principle.

d) Do not try to align a keyboard layout to the keyboard layouts of other languages because the alphabets are similar. Even though Telugu and Kannada have very similar alphabets, they do not share the same frequency of use of letters. For example, the use of *ba* (ಬ) and *ha* (ಹ) in Kannada is far higher than in Telugu. It should be noted that French and English keyboard layouts are not aligned with each other even though they share the same alphabet.

e) Balance the use of fingers on the left and right hands. Balance the use of index, middle, ring and little fingers according their proportional strengths. Do not overload any one finger excessively.

The principles listed above should be observed as the primary principles. In addition to them, the following secondary principles should be considered as far as possible:

f) Consider phonetic, alphabetical and linguistic affinities between pairs of Letters assigned to the BASE and SHIFT states of the same key.

g) Consider phonetic, alphabetical and linguistic affinities among letters assigned to the same finger.

h) Consider phonetic, alphabetical and linguistic affinities of Telugu letters with English letters. For example, after meeting the primary principles, we may consider assigning the letter 'ಲ' to Key_L, 'ತ' to Key_T and so on, as it is very common for Telugu people to switch between Telugu keyboard and the QWERTY keyboard. However, this should be done only in keeping the primary design principles (a) to (e) in view.

Thus the essence of the design principles is to focus on reducing the stress on fingers while keeping other reasonable considerations in mind.

B. Design Methodology

The following four step methodology is used in the design of the *Sarala* keyboard layout, which could be generically used in the design of a keyboard for any language or script.

a) Determine the frequency of use (FOU) of each letter. (Presented section III.)

b) Determine the ease of use (EOU) rating for each key on the keyboard. (Presented in section IV.)

c) Pair the letters to be assigned to the BASE and SHIFT states of the same key. (Presented in section VI.C.)

d) Finally, assign each pair of letters to a key based on the FOU of the letter and the EOU of the key. (Presented in section VI.D.)

C. Determining the Letter Pairs

The standard keyboard does not have enough keys to accommodate the more than 70 letters and punctuation marks shown in Table 1. Hence it is imperative that some letters need to be assigned to the SHIFT state of the keys.

The profile in Table 1 shows that only 27 letters, out of the more than 70 letters and punctuation marks, are used 90% of the time. This means that almost all of the frequently used letters can be accommodated in the BASE state of the keys.

Table 3 below shows the pairing of 'frequently used letters' with 'infrequently used letters' using the frequencies shown in Table 1 and observing the design principles (b) and (c) from the section VI.B above.

TABLE III

LETTER PAIRS FOR BASE AND SHIFT STATES

BASE	SHIFT	BASE	SHIFT	BASE	SHIFT
್	ಅ	ಕ	ಖ	'	"
ಾ	ಆ	ಗ	ಘ	.	ಜ
ಿ	ಇ	ಚ	ಛ	,	ಞ
ೀ	ಈ	ಜ	ಝ		
ು	ಉ	ಟ	ಠ		
ೂ	ಊ	ಡ	ಢ		
ೆ	ಎ	ತ	ಥ		
ೇ	ಏ	ದ	ಧ		

ై	ఐ	న	ణ	
ొ	ఒ	ప	ఫ	
ో	ఓ	బ	భ	
ా	ఔ	మ	ఁ	
ృ	ఋ	య	ఽ	
ౄ	ౠ	ర	ఱ	
ం	ః	ల	ళ	
అ	ఆ	వ	హ	
		శ	?	
		స	ష	

As is evident from Table 3, the *matras* are paired with the corresponding vowels. *Varga* letters such as *ka* (క), *pa* (ప) are paired with the corresponding aspirants *kha* (ఖ) and *pha* (ఫ). Other most frequently used and least frequently used letters are paired based on their phonetic affinity to the extant possible. Very infrequently used letters such as *jna* (�జ) and *cna* (ఞ) are paired with most frequently used punctuation marks, period and comma.

The combined frequency measure of the paired letters is shown in the following Table 4.

TABLE IV

COMBINED FREQUENCY OF USE OF PAIRED LETTERS

Letters with High Frequency of use	Letters with Low Frequency of use	Frequency of use for both letters combined
్	అ	8.97%
ి	ఇ	8.20%
ా	ఆ	7.26%
ు	ఉ	6.60%
న	ణ	6.41%
ర	ఱ	5.12%
ల	ళ	4.73%
ం	ః	4.69%
క	ఖ	4.48%
త	థ	3.87%
వ	హ	3.51%
ద	ధ	3.15%
ప	ఫ	3.04%
స	ష	2.97%
మ	ఁ	2.62%
చ	ఛ	2.28%
ే	ఏ	2.24%
య	ఽ	2.09%
గ	ఘ	2.02%
ో	ఓ	2.02%
ట	ఠ	1.90%
డ	ఢ	1.86%
.	ఙ	1.58%
ీ	ఈ	1.38%
ె	ఎ	1.23%
బ	భ	1.03%
ూ	ఊ	0.95%
,	ఞ	0.82%
శ	?	0.70%
ొ	ఒ	0.69%
ఙ	ఝ	0.61%
ై	ఐ	0.43%
ృ	ఋ	0.20%
'	"	0.31%
ా	ఔ	0.05%
ౄ	ౠ	0.00%

D. Assignment of the Letters to the Keys

The standard keyboard has only 26 letter keys, Key_A through Key_Z, but Table 4 has more than 26 pairs. Hence, it is imperative that some letters need to be assigned to keys that are used for punctuation marks or special characters.

Table 5 gives the letter to key mapping in the alphabetical order of Telugu alphabet based on the key ratings shown in Table 2 and frequency of use measures shown in Table 4.

TABLE V

ASSIGNMENT OF LETTERS TO KEYS

	Key_F	Key_J	Key_I	Key_Y	Key_U	Key_X
BASE	్	ా	ి	ీ	ు	ూ
SHIFT	అ	ఆ	ఇ	ఈ	ఉ	ఊ
	Key_Q	**Key_E**	**Key_]**	**Key_Z**	**Key_O**	**Key_**
BASE	ె	ే	ై	ొ	ో	ౌ
SHIFT	ఎ	ఏ	ఐ	ఒ	ఓ	ఔ
ATLCTRL			]			\
ATLCTRLSHFT			}			|
	Key_K	**Key_G**	**Key_H**	**Key_[**	**Key_;**	**Key_C**
BASE	క	గ	చ	జ	ట	డ
SHIFT	ఖ	ఘ	ఛ	ఝ	ఠ	ఢ
ATLCTRL			చ్	[		
ATLCTRLSHFT			ఛ్	{		
	Key_T	**Key_D**	**Key_N**	**Key_P**	**Key_B**	**Key_M**
BASE	త	ద	న	ప	బ	మ
SHIFT	థ	ధ	ణ	ఫ	భ	ఁ

	Key_A	Key_R	Key_L	Key_V	Key_W	Key_S
BASE	య	ర	ల	వ	స	ం
SHIFT	ఒ	ఱ	ళ	హ	ష	ః
ATLCTRL		్యా	ఴ			
ATLCTRLSHFT		ూ	ఀ			
	Key_/	Key_.	Key_,	Key_`		
BASE	శ	.	,	్		
SHIFT	?	ఙ	ఞ	ఋ		
ATLCTRL		<	>	`		
ATLCTRLSHFT				~		
	Key_`	Key_1	Key_2	Key_3	Key_4	Key_5
BASE	`	1	2	3	4	5
SHIFT	~	!	@	#	$	%
ATLCTRL		౧	౨	౩	౪	౫
KEY	Key_6	Key_7	Key_8	Key_9	Key_0	Key_-
BASE	6	7	8	9	0	-
SHIFT	^	&	*	(	)	_
ATLCTRL	౬	౭	౮	౯	౦	

The ATLCTRL used in the above table indicates an additional state for the keyboard that is achieved by depressing ALT and CTRL keys simultaneously on a standard PC keyboard. The ATLCTRLSHIFT gives one more additional state for the keyboard that is achieved by depressing ALT, CTRL and SHIFT keys simultaneously on a standard PC keyboard.

E. Sarala Layout

The resulting keyboard layout using the key assignments in the Table 4 is shown in Fig 2.

Fig 2. *Sarala* Keyboard Layout Overlay

A few key features of the *Sarala* keyboard layout are outlined below:

a) The right hand and left hand fingers are used almost equal amount of time at 55.4% and 44.6% respectively, balancing the stress on left and right hands, making it friendly for both left-handed and right-handed persons.

b) The index, middle, ring and little fingers are used on a decreasing scale of 48.44%, 22.54%, 16.17%, and 12.84% of the time respectively.

c) There is no need to use SHIFT key for 93.33% of the time.

d) Frequently used punctuation characters such as period, comma, quotation marks, hyphen and question mark are assigned to their respective standard keys.

e) Only one key (Key_`) in the fourth row is used for letters. All the numerals and the corresponding special characters in the SHIFT state are left in their standard positions. The Telugu numerals, which are used very infrequently, are assigned to the respective keys in the ATLCTRL state.

f) Where letters are assigned to a key that originally has special characters on the keyboard, such as colon, the same special characters are mapped to the ATLCTRL and ATLCTRLSHFT states.

g) Sarala has 65% phonetic similarity with QWERTY keyboard, i.e., క is assigned to Key_K, ర is assigned to Key_R, etc.

Sarala keyboard layout follows all the design principles from Section VI. B. Each letter is assigned based on its frequency of use (FOU) to a key based on the ease of use (EOU) of the key to minimize the stress on fingers while typing in Telugu.

VII. ADAPTING *SARALA* KEYBOARD LAYOUT

In the experience of the author and friends of the author, the time taken to get used to the *Sarala* layout was insignificant; a mere one to two weeks of typing fifteen pages of Telugu text using the new layout.

The learning curve can be made faster and smoother by using aids such as keyboard overlay sheets printed with Telugu Letters showing the *Sarala* layout or floating on-screen soft keyboards showing the *Sarala* layout.

Sarala keyboard layout can be added to a PC running Windows XP or Windows Vista operating systems by running a simple install program according to the accompanying instructions available from the author and from other download sites. One can switch back and forth between *Sarala* layout and standard English layout by simply pressing the ALT+SHIFT keys or CTRL+SHFT keys depending on the configuration.

In course of time, technologies should make it easy and possible to add this keyboard layout to computers running other operating systems like Mac OS or Linux.

Tips to familiarize oneself with Sarala layout:

The following simple aspects of *Sarala* layout may help one in easily familiarizing oneself with the keyboard:

a) Sixteen letters, which account for almost 65% of the usage, క, గ, చ, త, ద, ప, బ, న, మ, ర, ల, వ, ి, ీ, ు, ే, ో, are assigned to keys with similar phonetics on the

QWERTY layout. క is assigned to Key_K, గ to Key_G, చ is to Key_H, త to Key_T, ద to Key_D, న to Key_N, ప to Key_P, బ to Key_B, మ to Key_M, ర to Key_R, ల is Key_L, వ to Key_V, ి to Key_I, ీ to Key_Y, ు to Key_U, ే to Key_E, ో to Key_O. This assignment, while preserving all the design principles, makes it is to transition from QWERTY to *Sarala* layout and then switch back and forth.

b) డ is assigned to Key_C, the same finger as Key_D. స is assigned to Key_W, the same finger as Key_S.

VIII. Conclusion And Recommendations

It is unfortunate that the Inscript layout for Telugu, which became the de-facto standard did not consider the minimization of stress on the fingers as a key design factor.

The need for ergonomic keyboard layout is not specific to Telugu Language but to all languages. Keyboard layouts should be designed for all other Indian languages also based on the design principles and methodology outlined in this paper to minimize stress on the fingers for people using other language scripts.

The ease of use ratings used in this paper are based on common sense observations and not on thorough scientific investigations. Organizations involved and interested in Computing in Indian Languages should consider such scientific studies. They could fine tune the *Sarala* layout, if needed, based on the results of their studies.

Before too many people get used to the suboptimal Inscript keyboard layout, which could happen rapidly in the wake of Microsoft making it available on all Windows XP, Vista and Windows 7 based systems as the default layout, we must attempt at making ergonomic keyboard layout like *Sarala* available to every one. This is an historic opportunity that should not be passed by.

An ergonomic keyboard layout could be conceived and designed by a single individual like this author, but it cannot be made popular and acceptable for Telugu people at large without avowed interest and involvement of major organizations in the cause of reducing stress on the fingers. CDAC and DOE should consider endorsing the *Sarala* keyboard layout as 'the standard' or at least as 'a standard' for typing Telugu script. Technology providers like Microsoft, IBM, Sun Microsystems, Apple, Red Hat and Ubuntu should consider adding *Sarala* keyboard layout to the list of keyboards available with their respective operating systems and other software by default.

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