Optimization of Key Frequency in Keyboard Using Mathematical inclusion of Design

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ABSTRACT

This paper investigates the parameters affecting the occurrences of alphabets and its influence on placement of Keys. The Key Pair Statistics is considered as efficiency characteristics while the parameters considered are speed, ergonomic design and reducible Serious Repetitive Injury. The scope of this paper extends to the ergonomic design of the basic layout of keyboard resulting in the minimum wrist angle. The results of the statistics along with the Design angles are used to characterize the layout optimizing the user typing speed.

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Keyword *: - Key Pair Statistics; Serious Repetitive Injury; Wrist Angle.*

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1. INTRODUCTION

A keyboard for computers has a plurality of alphabetic characters assigned to keys in three rows corresponding to letter assignments in upper row, middle row and lower row. Keyboard contains a set of keys divided into four sections as Text Entry Section, Navigation Section, Numeric Keyboard Section and Function Key Section. The standard QWERTY keyboard layout was developed in late 1800's. Since then, people got acquainted with the same layout; so was retained for the computer keyboards. The conventional keyboard layout was earlier designed for the mechanical typewriters to avoid piling up striking levers on one another; so, it was not efficient to be used with the modern computer systems.

In order to improve the key arrangements for the efficient and faster typing, the anatomy of human finger must be analyzed. It includes the distribution of the load properly on the stronger fingers for the more key pressing while the dynamic fingers to more movements; so that, maximum advantage of the layout may be yielded.

2. STUDY OF KEYBOARD PATTERNS

The current standard keyboard is based on the first six characters from start of alphabetic characters, designed for mechanical typewriters in 1872 by C. Latham Sholes. Here, the letters were arranged in order to prevent the jamming of the mechanical key levers resulting into slower rate of typing. The QWERTY keyboard is much poorly optimized for the speed on electronic system, where mechanical key interface is no longer any issue.

In May, 1936, an improved keyboard was introduced to support the enhanced typing speed and the minimizing of finger strain. It recorded the frequency of two alphabet sequences in the English language as diagraphs. One major drawback of the Dvorak keyboard was the random placement of the alphabets, making the transition from QWERTY quite difficult.

The later invention called as XPeRT keyboard was based on the letters X, P, E, R, and T from the start of alphabetic row. Here, most of the possible letters are kept in their current standard location so as to ease the transition of experienced users to the new keyboard. Very high frequency letters are moved to achieve substantial speed improvements. Three high frequency letters are moved from the standard location, namely: A, E and N. Letter E is maintained at the left-hand side of the keyboard along with creating and placing it also on the right side of the keyboard. This effort is done because; E occurs twice as any other high frequency letter in the English Language. In further improving the speed factor of the keyboard, XPeRT places none of the very high frequency letters in such locations to be accessed by small fingers.

3. FREQUENCY BASED THEORY

For the optimum efficiency and speed; frequently used keys in the English language needs to be identified and placed to be accessible by Inner fingers of the keyboard. For its judgment, the frequency based theory is being incorporated for the most efficient placement of the letters of English dictionary.

3.1 Frequency of Letters

The frequency of occurrences of alphabets in English language has been derived here and statistics being presented in TABLE I. Based on the frequencies of letters in English language, three classes can be approached.

First is the High frequency letters having frequency range from 6.0% to 12.2% containing 9 letters as A (7.5%), E (12.2%), H (6.0%), I (7.6%), O (7.9%), N (6.0%), R (6.7%), S (6.7%) and T (9.8%). Next is the Medium frequency letters having frequency range from 1.8% to 3.4% containing 10 letters as D (3.4%), F (3.1%), C (3.0%), G (2.3%), L (3.3%), M (2.6%), P (2.0%), U (2.8%), W (2.0%) and Y (1.8%). And the last class as Low frequency letters having frequency range from 0.1% to 1.1% containing 7 letters as K (0.7%), J (0.1%), B (1.1%), Q (0.1%), V (1.0%), X (0.3%) and Z (0.1%).

Table -1: Single Letter Frequency in English

English Letter	Letter Frequency (%)
A	7.5
B	1.1
C	3.0
D	3.4
E	12.2
F	3.1
G	2.3
H	6.0
I	7.6
J	0.1
K	0.7
L	3.3
M	2.6
N	6.0
O	7.9
P	2.0
Q	0.1
R	6.7
S	6.7
T	9.8
U	2.8
V	1.0
W	2.0
X	0.3
Y	1.8
Z	0.1

According to this statistical data; only 9 most frequent letters represent 70.4% of all keystrokes, E having 12% of all keystrokes in English. 10 Medium frequency letters represent 26.3% of all keystrokes while 7 Low frequency letters represent only 3.4% of all keystrokes.

The objective of this statistical data of frequency of letters is to place the high frequency letters to be accessible by inner fingers or on upper rows or middle rows. It needs to be done while minimizing the key placement changes made with reference to standard QWERTY layout. The new layout incorporates certain movements of least letters as possible. O, I, R, and T are retained on the upper row while S on the middle row. Only A, E and N are moved to be accessible by inner fingers on the middle row. A and E are moved to the left-hand side while N to the right side of the keyboard.

3.2 Layout Changes on Key Frequencies

- In the standard QWERTY layout, the letter A is present at an awkward small finger position which is hereby moved to forefinger location on the right portion of the home row.
- Letters J and K present in the low frequency class as described earlier have been replaced by A. By moving A, N also needed to be moved from its bottom row, so that it did not have to strike by the same finger as A.
- E, being the letter with highest frequency in English language is kept both at left hand side as well as right hand side.

3.3 Diagraph Frequency Theory

The frequency of occurrences of alphabet pair such as RE and ER combined together defines the diagraph frequency. Being the statistical values for letter pairs ER and RE, the same on the keyboard; the statistical data generated lends itself much more readily to an accurate analysis.

The total value of all key pair statistics data is 3320 in English language. The value of key pairs HE and EH is 117, may be stated as EH (117). Hence, the percentage occurrence of key pair in English language is 117/3320*100%=3.5%.

The efficiency and speed can be achieved by avoidance of awkward key sequences, as striking two different keys with same hand or lower row to upper row using same fingers. Opposite hand diagraph placement supports a major factor in typing speed optimization. Its main objective is to optimize alphabet placement using diagraph frequency along with minimizing transition from the QWERTY layout.

From the diagraph data, it is deduced that the placement of high frequency letters at smaller finger or ring finger location is considered to be a serious flaw in the design. For physical reasons, 30% to 50% speed reduction is estimated for a key at small finger location. So, since single letter frequency of A (8.0%) and S (7.0%) resulting in total of 15%; assuming the speed reduction to be minimum at 30%, a net negative impact of 30%*50%=5% occurs in the overall typing speed on the keyboard. The Diagraph factor of various keyboard layouts is presented in TABLE II, showing highest Diagraph factor for XPeRT layout.

Table -2: Diagraph Factor of Keyboard Layout

Keyboard Type	Diagraph Elements		
	Opposite Hand	Same Hand	Diagraph Factor
XPeRT	2199	444	83%
Dvorak	2124	519	80%
“X”	2092	551	79%
Parkinson	1437	1206	54%
QWERTY	1330	1313	50%

The speed test results of Independent Test Agents in standard ideal condition has been presented in TABLE III; showing the typing speed in Words per Minute for Standard Keyboard and XPeRT keyboard.

Table -3: Independent Speed Test Results

Test Agent	Standard Keyboard	XPeRT keyboard	Percentage Gain
File Cart	33 wpm	68 wpm	106%
SW Transit	49 wpm	93 wpm	90%

4. ERGONOMIC DESIGN

The design of layout in an ergonomic pattern improves the efficiency and reduction of finger strain in reaching high frequency key pairs. It has mount and plurality of keys in an unbroken adjacent rows arrangement. Here, each row consists of a left portion and a right portion. These portions extend tangentially from the left hand and right-hand sides of the portion. The convex design to the user side of the keyboard improves the elongated portion resulting in minimum wrist angle.

4.1 Optimizing Wrist Angle

The standard layout of the keyboard consists of upper row, middle row and lower row in a horizontal manner. Due to this, the present keyboard deviation tends to be approximately 20 degrees between the wrist and palm defined as Wrist Angle, presented in Fig. 1.

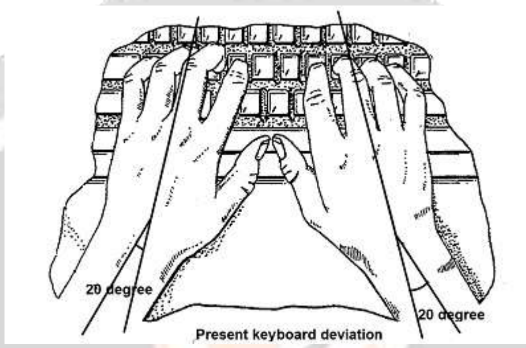

Fig -1: Present Keyboard Deviation

For the efficient and strain free typing, this angle should be reduced as low as possible for the natural hand position. The wrist angle of 20-degree results in a serious problem to developers and software coders over a longer period of time, known as Serious Repetitive Injury. Fig. 2 represents the hand position in the standard keyboard patterns resulting in Carpel Tunnel Syndrome.

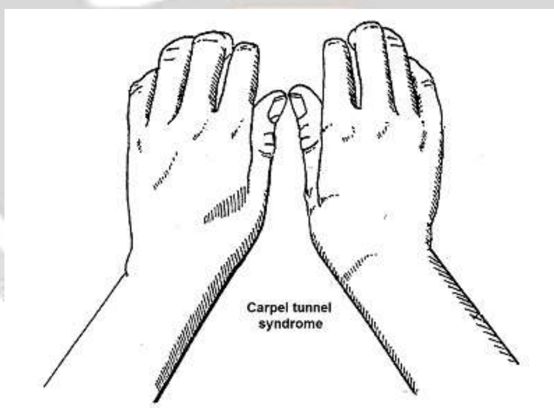

Fig -2: Standard Hand Position Resulting in Carpel Tunnel Syndrome

Fig. 3 represents the optimized ergonomic keystroke deviation, reducing the wrist angle from 20 degrees to 9 degrees.

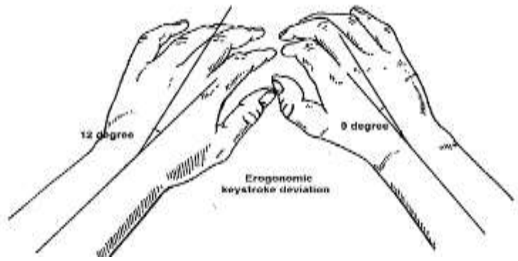

Fig -3: Optimized Ergonomic Keystroke Deviation

The new Ergonomic design facilitates the user to lower the wrist angle avoiding Carpel Tunnel Syndrome. Fig. 4 represents the present keyboard typing style.

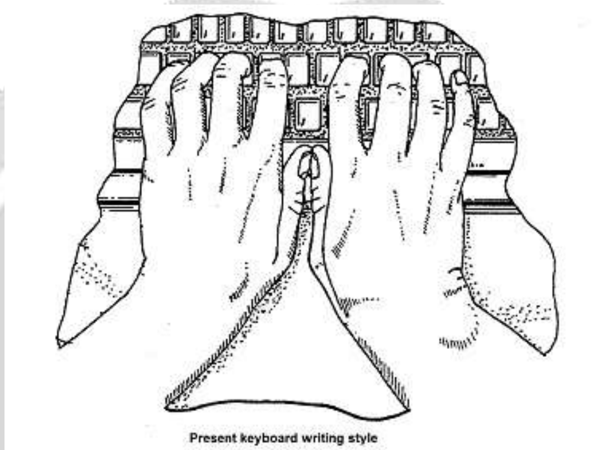

Fig -4: Present Keyboard Typing Style

Fig. 5 represents the new keyboard typing style, resulting in easy finger reach for upper row, middle row and lower row.

Fig -5: New Ergonomic Keyboard Typing Style

4.2 Mount Angle Concept

In Fig. 6, the angle α represents the angle at which, upper surface of the mount does slopes downwardly and β as the angle between horizontal surface and key surface.

Fig -6: Mount Angle Between Mount and Upper Surface

The upper surface should slope downwardly at angle of approximately 40 degrees. For natural hand position, this angle should be preferably range from 15 degrees to 25 degrees. Furthermore, each row of keys must have an upward slope angle greater than 2 degrees. The upward slope of keys in the lower row is less than slope of the rest of keys in the lower row, home row, upper row and function row.

The angle of particular row of keys measured from the horizontal axis is illustrated as angle β. The suggested angles for rows of key slopes kept upwardly as:

- Space bar: 1°
- Bottom row: 3°
- Home row: 5°
- Top row: 5°
- Numeric row: 8.5°
- Function key row: 13°

The concept of convex portion of left hand and right hand being implemented at the pattern can be illustrated in Fig. 7.

Fig -7: Optimized Ergonomic Keyboard Design for Faster Speed and Efficiency.

An Ergonomic keyboard as described consists of a mount having the front edge corresponding to the vertical edge of the keyboard, as close as possible to the user along with a portion of said front edge containing lateral curvature. The mount must have an upper surface, having at least a portion of upper surface sloping downwards and away as possible from the user.

The horizontal surface of the keyboard comprises of a mount having an accurate front edge of 27 degree corresponding to the vertical edge of the keyboard. A plurality of keys supported on the upper surface of said mount must be arranged in multiple rows, where the height of key rows closer to the user should be higher than the proceeding row.

Here, the key stagger is maintained between the adjacent rows similar to the standard keyboard layout, which means that the key stagger is similar on left hand side as well as right hand side of the keyboard. The only area where a slight change has been made is the right-hand side of key stagger. Since, the operations in this portion are mostly performed by the index and middle finger most agile of all fingers; no difficulty is faced in locating or striking these keys.

The standard keyboard users will find almost same distance and angle of finger throw substantially on this new design, experiencing them immediate tactile similarity with it. Hence, the new Ergonomic keyboard design is a perfect embodiment as an acceptable substitute in the work place requiring no additional practice.

5. LIMITATIONS OF THE INVENTION

The design of layout generally changes with the platform and technology, it is going to be; thus, the Ergonomic design is never final and changes with time. The angles of the rows of letters mostly depend upon the user over the system.

6. CONCLUSION AND FUTURE SCOPE

This new design helps to reduce the problem of Carpel Tunnel Syndrome along with the improvement in typing speed. The future scope of this invention involves the design that can be customizable according to each user. The Mount Angle and wrist angle is bit fragile concept, which needs further improvements.

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