Development of Non-QWERTY Balinese Script Keyboard Through Tamiang Keyboard Optimization With Letter Frequency Concept

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Abstract. Aksara Bali (Balinese Script) is a traditional Indonesian script that developed in Bali, and also known as Hanacaraka. Tamiang Keyboard is a non-qwerty keyboard for typing Balinese script. This keyboard was developed using character extraction methods from the Balinese language dataset by rewriting Balinese script into Latin or Roman characters. The advantage of using the Tamiang keyboard is that users can type Balinese script like writing or “nyurat” Balinese script without various rules such as when using script fonts. Tamiang Keyboard development focuses more on the typing mechanism and placement of Balinese letters on a keyboard button. However, the placement of letters on the keyboard is only based on the separation of letters that often appear on the datasets. This process has an impact on the effectiveness and convenience of users in typing Balinese language using Tamiang Keyboard. In this study, a new Balinese script keyboard was developed by applying the letter frequency concept to optimize Tamiang Keyboard. Letter frequency calculations are used to analyze aspects of home row usage, hand load analysis, and analysis of finger loads when typing balinese language with Tamiang Keyboard. The analysis of these three aspects is used for re-mapping the letters on the keyboard.

1. Introduction
Bali is one of the islands and provinces in Indonesia that has become a tourist destination for both local and foreign tourists. Bali has various types of tours ranging from nature, culinary, to culture [1]. The problem of decreasing cultural use in Bali is one of the initial reasons why in developing cultural aspects there is a need for technological assistance, especially the implementation of Balinese scripts and languages. The application of technology is expected to make it easier to learn Balinese languages and scripts. The intensity of the use of Balinese script by the current generation is very low. This happens because it is very difficult to obtain media or tools that can make it easy in writing (nyurat) Balinese script. Balinese script is called Hanacaraka and has been used since the 11th century [2]. Balinese script has a unique writing rule called Pasang Aksara. Balinese script has 18 basic syllables, 5 vowels, 10 digits, and punctuation written through 185 characters. Balinese script Hanacaraka only has 18 character consonants attached to syllables. Vocal characters can be attached either after, before, above, or below the main characters or syllables [3]. However, only one vowel is attached to the Ha syllable. In addition, there are only two punctuation marks, that is, commas and periods. Balinese script generally has no spaces between the words in it.

The keyboard is an input tool on computer devices. The main function of the keyboard is to provide input in the form of text to the processor [4]. The Balinese script keyboard Tamiang is one of the keyboards that can be used in typing Balinese characters [5]. The development of the Balinese Script Keyboard called Tamiang was created using character extraction methods from the Balinese language...
dataset, which were obtained by rewriting Balinese script into Latin or Roman [5]. The appearance of the Tamiaing keyboard layout can be seen in Figure 1.

Figure 1. Tamiaing Balinese Script Keyboard

The advantage of using the Tamiaing Keyboard is that users can type Balinese script like a "real writing or nyurat" Balinese script, without using certain rules such as the use of the Bali Simbar font. From the point of view of learning, this keyboard can also be used as a medium to support the learning process of Balinese script in class. Tamiaing Keyboard Development focuses more on the typing mechanism and placement of letters on a keyboard button. While the distribution of characters in the keyboard layout is only based on the separation of letters that appear most often. This has an impact on the effectiveness and convenience of users in typing using this keyboard.

According to Nakic-Alfirević & Đurek research, a keyboard layout is supposed to refer to the optimal level, the optimal meaning can be interpreted as the fastest [6]. There are several factors that can affect comfort and speed when typing in a keyboard layout, namely: the distance traveled by the finger during normal typing, the anatomy of the human hand, and certain regularities found in the language text used. From these factors, certain regularities found in the language text used (the nature of language) are the most suitable factors for analysis. The finger mileage factor and anatomy of the human hand cannot be analyzed with certainty because each human being has different forms and abilities [5]. Therefore, making the optimal keyboard layout for typing can be done by measuring the appearance of a letter or letter frequency.

In this study a new Balinese script keyboard was developed by applying the letter frequency concept to typing Balinese characters with the Tamiaing Keyboard. In this study, the letter frequency calculation mechanism was used to analyze aspects of home row usage, hand load analysis, and analysis of finger load when typing with the Balinese Tamiaing Script keyboard. These three aspects will be used as a reference in developing the new Balinese script keyboard. Home row is the position where the finger starts and rests on the keyboard. August Dvorak is a keyboard layout designer Dvorak designing a location where placing vowels and dies appear frequently on the home row keyboard [7,8]. Dvorak thinks that typing can be done maximally if the characters that appear frequently are on the home row position of the keyboard because it can minimize the time needed for the fingers to move. In addition, there is the fact that it is easier to type using both hands rather than typing a series of characters with the same hand. This is because if we type using both hands there will be a much higher level of freedom [6]. The division of the load on both hands can improve typing ability. The division of the load typing the keys on the keyboard must be arranged so that it is divided equally on both hands. The division of the load on the hand must also be applied to all fingers, this aims to give the right portion of the finger [8].

2. Method
In optimizing and developing the Balinese script Tamiaing keyboard layout for typing the Balinese language, in this study the data used was a dataset of Balinese scripts. This Balinese script dataset has been grouped according to the Balinese script literary category. A total of 100 datasets of Balinese script will be used in this study. The dataset specifications used can be seen in Table 1.
Table 1. Balinese Script Dataset Specification

| Category               | Number of Document |
|------------------------|--------------------|
| Balinese Script Short Stories Dataset | 12                |
| Balinese Script History Dataset          | 11                |
| Balinese Script Orti Dataset             | 11                |
| Balinese Script Pabligbagan Dataset      | 7                 |
| Balinese Script Paribasa Dataset         | 17                |
| Balinese Script Pidarta Dataset          | 11                |
| Balinese Script Poetry Dataset           | 10                |
| Balinese Script Story Dataset            | 21                |
| Total                                 | 100               |

Letter Frequency is the most important aspect in analyzing a keyboard layout. In the calculation, the letters that appear most often and which are rare will be seen. Letters that rarely appear should be placed in the hardest position that can be taken by the finger when typing and easily accessible positions are occupied by letters that often appear. In this study there are three aspects that are used as a reference for optimizing the Tamiang Balinese script keyboard namely the use of home row, hand load equalization, and finger load when typing in Balinese. For good typing, each finger is given an allocation to access certain keys, generally the eight fingers are the left little finger, left ring finger, left middle finger, left index finger, right index finger, right middle finger, right ring finger, finger right little finger, while thumb is used to type spaces [9]. The load of each finger can be seen in Figure 2.

![Figure 2. Finger Load Map on The Keyboard [9]](image)

To measure the quality of a layout, there are several aspects that can be considered, and the following aspects are commonly agreed upon by each keyboard layout designer: (1) Limiting the use of weak fingers, such as the little finger sweet, (2) Limiting the use of bottom row, (3) Maximizing the use of home row, (4) Limiting finger movements, (5) Limiting the same finger movements, (6) Balanced hand weight between right and left hands, (7) Maximize alternation of hand movements [9]. This aspect will be used as a guideline in producing the new Balinese script keyboard as a result of the optimization of the Tamiang keyboard. The flow process of calculating the letter frequency and optimizing the Tamiang Balinese script keyboard is shown in Figure 3.

![Figure 3. The flow process of calculating the letter frequency and optimizing the Tamiang Balinese script keyboard.](image)
3. Results and Discussion

Evaluation of keyboard layout is done by calculating the percentage of occurrence of each Balinese character in each dataset. The evaluation process refers to aspects of the home row, hand load equalization, and even distribution of finger loads. The results of the letter frequency calculation are used as a reference to evaluate the Balinese script Tamiang keyboard layout. In the calculation there are 100 datasets of Balinese characters that are used according to their respective categories. The layout of Tamiang Balinese script keyboard can be seen in Figure 4.

![Tamiang Keyboard Layout](image)

Table 2. Tamiang keyboard evaluation based on aspects of hand load, use of home row, and finger load.

| Aspect           | Description      | Weight Value |
|------------------|------------------|--------------|
| Hand Load        | Right Hand       | 56,14 %      |
|                  | Left Hand        | 43,86 %      |
| Row Usage        | Top Row          | 19,93 %      |
|                  | Home Row         | 47,57 %      |
|                  | Bottom Row       | 32,51 %      |
| Finger Load      | Right Little Finger | 9,23 %    |
|                  | Right Ring Finger | 6,47 %      |
|                  | Right Middle Finger | 11,85 %   |
|                  | Right Index Finger | 22,45 %    |
|                  | Left Little Finger | 10,46 %    |
|                  | Left Ring Finger  | 11,33 %      |
|                  | Left Middle Finger | 9,87 %      |
|                  | Left Index Finger | 18,34 %      |

The placement of letters on the new keyboard is based on the percentage of the results of the calculation of the three aspects on the Tamiang keyboard with brute force method. The placement of letters on each key is arranged or sorted based on the percentage of the calculation results on the keyboard layout as a result of optimization. Making a new keyboard layout aims to provide better percentage results than the previous Tamiang layout. New Keyboard Layout results from the optimization of the Tamiang keyboard can be seen in Figure 5.

![Keyboard layout results from the optimization of the Tamiang keyboard](image)
The placement of keys for each character is based on the appearance of each character in the document produced by the letter frequency calculation system in the Tamiang Balinese script keyboard layout. There are several changes in character position on the Tamiang keyboard. The first change is the position of the “Carik Pamungkah” button group that is moved on the top right row on the keyboard. The position of the button group filled by “Pameneng” and "Panti" are moved in the lower right row. The two groups of buttons are moved to adjust the percentage value in the top row and bottom row which previously has a higher value compared to the home row, then for the position left before it is filled by the "carik siki" and group button “Carik Pareren ". It is also intended that the displacement does not affect the lower row values which tend to be higher if both the "Carik Siki" and "Carik Pareren" buttons remain in the bottom row position on the right side.

Reposition also occur in the section of the "Cecek" button which is initially in the position of the upper left row moved in the upper right row, next to the group of the “Carik Pamungkah” buttons. This move is done to balance the use of the left little finger that is used less frequently, so the percentage needs to be increased by placing the "Pa" character button group. In addition, the reposition of "Cecek" also aims to place the position of the "cecek" on the grouping of “Penggantung Aksara” so that they can be in groups with similar characters. In the group position the "Ukare" and "Ekare" buttons, whose positions have been occupied by the "Cecek" button group, are moved to the group position of the "Pa" button in order for their position to be in the same group as allied characters.

The position of the "Bisah" button is placed at the bottom row position next to the “Adeg-Adeg” button. With this, the button position can be more easily found because it has gathered in the “Penggantung Aksara” part. In the script position "Ha, Na, Ca, Ra, Ka, Da, Ta, Sa, Wa, La, Ma, Ga, Ba Nga, Pa, Ja, Ya" is repositioned based on the results of letter frequency calculations, so that the position of the existing keyboard layout can affect the value of the percentage of fingers to a more optimal level. The last change occurs in the literary voice part keys which are remapped in such a way as to affect the percentage of finger calculations. The percentage of each aspect on the new keyboard as a result of Tamiang keyboard optimization can be seen in Table 3. Table 3 shows the results of the calculation of each aspect of the evaluation which includes hand use, line use and finger use. The percentage results in Table 3 show the level of improvement based on the three aspects when compared to the results of the previous Balinese script Tamiang keyboard layout.

| Table 3. The New Tamiang Keyboard Evaluation |
|---------------------------------------------|
| Aspect         | Description      | Weight Value |
| Hand Load      | Right Hand       | 50,18 %      |
|                | Left Hand        | 49,82 %      |
| Row Usage      | Top Row          | 29,08 %      |
|                | Home Row         | 39,18 %      |
|                | Bottom Row       | 31,74 %      |
| Finger Load    | Right Little Finger | 7,05 %      |
|                | Right Ring Finger | 7,65 %      |
|                | Right Middle Finger | 8,38 %     |
|                | Right Index Finger | 27,04 %    |
|                | Left Little Finger | 6,34 %      |
|                | Left Ring Finger  | 7,96 %      |
|                | Left Middle Finger | 8,60 %     |
|                | Left Index Finger | 26,99 %     |

The research conducted by Dvorak found that typing can be done maximally if the characters that appear frequently are on the home row position of the keyboard because it can minimize the time needed for the finger to move [8]. In addition, there is the fact that it is easier to type with both hands than typing a series of characters with the same hand because there is a much higher level of freedom. Based on the percentage of hand and line use, shown in Table 3, it can be concluded that the use of the hand on the keyboard that is produced almost reaches 50% -50%. This means that the use of improved layouts has
resulted in a keyboard layout that is able to balance the use of both hands. Whereas in terms of row usage, the calculation results in Table 3 have shown dominance in the home row with the values in the upper and lower rows not too lame. So that the resulting keyboard layout has a fairly ideal comparison on line usage when referring to Dvorak's research [8].

Even distribution of the load on the hand when typing must also be applied to all fingers, this aims to give the right portion of the finger. On the keyboard that has been developed, the load on each finger is more optimal when compared with the results of the percentage of Tamiang keyboard layout. This is evidenced by the results of the load calculation using fingers that have prioritized the finger with access to the widest movement, namely the index finger, then followed by the middle finger, ring finger, and little finger as the finger with the narrowest access movement.

4. Conclusion
In this study a new Balinese script keyboard layout has been developed which is optimal for typing Balinese characters in Balinese. This new keyboard was developed by optimizing Tamiai's keyboard in terms of hand load, home row usage, and finger load when typing. This aspect was evaluated using a letter frequency calculation in 100 datasets of the Balinese script document, to be further mapped on each keyboard button as a guide for re-mapping the layout. The evaluation results show that the new keyboard developed has shown optimal values for aspects of hand load, use of home row, and finger load in typing.

5. References
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