# An Study of the Heuristics Applied to Casandra Virtual Keyboard

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**Abstract.** *Nowadays computers have became an important channel of communication for handicapped people through chat, social networks, blogs, digital newspapers, magazines, and wikipedias. Switching devices combined with virtual keyboards allow the physically impaired user to operate many applications that are not adapted to disabilities. In this paper we describe the many heuristics included in the virtual keyboard Casandra. Experimental results show how useful such heuristics are. The handicapped user may reach the speed of 4.1 words per seconds using all the heuristics.*

**Key words:** Virtual keyboard, word prediction, handicapped people, switching devices.

## 1 Introduction

In the latest years, computers have became an important channel of communication. Many handicapped persons are dependent on their computer to work and communicate. Heavily disabled people find a feeling of autonomy through computers, because they provide many communication channels (chat, social networks, blogs) and information sources (digital newspapers and magazines, wikipedias) through Internet.

In order to achieve a comfortable and suitable communication, handicapped people must have an useful writing system in their computer [11]. There are several modified keyboards that can help disabled persons to type in a computer. For instance, the Contoured keyboard proposed by Kinesis Ergo2 [3] has been designed with keys clustered in two groups to reduce arms and hands moves while typing. An improvement in arm position is provided by the Maxim keyboard [5]. It can take various angle values between the two arms (wrists can rest on mobile parts, as often provided with keyboards). The arm position is even more flexible in the Evolution keyboard [4]. It is made of two parts, totally independent. More specific keyboards also exist, such as small keyboards, which are used with a mouth stick: they must be sensitive to low pressure and most frequently used keys must be near the center of the keyboard. Other specific keyboards may also be found: for only one hand or with an improved key separation.

Another option are simulated keyboards, also called virtual or screen keyboards. In this case, the keyboard is displayed on the screen, and it is necessary to move a cursor to select a key. Cursor moves can be achieved by a mouse, joystick or any physical input device. Even if this keyboard is displayed on screen, for a given user a bad arrangement of keys may slow down the typesetting rate, since the pointer moves are similar to the finger moves of a single finger user. For some handicapped people is not even possible to obtain a mouse click from the user and the click must be automatic.

Several virtual keyboards can be found in Internet, such as Windows XP virtual keyboard [12], Click-N-Type keyboard [17], CVK keyboard [7], ScreenDoors 2000 keyboard [10], Keystrokes for Apple computers [1] or GOK for Linux [6]. Different input methods are available, such as linear key selection (one dimension), bidimensional key selection (within rows and columns), key block selection, etc. The later method is useful to first select a group of keys and after the key inside the group. For instance, keys can be virtually clustered in Microsoft virtual keyboard as in Clavicom keyboard [8].

Several improvements are often present: CVK keyboard can zoom on the selected key, and Click-N-Type keyboard can spell scrolled keys. It is often possible to use sound to verify typing (CVK, Clavicom). Moreover, virtual keyboards can modify their display characteristics: size of keyboard/keys can vary (ScreenDoor and Wivik [15]). In order to improve the typing rate, keyboards are equipped with a prediction system. Thanks to a dictionary, they can provide a word list from the first selected letters.

Sybil is another computer system for persons with speech and motion impairments [16]. The virtual keyboard of Sybil is a set of keypads, as shown in Figure 1. In order to reduce the number of steps to reach a certain key in scan mode. Jump keys provide switching between keypads; these are usually in the first keys of keyboard. An improvement of Sybil is the dynamic arrangement of letters in the keyboard. The most frequent letters are positioned in the more quickly accessible places, facilitating their access in scan mode (a similar approach to the proposal of Colas et al. [2].

In this paper we propose a virtual keyboard similar to Sibyl, with some improvements to Schadle's system. Our virtual keyboard, named Casandra [9], has several prediction modes both for keys and word completion. Some modes are more adequate for people with severe motion impairments, while other are more useful for those with moderate motion impairments.

The paper is organized as follows. The Casandra virtual keyboard is described in Section 2. In Section 3 all the experiments with the prediction modes of Casandra are explained. The results of the experiments and its discussion is in Section 4. Final conclusions and future work are shown in Section 5.

## 2 Description of Casandra virtual keyboard

The interface of Casandra is designed for a single switch input device. It consists of a virtual keyboard with row-column scanning, which stays on top of all the


**Fig. 1.** Display of Sibyl

other windows on the screen without being in focus. Casandra remains in a position that does not hide the application window where the user enters text. Each key selected in the virtual keyboard will produce an equivalent key press as produced by the real keyboard. Such key will be sent to the focused window, which may be a text editor, an e-mail client, a web browser, etc.

The keys in Casandra are organized in three pads. The main pad has letters, the space, and a switching key to access the other pads. The second pad (the word pad) has a set of six words obtained from word prediction given the keys already entered by the user. The third pad contains numbers and other useful punctuation characters.

The flow diagram between pads is shown in Figure 2. The user may switch between the letter pad and the other pads through a special symbol accessible in the upper left corner of the letter pad. Once this symbol is selected (only two scans are necessary to accomplish this), the word pad is activated. If the user does not select the word pad, the number/punctuation pad is activated. If this pad is not selected, then the letter pad is activated again and the row scan starts again.

The selection of word or number/punctuation pads activates the row scanning. When a word or a number/punctuation is chosen, it is sent to the focused window, and then the letter pad is activated to continue the writing process.

An example of the virtual keyboard is shown in Figure 3. The letters are organized in the pad by using their occurrence probability. The more frequent letters for Spanish are located in positions accessible with fewer scannings. The number of scannings ($n$) is defined using the Hamming distance: $n = r + c$. Where $r$ and $c$ are the number of scanned rows and columns, respectively. The

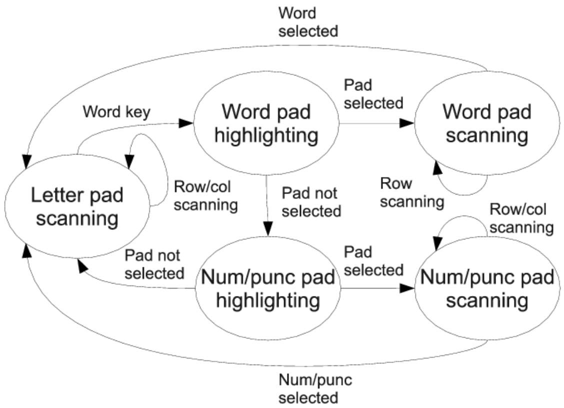


**Fig. 2.** Flow diagram between pads of Casandra.

symbols to switch to the word pad and the space are located in the upper-left corner, because they are the most probable.

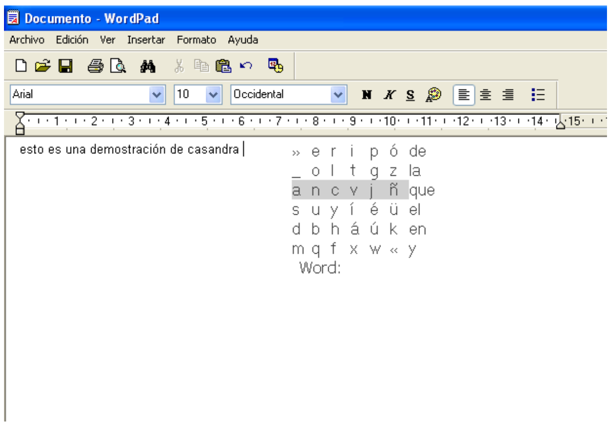


**Fig. 3.** Display of Casandra

The word pad has a high probability of being used because Casandra has an internal word prediction algorithm which uses many statistical tools, such as unigrams, bigrams and trigrams of words and part-of-speech tags (morphosyntactic data with PAROLE format [18]), and also some specifics for Spanish language, such as concordance in gender and number, and verbal tenses (similar approach to the work of Palazuelos et al. [14]). The words in the dictionary are filtered taking into account the partially entered word, using the characters already pressed.

The space also occurs often because most words are finished with such separator. This character will not be written in words that are predicted, because the predictor automatically adds a space after the predicted word. Such character will be deleted if the next character is a punctuation mark that according to writing styles should be attached to the latest word.

The backspace is located in the lower-right corner because may not be a frequently used key to correct orthographic errors or to delete and rewrite some part of the text. This key has a special long-selection mode. After backspace is chosen, it remains selected until the user deselects it using the switching device. In this way, the user may delete several characters without new row and column scannings.

### 2.1 Letter scanning suppression

Casandra has a special mode for letter selection, named letter scanning suppression. In any language there are restrictions about the letter that may follow another letter. For example, it is not possible to write the letter *a* after a letter *a*, and such letter should not be offered to the user as an alternative. This condition may be even more strict if the previous letters in the word are taken into account.

An experiment was conducted to measure the number of possible letters given the number of previously written letters and the length of the word in letters. The results shown no influence of the length of the word in the number of possible letters.

The number of possible letters is highly influenced by the number of already written letters in a word. As shown in Figure 4, the number of possibilities rapidly decays after three letters to 6.2 options in average. As a consequence, there will be a higher gain for long words than shorter words. The later ones will be mostly written by word prediction, as only less than 200 words have three letters or less.

## 3 Experiments with prediction modes of Casandra

The experiments conducted with Casandra are designed to measure the impact of the different heuristics to improve the speed of writing. The number of characters per minute (CPM), or the number of words per minute (WPM), is an important measure to evaluate how satisfactory is the writing process for handicapped people. The number of word per minute is equivalent to the number of characters per minute divided by 5.5 [13]. This relation considers that the words in Spanish are five letters long in average.

One of the heuristics that is evaluated in Casandra is the word prediction. It is important for the user to have a high number of predicted words in order to

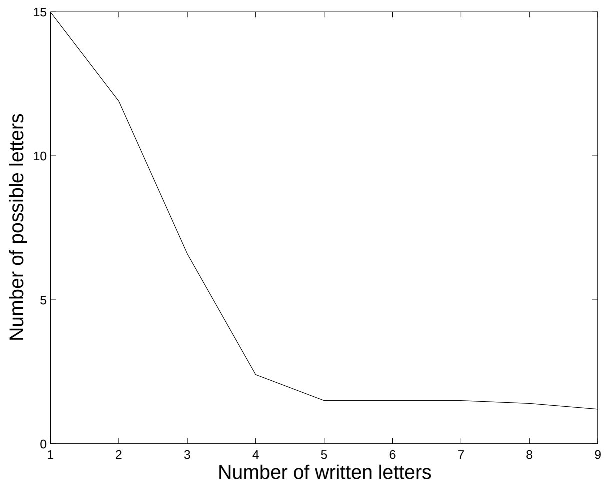


**Fig. 4.** Number of possible letters given the number of already written letters in a word

highly increase the writing speed. A word predicted saves the highest number of scannings, and also the typing of the space word separator.

Another heuristic under evaluation is the letter scanning suppression. Any letter with null probability of occurrence after the previously written letters should not be initially offered to the user as a choice. The main reduction will occur in the number of column scannings, rather than for row scannings. The later will only occur when the complete key row is supressed, and it happens only for long words with five letters or more.

In this paper we also consider for evaluation the heuristics proposed by Schadle. The distribution of the letters in the keyboard changes according to the previously written letters. In this way, the most probable letters are placed in the upper left corner, and are accessible with fewer scannings.

Two texts were used in the experiments to evaluate the WPM rate for each experimental setup: Esopo fables and The little Prince. The user is simulated using a software that reads a text file and selects rows and columns in the virtual keyboard. In this way it can be observed the average performance of the system with enough data. In these experiments were used around 500 words in each run, because experiments with longer runs show an stabilization after this number of words.

## 4 Experimental results and discussion

The experimental results for the different heuristics are shown in Table 1: without any heuristict(NH), letter suppression(LS), word prediction(WP), letter suppression and word prediction(LS-WP), and letter suppression with word prediction and letter reordering(LS-WP-LR).

**Table 1.** Word per minute rate for different heuristics and texts

| Text | NH | LS | WP | LS-WP | LS-WP-LR |
|---|---|---|---|---|---|
| The Little Prince | 2.647 | 2.837 | 3.803 | 3.899 | 4.138 |
| The Esopo Fables | 2.616 | 2.807 | 3.714 | 3.802 | 4.086 |

The NH column shows the poor results without the use of any heuristics. Only 2.6 words can be written in a minute. It is a very slow writing speed that may disappoint handicapped people. The speed of writing must be as high as possible to encourage the use of the virtual keyboard and enable the access to digital communication media to physically impaired users.

The speed of writing for Letter Suppression algorithm is slightly higher. The gain is very small, and LS should not be used as the only heuristic to enhance the writing. The main gain occurs for long words, as show in Figure 5. Words longer than five letters have an increasing saving of scans than shorter words.

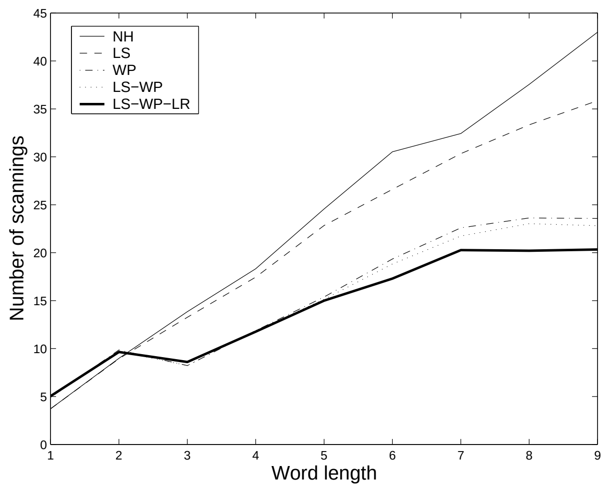


**Fig. 5.** Number of scannings for different word lengths

In Table 1 and Figure 5 may be observed that the main gain in writing speed is obtained with the word prediction. The speed in number of words per minute increases in one, while the number of scans for words longer than three letters drop fifty percent or more.

Letter reordering does also bring an additional increase in the speed of writing, with an average improvement of 0.3wpm. In Figure 5 it is also shown a small reduction in the number of scans, mainly for words longer than five letters.

Table 2 shows the number of predicted words after $n$ entered letters for a word of length $m$. The words of length one mainly correspond to punctuation characters, rather than real words.

Word prediction only has success in half of the total number of words. However, any hit produces a great saving of scannings, because the rest of the letters are typed without any additional scannings.

The last column show the average number of letters that are necessary to predict a word of length $n$. It is proportional to the number of letters for short words, while it saturates for longer words. A word of length five may be predicted after two letters have been typed.

**Table 2.** Number of predicted words after $m$ entered letters for a word of length $n$

| | $NP$ | $m=1$ | $m=2$ | $m=3$ | $m=4$ | $m=5$ | $m=6$ | $m=7$ | $m=8$ | $\bar{m}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| $n=1$ | 153 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $n=2$ | 61 | 44 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| $n=3$ | 14 | 37 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 1.1 |
| $n=4$ | 0 | 10 | 9 | 3 | 0 | 0 | 0 | 0 | 0 | 1.6 |
| $n=5$ | 2 | 9 | 5 | 4 | 4 | 0 | 0 | 0 | 0 | 2.1 |
| $n=6$ | 0 | 7 | 8 | 11 | 7 | 5 | 0 | 0 | 0 | 2.8 |
| $n=7$ | 1 | 2 | 7 | 8 | 6 | 10 | 5 | 0 | 0 | 3.7 |
| $n=8$ | 1 | 0 | 3 | 9 | 8 | 1 | 4 | 1 | 0 | 3.8 |

## 5 Conclusions and future work

In this work it is presented the virtual keyboard Casandra. This software includes several heuristics to increase the speed of writing: letter suppression, word prediction and letter reordering.

Experimental results show that each heuristic that is appended contributes to a better speed of writing, from 2.6 words per minute without heuristics, until 4.1 words per minute with all the heuristics. Letter suppression and word prediction are the most used for all kinds of users. However, letter reordering should only be used for strongly handicapped users, because they may have more time to read the keyboard during each scanning. Short scanning periods would make difficult and tiring the writing process with continuous changes in the key distribution of the virtual keyboard.

Future work will focus in the refinement of the word prediction algorithm, because it contributes to the highest scanning saving.

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