Keypad for Large Letter-Set Languages and Small Touch-Screen Devices (Case Study: Urdu)

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Abstract

Composing Urdu is a thorny task on touch-screen devices particularly handheld modern devices such as smart phones and PDAs. Design and development of optimal keypad for Urdu composing is complicated due to its relatively large letter-set. Conventional QWERTY replica keypad has migrated from computers to small screen devices. The multi-tap T9 keypads are also in use. These have raised grave issues in composing Urdu text on small touch-screen devices. Last but not the least, health concerns have been ignored in development of input systems for Urdu and other languages with large letter-sets.

We developed a novel keypad for Urdu that has been optimized for accurate, easy, speedy and efficient typing on small touch-screen handheld gadgets. We carefully designed our proposed keypad so that it offers better visibility, usability, extendibility, aesthetics and user friendliness. We also took the users' health issues into account at the design time of our suggested keypad.

The evaluation through applying automated procedures, our proposed keypad showed improvement by 52.62% over the existing keypads. In addition to automated procedures, we carried out the users evaluation for real world performance comparison between our proposed keypad and in-the-market generic keypads. Our proposed keypad is optimized for Urdu. However it is applicable to Arabic, Persian, Punjabi and other Perso-Arabic script languages. With minor changes in the backend script settings, our proposed keypad is applicable to non-Perso-Arabic script languages with larger letter-sets e.g. Hindi etc.

Keywords: *Urdu Touch-Screen Keypads, Urdu Smart Phones input, Urdu Input Method Editor, Hygienic Design, Perso-Arabic Script Input.*

1. Introduction

In line with the growth of touch screen devices, IMEs (Input Method Editor/Environment) and on-screen/virtual keyboards have been hot areas of research lately (Ko et al. 2011; Jennifer Mankoff and Gregory D. Abowd, 1998; Andrew Sears et al. 2001). Composing Urdu on generic touch screen gadgets and PDA (Personal Digital Assistant) is a thorny job. Many modern gadgets either lack a good interface for typing Urdu e.g. Apple iPhone, or provide sluggish, inconvenient and hard to use keypads. There is no widely used agreed-upon keyboard or IME for Urdu (Asad Habib et al. 2011). We live in the age of touch screen gadgets. The future trends also show promising growth for them. Currently available input systems developed for standard PCs have room for improvement in efficiency, visibility and usability etc. The English QWERTY type keypads are not suitable for data input of languages with relatively large letter-sets. This concern becomes graver for non-Roman script languages such as Urdu and other Perso-Arabic script languages. Although it is spoken by a large population, the presence of Urdu is quite limited on the WWW. Among others, one of the reasons is the difficulty in composing Urdu on modern computers particularly the touch screen devices. This problem gets more critical on small screen handheld gadgets.

We developed a novel keypad for Urdu that is compliant with five golden principles of Ergonomics i.e. Performance, Ease, Aesthetics, Comfort and Safety. Our suggested keypad has been optimized for accurate, easy, speedy and efficient typing on small touch-screen handheld gadgets. We carefully designed our proposed keypad so that it offers better visibility, usability, aesthetics and user friendliness. Our optimization technique for arrangement of alphabets and unique interface for data input is extendable and equally applicable to other natural languages with large letter-set, in particular the Perso-Arabic script languages such as Sindhi, Kashmiri, Punjabi, Pashto etc.

For evaluation of our novel proposed keypad, we performed two types of evaluations; a) Automated evaluation procedure b) Users evaluation. Our automated experiments on a large Urdu corpus reveal more than 52% improvement over contemporary keypads available in the market. We also carried out real world analysis through users evaluation.

The results of our evaluation are discussed in much detail in Section 7. The rest of the paper is organized as follows. Section 2 illustrates numerous character level NLP (Natural Language Processing) applications. Section 3 discusses Urdu language. It explains important issues related to Urdu text input and the challenges to develop Urdu IME. Section 4 is about additional design parameters. The Urdu keypads currently in use and our proposed keypad are discussed in Section 5. Experiments, model and methodology are discussed in Section 6. Section 7 is about comparison and evaluation of the proposed keypad. Section 8 concludes the paper. Future directions are mentioned in Section 9.

2 Character-Level NLP Applications

NLP is a vast field of study. It has applications at numerous levels. These levels include inter sentential applications such as discourse analysis, sentence level applications and intra sentential applications e.g. phrase or words analysis etc.

NLP also deals with various applications at the "character level" as shown in Figure 1. These include Script Generation, Romanization, Transliteration, Transcription and Development of IME, keypads and their Graphical User Interface Designs etc. This research targets on the latter applications of character-level. We have come up with novel keypad for text input on small touch screen devices such as mobile phones and PDAs. Our proposed keypad is explained in detail in Section 5.

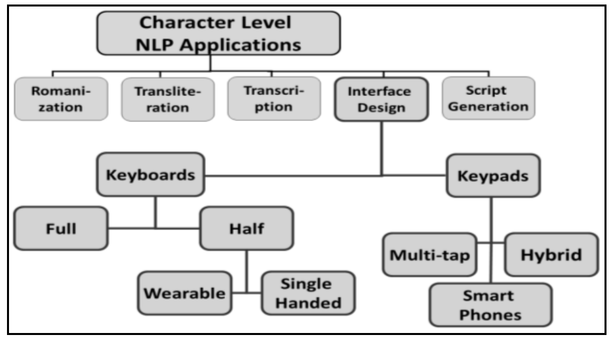

Fig. 1 Character level applications of NLP.

3. Urdu

Urdu is the national language of Pakistan and an official language of some states in India e.g. Uttar Pradesh (India's most populous state). Urdu is the Lingua franca of Indo-Pak subcontinent and spoken in various parts of the world due to the large South Asian Diaspora. Urdu has many interesting integral linguistic features such as rich morphology etc. Some salient features of Urdu language are mentioned as follows.

3.1 Size of Urdu

Urdu is the national language of Pakistan. It belongs to the language family of central Indo-Aryan language (Colin P. Masica, Cambridge Language Survey, 1993). It is spoken by a large population of speakers across a score of countries. Urdu is written from right to left in Perso-Arabic script. Its grammar is both gender and number sensitive. It is the 2nd largest Arabic script language according to the number of speakers (Lewis, 2009; Weber 1999).

Phonetically, Urdu is quite similar to Hindi. Written Urdu and Hindi use different and mutually exclusive scripts. However, in spoken they appear to be the same language. Rai and Alok (2000) stated, “One man’s Hindi is another man’s Urdu”. Hindi is written in Devanagri script while Urdu is written in Perso-Arabic script. Ethnologue (Lewis, 2009) considered Urdu and Hindi as the same language and ranked it the 5th largest language of the world according to the number of speakers. The numbers of Urdu and Hindi speakers are given by Table 1 (Malik et. al. 2009).

Table 1: Hindi and Urdu Speakers

	Native Speakers	***2nd Language Speakers***	***Total***
Hindi	366,000,000	487,000,000	853,000,000
Urdu	60,290,000	104,000,000	164,290,000
Total	426,290,000	591,000,000	**1,017,000,000**

3.2 Urdu Script

Here the term script refers to the continuous natural and native way of writing Urdu text. Based on the correct and appropriate shapes of individual letters Urdu ligatures, words, phrases and sentences are formed. Collectively all of these are referred to as Urdu script.

Urdu is written from right to left. Arabic has 28 base letters while Persian has 32 letters. Both Arabic and Persian letter-sets are subsets of Urdu. However, the exact number of Urdu letters is not agreed upon. Numerous articles report different numbers of letters (Ijaz and Hussain, 2007; Malik et al. 1997; Habib et al. 2010). The largest letter set contains 58 letters (NLA Pak). It is shown in the following Figure 2.

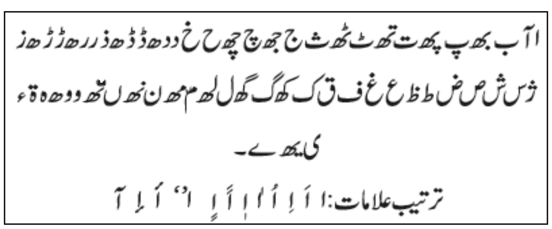

Fig. 2 The 58 letters-set of Urdu alphabets.

According to Afzal and Hussain Urdu alphabet has 57 letters and 15 diacritical marks (Afzal and Hussain, 2001). Hussain (2004) reported 41 letters in Urdu. Ijaz and Hussain (2007) mentioned 56 letters. Habib et al. (2010) reduced the Urdu letter-set to 38 basic letters that are shown in Table 2.

Table 2: Basic 38 Urdu letters and their corresponding Roman letters for Romanization

Roman Letters	***Urdu Letters***	***No.***
a,e	ا	1
~	آ	2
b	ب	3
p	پ	4
T	ت	5
t	ٹ	6
S	ث	7
j	ج	8
C	چ	9
H	ح	10
K	خ	11
D	د	12
d	ڈ	13
Z	ذ	14
r	ر	15
R	ڑ	16
z	ز	17
J	ژ	18
s	س	19
sx	ش	20
Sx	ص	21
Zx	ض	22
Tx	ط	23
zx	ظ	24
3	ع	25
G	غ	26
f	ف	27
q	ق	28
k	ک	29
g	گ	30
l	ل	31
m	م	32
n, N	ن،ں	33
o,v,w	و	34
h	ہ،ھ	35
’	ء	36
y	ی	37
Y	ے	38

Urdu has no distinct upper and lower case letter forms. However the Romanization scheme shown in Table 2 (Habib et al. 2010) is case-sensitive (Roman letters only) that helps in distinguishing the correct Urdu pronunciation. The table is arranged for reading from right-to-left in order to comply with the native Urdu reading style. Each Urdu letter is mentioned along its respective letter used for Romanization. Lower-case Roman letters represent the pronunciations exactly similar to their respective pronunciations in English. Upper-case letters represent similar but non-equal English pronunciation for the same letter.

Designing optimized Urdu keypads for small screen widgets is a knotty problem. Relatively large letter-set and no agreement over the total number of letters in Urdu alphabet make the problem more complex. In addition to the 58 letters shown in Figure 2, Ligatures and Diacritics are also borrowed from Arabic in Urdu. Ligatures are fixed blocks of letters each represented by a single Unicode. The unigram frequencies of Ligatures and Diacritics are very low. Therefore we allocated them a single button on our proposed keyboard layout. Diacritics are another set of low frequency characters. They are small macron-like characters normally used to show the correct pronunciation of letters in a word. Both the Ligatures and Diacritics are used mostly in religious texts that have become part of Urdu but they have been originally borrowed from Arabic and Persian.

3.3 Contextual shape changes of Urdu letters

Urdu letters change their shape based on their respective positions inside a word. A letter can have up to four different shapes i.e. base, initial, medial and final shapes.

Example:
A letter is in its base shape when it appears alone as a disjoint letter e.g. the letter "ج" pronounced as ***jim*** with IPA (International Phonetic Alphabet) "**[d͡ʒ]**" . Rest of the three shapes of "ج" are shown in Figure 3.

Fig 3 Contextual shape changes of letter "ج"

Initial shape refers to the shape of a letter when it appears in the beginning of a ligature. Medial shape of a letter is written when it is joined by both the preceding and the following letters inside ligature. Final shape appears when a letter marks the end of a word or ligature. Durrani and Hussain (2010) discussed this property of Urdu letters in much detail.

4. Design Parameters

At present, more and more data is being generated and uploaded using touch screen smart gadgets. These gadgets come in various shapes and screen sizes such as tablet PCs and mobile phones etc. Recently, there have been zero button touch screen laptop systems in the market e.g., the Acer ICONIA. The current trends and types of new gadgets being introduced in the market suggest the growth of touch screen systems in the days to come.

Design constraints are not limited only to Urdu language and its specific features. There are some additional design issues also that are summarized in the following sub-sections.

4.1 Hygienic design

Different interfaces suit different devices for users who need to input data in different natural languages. Full keyboard replica designs with base and shift versions e.g., QWERTY and Dvorak etc. cause usability problems as well as visibility problems hence not viable for small touch screen systems. The handheld touch screen devices offer very little screen area for keypad parking. This means that in QWERTY type keypads, the individual key size to type an Urdu letter becomes too small to clearly see and type with fingers. Thus such a keypad is more prone to errors during text entry. Besides, data input using small screen devices bring about health hazards to the user. Eyesight weakness, RSI (Repetitive Strain Injuries) and CTS (Carpal Tunnel Syndrome) etc. are only a few health hazards caused by technology/devices that we use in our daily life. For example, in case of eyesight, the closer objects put greater strain on the muscles converging the eyes retina (Ankrum, 1996). Stress on convergence system of eyes is crucial factor for strain (Jaschinski-Kruza, 1988; NASA, 1995). Thus we need to keep hygiene in prime focus during design and development of input systems, particularly for small touch screen devices.

We put forth hygiene in prime focus at the design time. Small devices put more strain on eyes due to acute and meager visibility (Andrew Sears et al. 2001; Ankrum, D.R, 1996; Atencio, R, 1996; Jaschinski-Kruza, 1988). RPA (Resting Point of Accommodation) and Convergence prospects were among important considerations at the design time. RPA deals with the point when the lens capsule changes shape to focus on a close object (Jaschinski-Kruza, 1988). Convergence allows the image of the object(s) to be projected to the same relative place on each retina (Ankrum, D.R, 1996). RSI (Repetitive Strain Injuries), CTS (Carpel Tunnel Syndrome), CTD (Cumulative Trauma Disorder) and ophthalmic endemics etc. are caused by regular and prolonged use of computers and its gadgets (NASA standards, 1995).

We developed distinct touch screen keypad that is “hygienic” to the users. At the same time, our design facilitates fast, correct and easy Urdu composing.

4.2 Virtual Keypads

Virtual keypad is also called soft keyboard (I. Scott MacKenzie and Shawn X. Zhang, 1999; Andrew Sears et al. 2001; I. Scott MacKenzie et al. 1999). Unlike the physical hardware keyboard(s), a virtual keypad shows up on the screen. Thus it consumes no physical space in the real world. However, it needs a much precious resource i.e. the screen area and uses some part of the same screen where data is typed i.e. the editor (Andrew Sears et al. 2001). This gives rise to new concerns such as position, size, and orientation etc. of the virtual keypad w.r.t. the editor. We can make the virtual keypad context sensitive so that it is visible only when the user wants to input or edit text (Uta Hinrichs et al. 2007). Theoretically we can show several distinct keypads at the same time, nonetheless a single user is expected to use only one virtual keypad at a single time.

We borrow the assessment method of virtual keypads from the physical hardware keyboards evaluation technique. This comprise of two major parameters; a) the easiness to learn and b) efficiency (I. Scott MacKenzie et al. 1999). The former parameter takes into account the time needed for a novice to become a veteran with the keyboard whereas the latter parameter refers to the composing speed by a skilled user, a user well familiar with the system under study.

5. Contemporary and proposed keypads

Apart from the conventional QWERTY and Dvorak keyboards, there are a number of keypads used for text entry e.g. Multi-tap T9, odometer-like, touch-and-flick, Septambic keyer and Twiddler etc. (Wigdor, 2004).

5.1 Existing On-Screen Keyboard

Microsoft Windows comes with a built-in soft keyboard called the OSK (On-Screen Keyboard). It supports a number of languages including Urdu that is a replica of the generic and classical QWERTY type hardware keyboard. This OSK is shown in the following Figures 4(a) and 4(b).

Fig. 4 (a) Base version of Microsoft Windows Vista OSK (On-Screen Keyboard).

Fig. 4 (b) Shift version of Microsoft Windows Vista OSK.

This OSK has migrated to many touch screen platforms including tablet PCs and smart phones. However, in our research we reached a conclusion that this keypad does not provide optimum performance and ease of use.

5.2 Multi-tap T9 Keypads

For mobile phones, Multi-tap T9 replica keypads are also in use that is shown in the following Figure 5.

Fig. 5 Samsung SGH-C140 Urdu/Arabic T9 keypad.

The working of Urdu Multi-tap keypad is explained in the Table 3.

Table 3: Multi-tap input table for T9 keypads

Numeric Buttons	***Number of taps to type an Urdu letter***						
	I	***II***	***III***	***IV***	***V***	***VI***	***VII***
②	ب	پ	ت	ة	ٹ	ث	
③	ا	آ	ؤ	ۂ	ء		
④	س	ش	ص	ض			
⑤	د	ڈ	ذ	ر	ڑ	ز	ژ
⑥	ج	چ	ح	خ			
⑦	ن	و	ھ،ہ	ی	ے		
⑧	ف	ق	ک	گ	ل	م	ں
⑨	ط	ظ	ع	غ			

Urdu letters are typed using numeric buttons labeled 2 through 9 (encircled digits) on a multi-tap mobile phone Urdu keypad. The numeric button with label 0 and 1 are not shown in Table 3 due to the reason that they are reserved for typing special characters. The left-most column shows the encircled numerals as row headers and represent the corresponding buttons of a multi-tap mobile phone Urdu keypad. The column headers, marked by Latin numerals, represent the Urdu letters that will be typed when the corresponding button (numeral in row header) is tapped/pressed a specified number of times. For example tapping the number 8 button only once will type the Urdu alphabet "ف" . Tapping the same button seven times will result in typing the Urdu alphabet "ں".

Both the above mentioned types of keypads are difficult to use and slow on touch screen systems. The multi-tap T9 type Urdu keypads have en suite shortcomings. According to unigram Urdu letters frequencies, the letter "ی" is the 2nd most widely used letter in Urdu. Ideally high frequency letters should be typed with single tap (press) of a button. Table 3 shows that typing a single "ی" requires four taps of key ⑦. The same flaw applies to some other high frequency letter as well e.g. "ر" on key ⑤ and "ے" on key ⑦ etc.

In the same way, the full sized QWERTY like keyboards are not free from weaknesses. They are not feasible for touch screen devices, in particular devices with small screen where limited screen area needs to be used astutely. This issue becomes more challenging when we design keypads for languages with a large number of alphabets such as Urdu language. The trade-off issues in size and position of keyboard, editor, and individual buttons etc. require great care at the design time. A good design must comply with the five principles of Ergonomics; Performance, Ease, Aesthetics, Comfort and Safety (Karwowski, 2006). This goal becomes difficult to achieve if large number of keys (for large number of letters) have to be designed in a limited screen area.

Keeping the above points in view, we propose the following keypad for small size touch screen devices. Careful thought process during the design phase enabled us to make individual buttons large enough to be clearly visible and suitable for easy typing of Urdu text.

From the point of view of hygiene, we tried to develop the keypads in such a manner that would be health friendly having much visibility and usability coupled with crafty arrangement of keys that is ideal for fast, correct, easy and efficient composing. Our optimization technique for arrangement of alphabets and unique interface for data input is extendable and equally applicable to other natural languages and various sizes of touch screen devices.

5.3 Proposed Keypad for small size touch screen devices

Figure 6 shows the base version of proposed frequency-based keypad for touch screen mobile phones. There are seven letters called base letters on seven keys in this keypad. The individual letters are selected based on their unigram frequencies in a 55-million character Urdu corpus. The arrangement of these letters is done on the basis of their corresponding character/letter neighborhood or character bigram frequencies. The letters in the base version, as shown in Figure 6, are not arranged in alphabetical order in Urdu. For the sake of easy understanding, easy memorizing and better visibility, all the remaining Urdu letters are shown in small font on the corresponding edges of each button. The leftmost button on lower row can be used for changing the input language, writing Ligatures, numeric characters, special characters and Diacritics etc. Comparison statistics of our proposed keypad are tabulated in Section 6.

The base version of keypad shows the most frequently used Urdu letters. This results in much faster and more accurate composing of Urdu text.

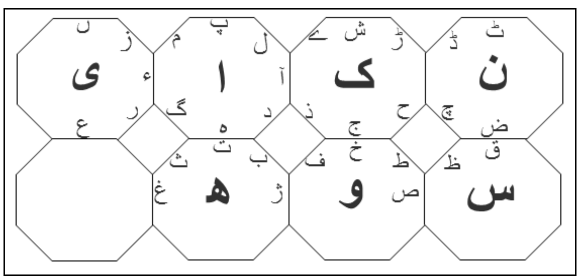

Fig. 6 Proposed keypad for touch screen mobile phone.

Handheld touch screen widgets come in various sizes. Our proposed keypad is flexible enough to adapt to different screen sizes. Hence it is possible to increase or decrease the width or length or both to fit the screen dimensions of a specific device on which this keypad is required to be deployed. For example for Apple iPhone 4S, the recommended dimensions are;

Table 4: Recommended size (in centimeters) of proposed keypad for Apple iPhone 4S

	Width/Height	***Length***
Keypad (base form)	2.50	5.00
Button (base form)	1.25	1.25

The above width, height and length are valid when the iPhone is in portrait mode. Recommended size depends on whether iPhone is in portrait mode or landscape mode. In case, iPhone is in landscape mode then the recommended size should be much longer horizontally.

The working of our proposed keypad is explained in the following.

When a “button press” event occurs then a single button gets the focus and expands into a smaller sub-keypad with the pressed letter displayed in the center of surrounding letters. Up to 8 neighboring letters of the pressed letter are displayed. These 8 new letters are displayed on a separate layer. The newly displayed 8 letters consist of 4 horizontal neighbors and 4 diagonal neighbors. The user will need to flick his finger in the direction of a particular letter in order to type it. In case of typing a base letter, no flick is required. Only tapping the base letter will do the typing. Beginners will need to look at the screen to select the correct neighboring letter. However experienced users can “touch type” in order to type their desired letter(s). The term “touch type” is sometimes referred to as “blind touch” also. The individual button sizes are big enough for blind touch and/or thumb typing. The size of buttons and their dimensions are flexible and can be adjusted according to the device on which the keypad is required to be deployed. A technique called “Onion Skinning” is used to show the new layer on top of the base layer. The diagonal and horizontal neighbors appear on a new layer on top of the base layer. In practice all the 8 neighboring letters will be visible and available for user to type. The diagonal neighboring letters can be used by a user just like the horizontal neighboring letters and vice versa. The event of a “button press” is illustrated in the following Figure 7 where the horizontal and diagonal neighbors are shown separately for better visibility and aesthetics.

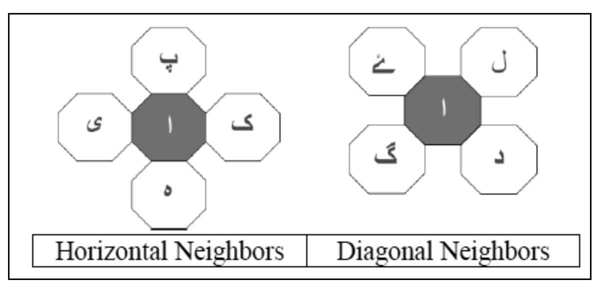

Fig. 7 Illustration of a button press event.

6. Experiments

We carried out experiments on a general genre corpus of size 15,594,403 words. Using the unigram and bigram frequencies in a large corpus, we developed novel Urdu touch screen keypad as shown in Figures 3 and 4. The bigram characters neighborhood statistics reveal that the non-alphabetic arrangement of Urdu letters alone results in additional 17% improvement in the efficiency of our proposed keypad. The results of our experiments revealed ample significance that is explained in the comparison and evaluation Section i.e. Section 7.

6.1 Methodology

The methodology we adopted is enlisted stepwise in the following.

1. Calculate a frequency distribution for the words in an Urdu corpus of 15,594,403 words
2. Calculate a frequency distribution for the alphabets in the words i.e. the Unigram frequency distribution
3. Calculate a frequency distribution for the intra-words neighborhood of alphabets i.e. the characters bigram frequency distribution
4. Based on unigram frequencies, decide which alphabets will be on displayed in the "Base Version" of the keypad
5. Based on bigram frequencies, decide the order of alphabets for display in "Base Version" of the keypad
6. Carefully design the input method keeping in mind certain additional factors such as health issues and Ergonomics
7. Compare the existing and proposed system using suitable statistical models

6.2 Model Used

In order to measure the efficiency of our proposed keypad, we use the model presented by Mark D. Dunlop and Finbarr Taylor (CHI-2009).

$$T(P) = T_h + w\,(K_w T_k + r(T_m+T_k))$$

where
T_h = 0.40s → homing time for the user to settle down on keyboard
T_k = 0.28s → time required to press a key
T_m = 1.35s → response time to a word prediction event
K_w = 5.421 (U) → average length of an Urdu word (our modification in the original model)
w = No. of words
r = 1.03 → ranked word list selection time

To date, there is no full-fledged Urdu word prediction IME. In case of English and some other languages, existing touch screen systems start word prediction as soon as the user types the first letter. For words with length up to two letters, this seems to bring hardly any improvement to the typing speed. On the contrary, it makes the system more complex and larger in size putting more overhead on CPU. We recommend that word prediction should start after the second letter has been typed by the user. In the corpus we used, out of 15,594,403 words, 4,784,234 words are less than or equal to two letters in length. Hence for the experiments of this study, we discarded the words having length less than or equal to two character. The main reason to do so is; by the time the system is able to predict the desired word, the user will have already typed two letters or tapped the screen twice. Users evaluation showed that responding to a word prediction event and then tapping the appropriate option takes longer than typing the next alphabet from the keypad. Reducing the size of corpus gave us the extra advantage of using a smaller corpus of size 10,810,169 words that subsequently resulted in the low CPU overhead and less memory requirement for our proposed input system.

The bigram character neighborhood matrix of the entire corpus gifted us with an additional boost in typing speed in performance. Some Urdu words contain double and repeating letters. Using our proposed keypad the user needs to tap the same button twice in order to type a repeating letter. On the contrary, the same repeating letter can cost up to 12 taps in order to type it twice using a multi-tap T9 type of keypad,

We categorized the words with repeating letters in three different groups. These groups and their respective examples are presented in the following sub-sections.

1. Native Urdu Words

These are purely native single Urdu words. In comparison to our proposed keypad, typing this kind of letters i.e. the repeating letters take much longer on the existing generic multi-tap T9 keypads.

مقرر، ضرر، سبب، ممکن، کوشش، ممالک، مدد

2. Native Urdu Words (Compound)

These are Urdu words that are made up of a root word followed by a suffix. In such a case, the root word ends with a letter whereas the suffix begins with the same Urdu letter. This results in a repeating letter when a user types such a compound word.

خبررساں، دوررس

3. Foreign Words

Sometimes foreign words are written in native Urdu script. Examples of such foreign words are scorer, lecturer and manufacturer etc. These types of words result in repeating letters when written in native Urdu script. Thus they consume less time in typing on our proposed keypad.

سکورر، لیکچرر، مینوفکچرر

7. Results and Comparison Evaluation

We compared the performance of proposed keypad with its existing counterparts. The evaluation was done by two distinct techniques; a) Automated performance evaluation b) Users evaluation.

7.1 Automated Performance Evaluation

Pressing a button several times to type a single letter/character is called a "tap". A "touch-and-flick" refers to a touch followed by a flick for typing a letter on a touch screen platform.

The reduced corpus size and assumption of "touch=tap" put the bias in favor of the existing systems because a tap takes longer than a touch-and-flick. However, we still achieved results that show substantial improvement over the existing systems. The comparison of time required to type the corpus using existing Multi-tap T9 and our proposed keypads are illustrated in the Table 6. Thus the proposed keypad is 48.65% faster than its contemporary counterparts.

Table 6: Time analysis results chart

Time	*Multi-tap (existing)*	*Touch Screen*
Seconds	263,380,598	135,249,436
Hours	73,161.28	37,569.29
Days	3,048.4	1,565.4
Improvement		**48.65%**

The second parameter for automated comparison of proposed keypad with existing in-the-market keypads is the number of taps/touches. Our proposed keypad outperformed its counterparts on this measure also. The results are tabulated in Table 5. It shows that the proposed keypad achieved 52.62% improvement over the existing multi-tap keypad.

Table 5: Comparison of number of taps/touches required to type the corpus

	Multi-tap keypad (existing)	*Touch Screen keypad (Proposed)*
	170,580,560	80,818,830
Improvement		**52.62%**

A simple everyday life observation reveals that a tap takes longer than a touch-and-flick. As seen in Table 3, typing with the help of Multi-tap T9 keypad is slow and time consuming. There are multiple reasons behind it. Some high frequency Urdu letters require 4 to 5 taps of a button to type them. Similarly some of the buttons need 7 taps to type a single letter. On the contrary, our proposed keypad requires a maximum of 2 taps/touches to type a letter (supposition; tap=touch=flick). Notwithstanding this supposition puts the bias in favor of the existing multi-tap system, we were able to reduce the typing payload by 46.10% w.r.t. composing all the letters in Urdu alphabet-set. Table 7 shows this comparison for both the existing and proposed keypad layouts.

Table 7: Comparison of cumulative typing payload to type all letters in Urdu alphabet set

	Multi-tap (existing)	*Touch Screen*
Total number of taps	154	83
Improvement		**46.10%**

7.2 Users Evaluation

Figure 8 shows the real world analysis through user evaluation.

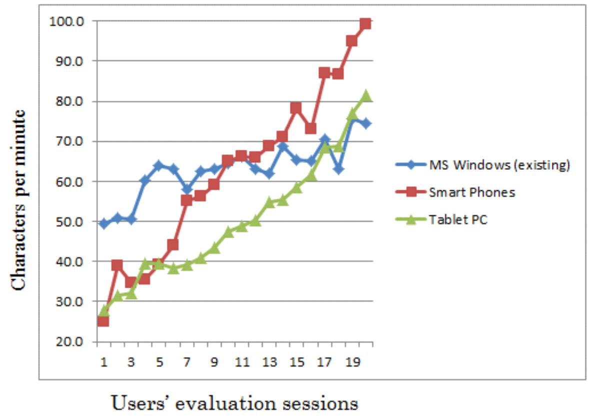

Fig. 8 Users evaluation results chart.

The user evaluation was carried out by three native Urdu speakers (all males and volunteers). Their ages ranged from 25 to 32 years. Two users were right-handed and one was left-handed. All of them were well versed with computers and experienced in typing but none of them was a professional typist. However, all of them had the experience of using the Microsoft Windows OSK for Urdu and Multi-tap T9 Urdu mobile keypad. The Acer ICONIA zero button PC running Microsoft Windows 7 was used as a test bed during users evaluation. Each user was allowed to re-size the width and/or height of the entire OSK keyboard to adjust the width and height of Microsoft's OSK according to the size of his hands and fingers. Our proposed keypad was novel for all the three participants. Except for a 10-minutes initial briefing, no training sessions were conducted before the volunteers could use our proposed keypad for typing unseen Urdu text.

We conducted 20 typing sessions. A session means that each user was given unseen text to type on the Microsoft Windows OSK, the multi-tap T9 keypad and on our proposed keypad. The order to use the three keypads and the text to type by each user was all random. The text length was also kept random and the users were always given unseen text to type. This user evaluation procedure was adopted in order to prevent the bias in favor of a particular keypad and/or a user.

The results have been averaged and illustrated in Figure 8. X-axis represents the number of sessions while Y-axis means the typing speed of users in characters per minute. All the values in the chart are averages of all the three users who performed typing in a random order using random order of keypads and random pieces of text. As clear from the chart, the learning curve for our proposed keypad is the fastest to memorize. The users took only two sessions to learn it in order to surpass their speed of typing using a Multi-tap T9 keypad. This shows that our proposed keypad is easy to understand and memorize, hence user friendly.

Since the users were familiar with Microsoft Windows OSK and since they were able to use both their hands to type Urdu text, therefore the advantage was in favor of Microsoft OSK when we started users evaluation. Nonetheless, it took our novel keypad 9-user sessions to show better performance than the Microsoft Windows OSK. During evaluation of our proposed keypad, the users evaluation did not show any significant difference between the working and performance of the diagonal and the horizontal neighboring letters illustrated in Figure 7.

8. Conclusion

We proposed a novel keypad for small handheld touch screen devices. The comparison analysis were performed on two distinct tracks; the automated procedures and by detailed user study. Both the evaluation method showed promising results. In addition to a significant amount of improvement over existing keypads, our proposed keypad design is flexible because the size and dimensions of keypads, buttons, and editors can be adjusted according to the device on which the keypad is to be deployed. Similarly our keypad offers greater usability because Urdu letters include all the letters of Arabic and Persian. Hence our keypad is equally usable by the Arabic and Persian users. The keypad is optimized for Urdu though. With minor additions, our input system is extendible to other Perso-Arabic languages as well.

9. Future Directions

We intend to make our keypad public to research community for further extendibility to their respective native languages. More thorough testing of our keypad by a score of human subjects is also welcome. Additionally, we want to extend our keypad to include other Perso-Arabic languages such as Punjabi, Pashto, Dari and Potohari etc. Touch screen devices come in various shapes, screen sizes, hardware and software platform. We intend to develop optimized keypads for various touch screen gadgets such that each keypad best suits a certain type of gadgets. Our proposal of an optimized keypad for mid-size touch screen devices such as tablet PCs is already in its final stages of evaluation. Another possibility to exploit our work can be in the design of a single hand operated keypad (separate designs for each of the left and right hand), single finger operated and two fingers operated keypad designs suitable for numerous touch screen devices.

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